Weekly オンラインEMC基礎セミナー

EMIテストレシーバ タイムドメインスキャンの基礎

2020/06/22

ローデシュワルツジャパン株式会社

ROHDE&SCHWARZ
Make ideas real

本日の内容

- パルス性広帯域ノイズの特徴・測定の難しさ

- パルス性広帯域ノイズ測定のために
  - FFTを活用した「タイムドメインスキャン」
  - 「タイムドメインスキャン」を生かすダイナミックレンジの重要性

本日の内容

- **パルス性広帯域ノイズの特徴・測定の難しさ**

- パルス性広帯域ノイズ測定のために
  - FFTを活用した「タイムドメインスキャン」
  - 「タイムドメインスキャン」を生かすダイナミックレンジの重要性

パルス性広帯域ノイズの特徴・測定の難しさ

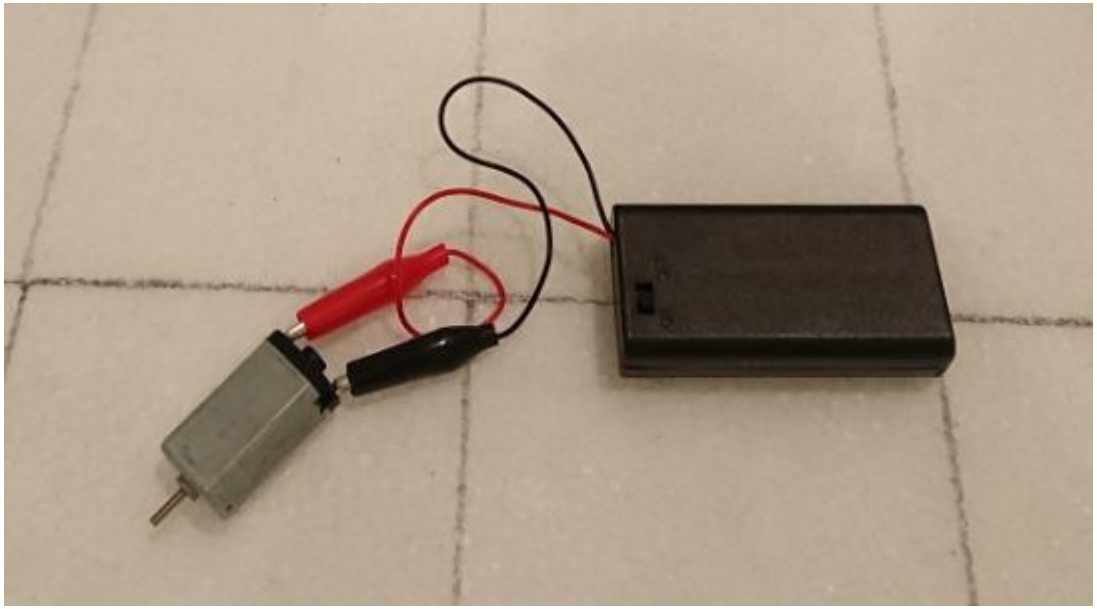
さまざまな無線アプリケーション と その周波数

100 kHz　1 MHz　10 MHz　100 MHz　1 GHz　10 GHz

幅広い周波数にわたり、様々な無線アプリケーションが用いられている

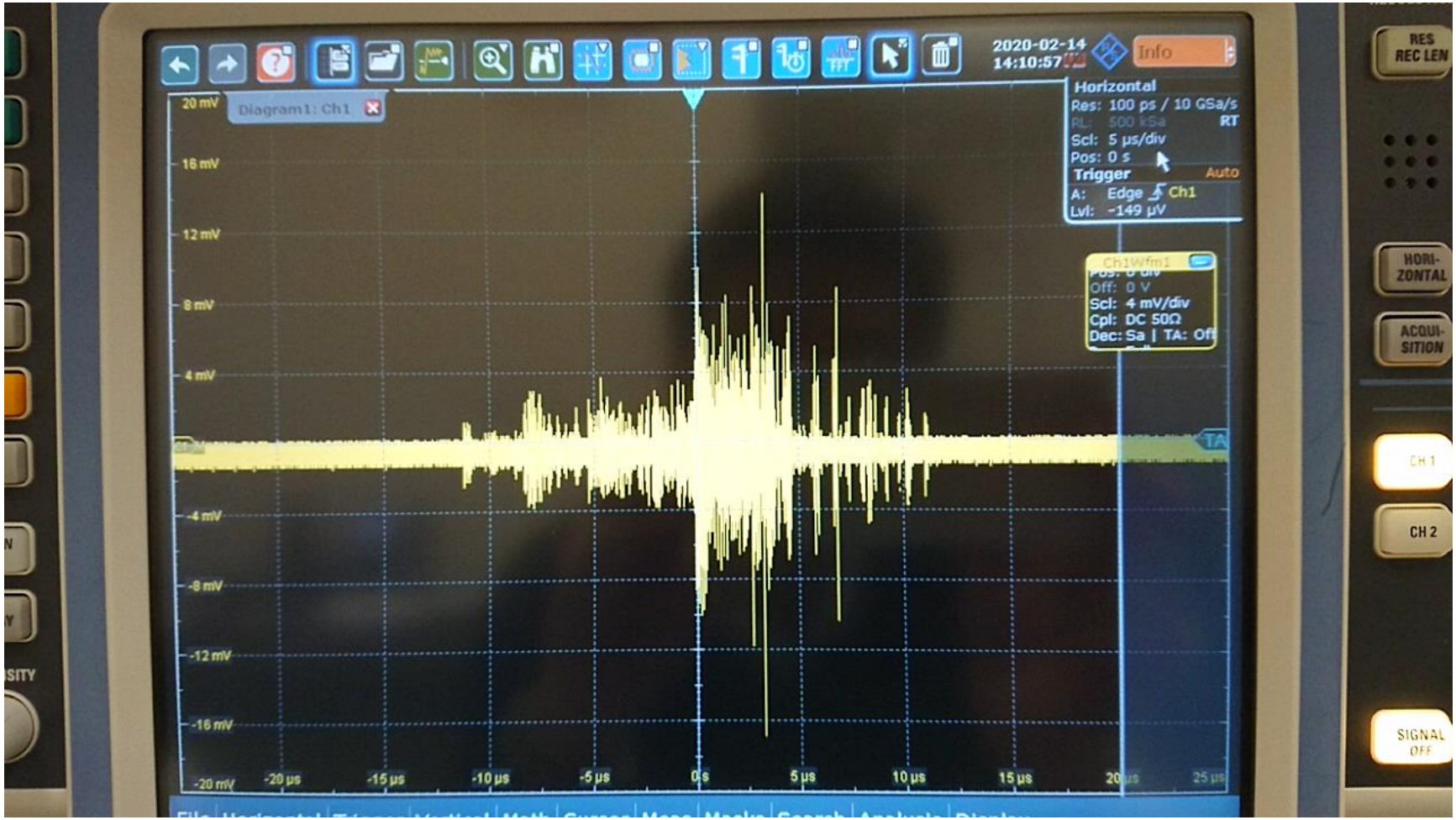
パルス性広帯域ノイズの特徴・測定の難しさ

実験: 3V DC モーター @ 3m EMI 測定



パルス性広帯域ノイズの特徴・測定の難しさ

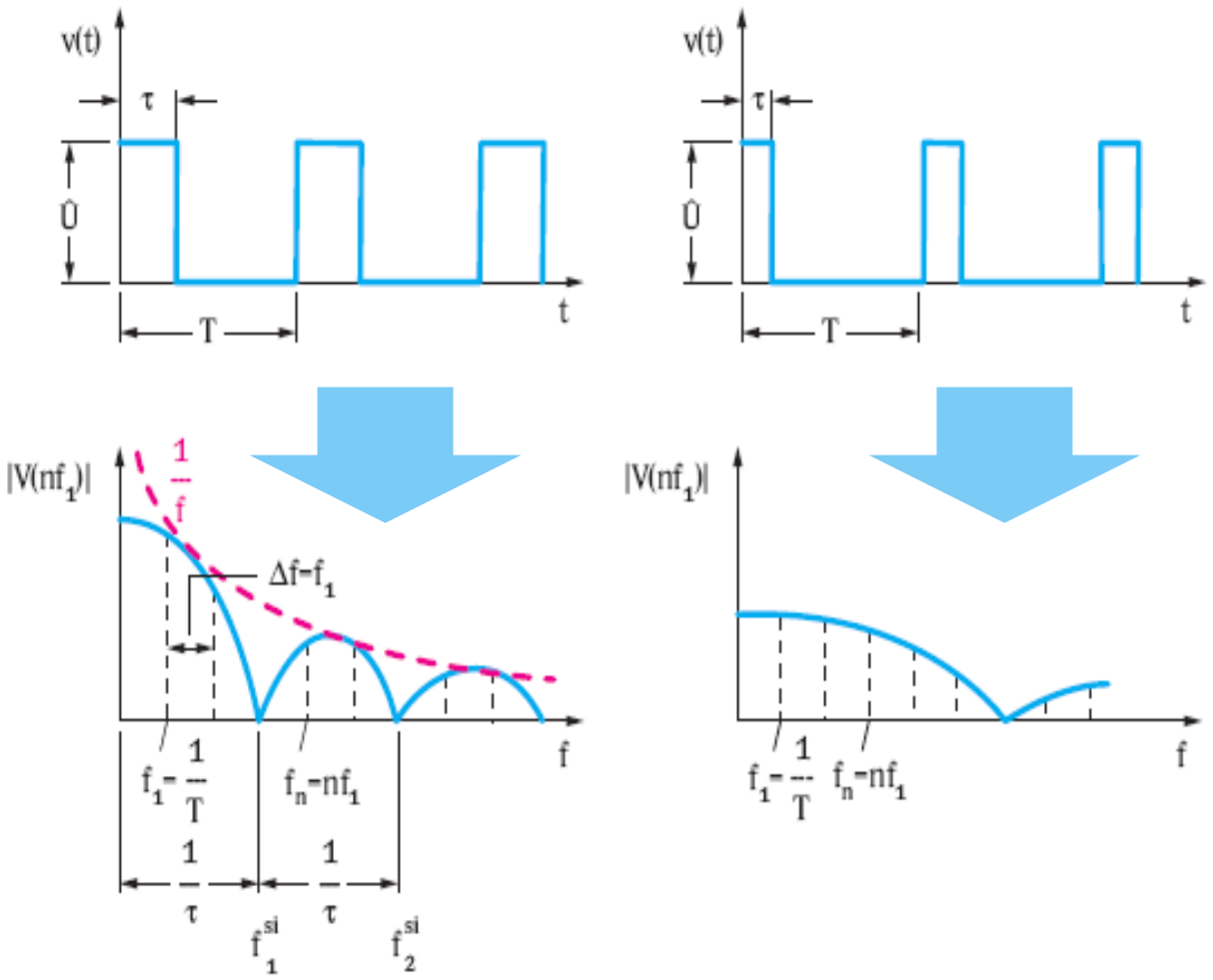
実験：3V DC モーター @ 3m EMI 測定



アンテナで受信し時間軸で観測すると、パルス性のノイズである事が分かる

パルス性広帯域ノイズの特徴・測定の難しさ

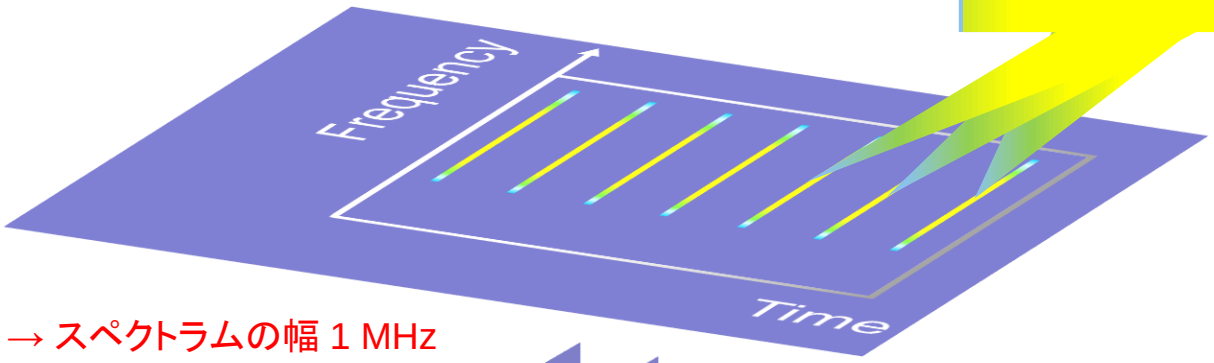
パルス状のノイズ（時間軸） と ノイズスペクトラム（周波数軸）



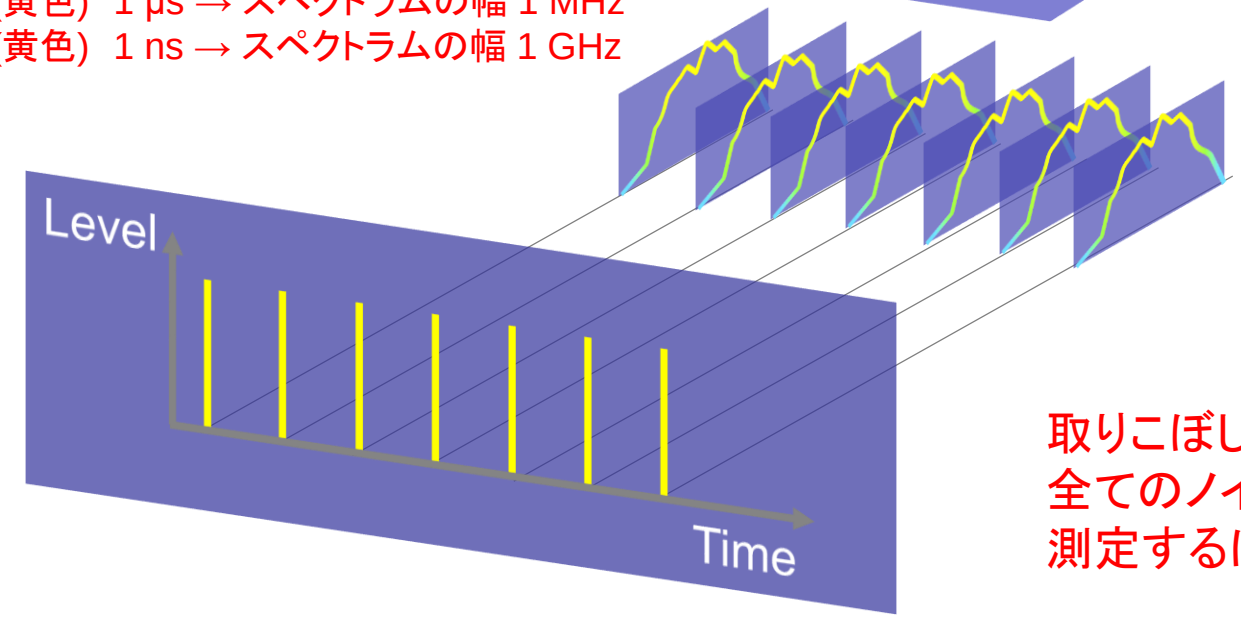
パルス性広帯域ノイズの特徴・測定の難しさ

パルス性広帯域スペクトラムの観測

パルス性妨害波の
広帯域スペクトラム



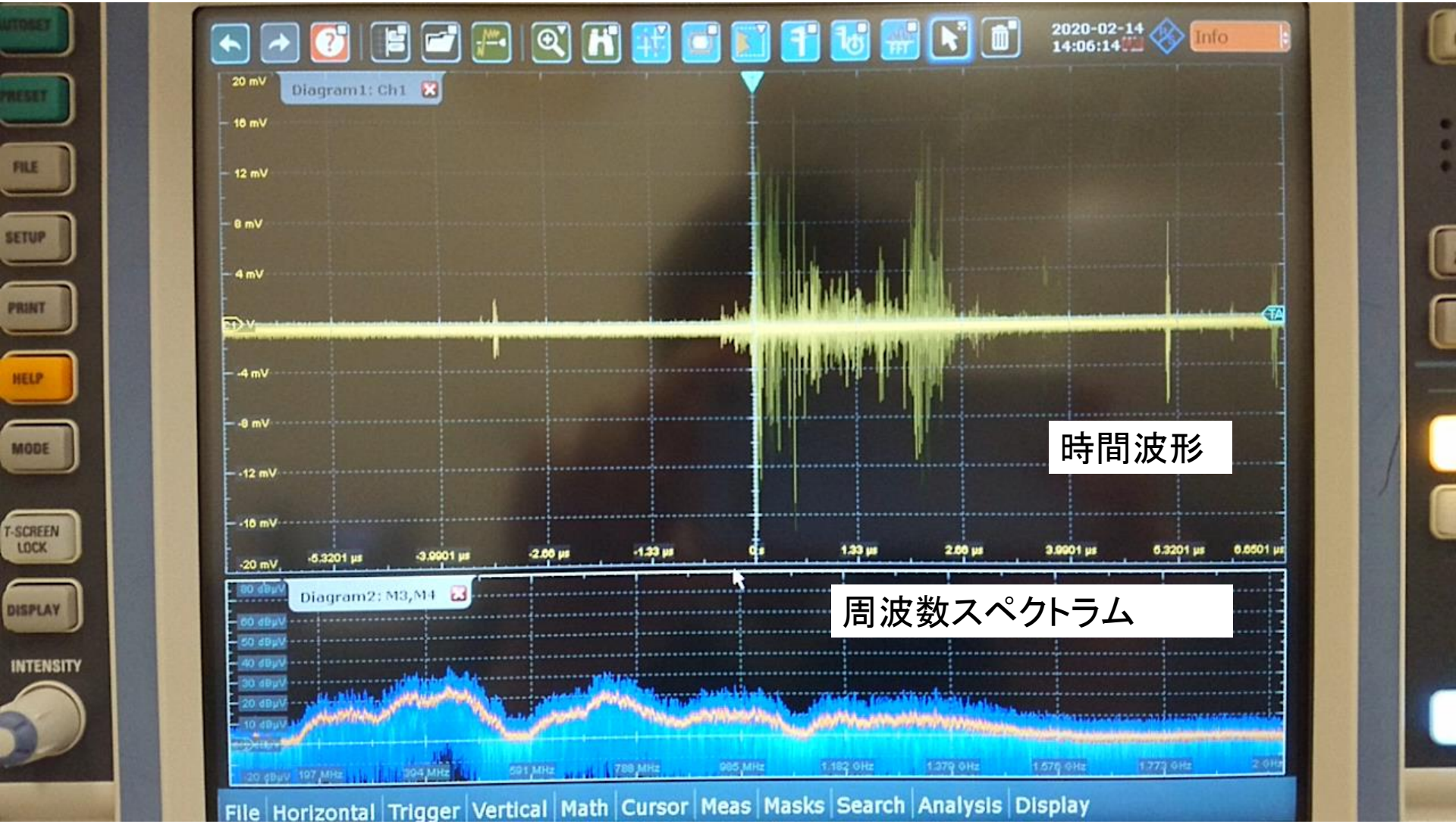
発生時間(黄色)　1 µs → スペクトラムの幅 1 MHz
発生時間(黄色)　1 ns → スペクトラムの幅 1 GHz



取りこぼし無く
全てのノイズを捕らえて
測定するには？？

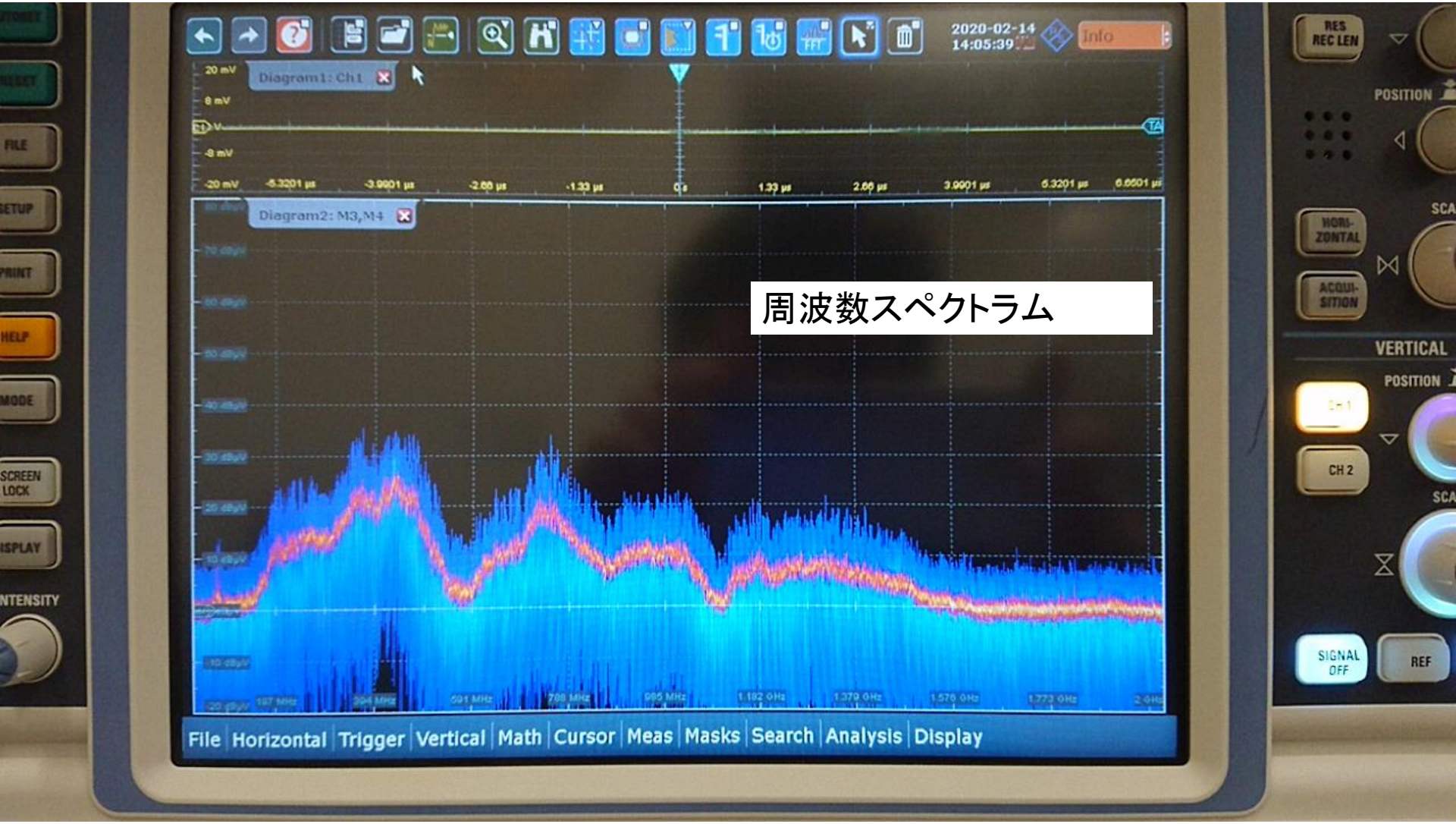
パルス性広帯域ノイズの特徴・測定の難しさ

実験：3V DC モーター @ 3m EMI 測定 -パルス性広帯域スペクトラムの観測



パルス性広帯域ノイズの特徴・測定の難しさ

実験：3V DC モーター @ 3m EMI 測定 -パルス性広帯域スペクトラムの観測



パルス性広帯域ノイズの特徴・測定の難しさ

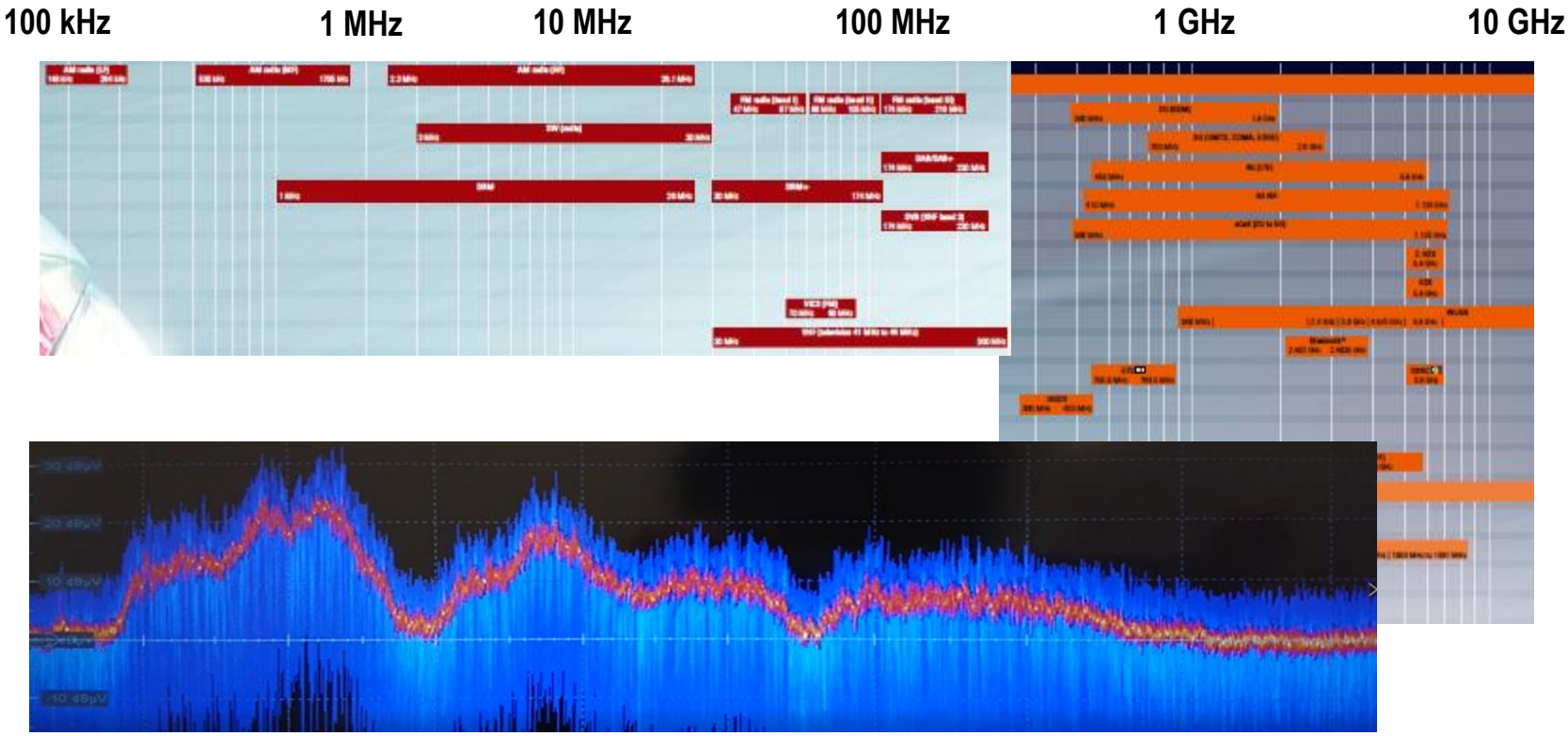
さまざまな無線アプリケーション と その周波数

100 kHz　1 MHz　10 MHz　100 MHz　1 GHz　10 GHz

幅広い周波数にわたり、様々な無線アプリケーションが用いられている

パルス性広帯域ノイズの特徴・測定の難しさ

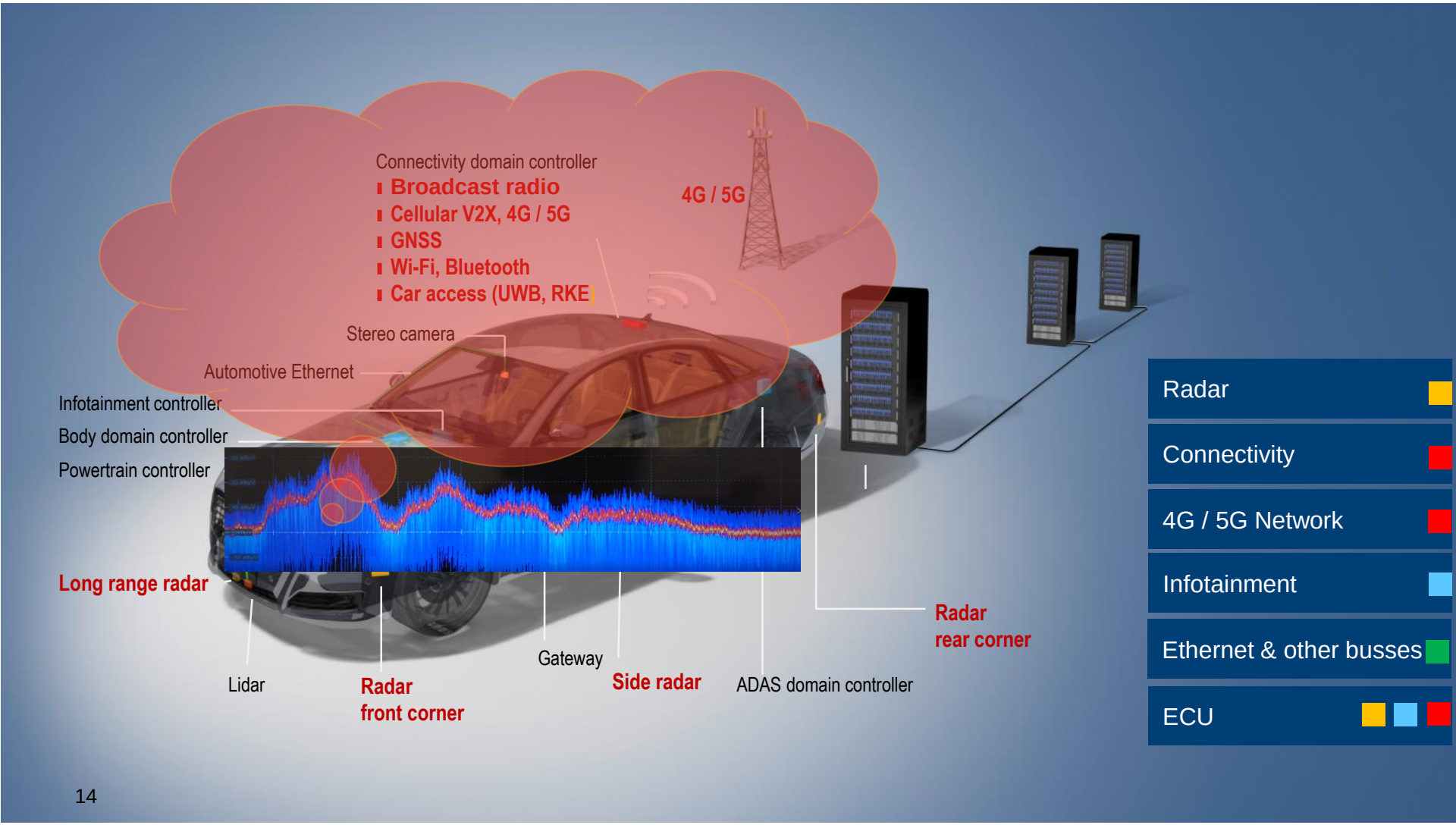
実験: 3V DC モーター @ 3m EMI 測定



パルス性ノイズは、、幅広い周波数にわたる様々な無線アプリケーションの障害に。。

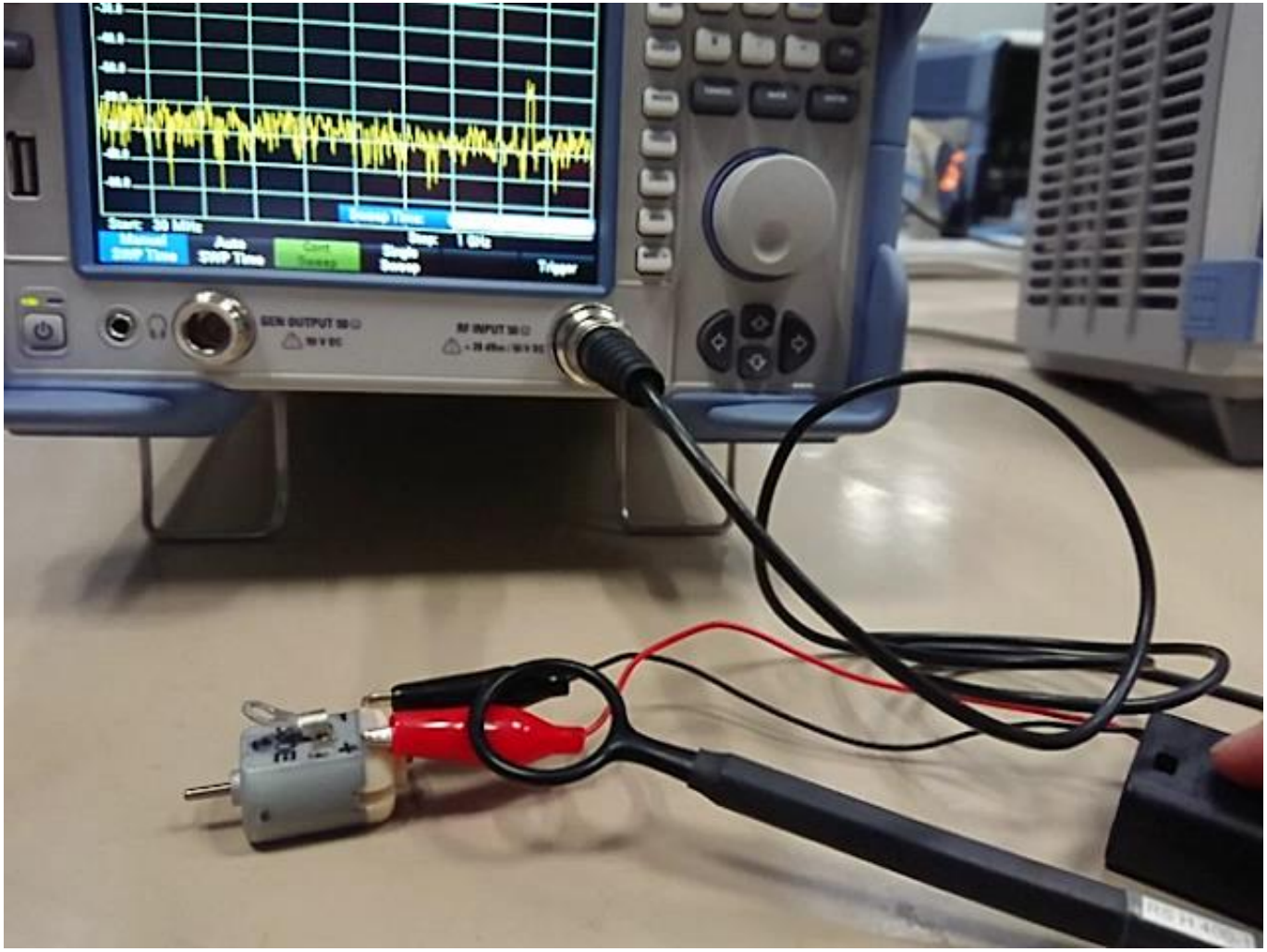
パルス性広帯域ノイズの特徴・測定の難しさ

さまざまな無線アプリケーション



パルス性広帯域ノイズの特徴・測定の難しさ

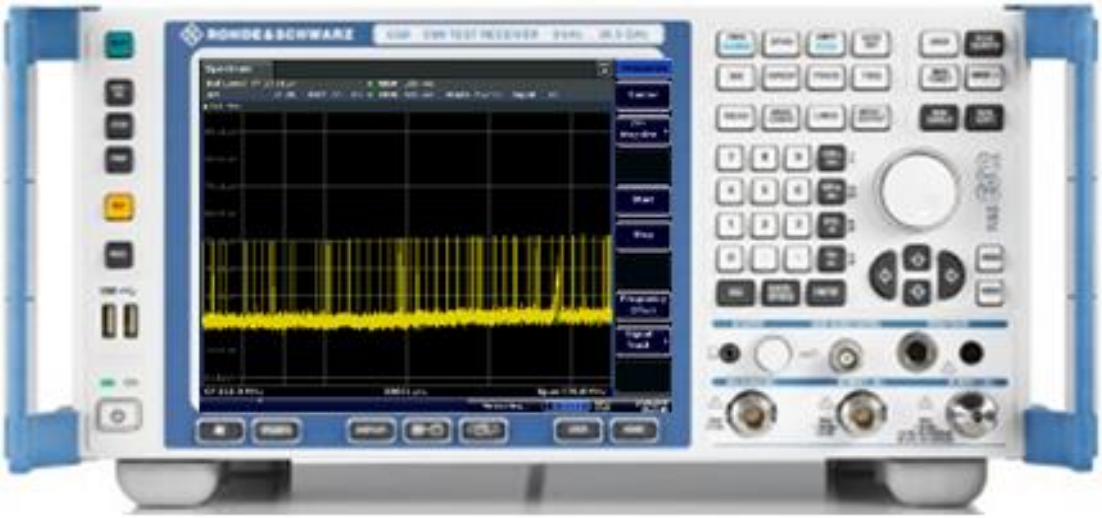
スペクトラムアナライザ測定の難しさ



パルス性広帯域ノイズの特徴・測定の難しさ

スペクトラムアナライザ測定の難しさ

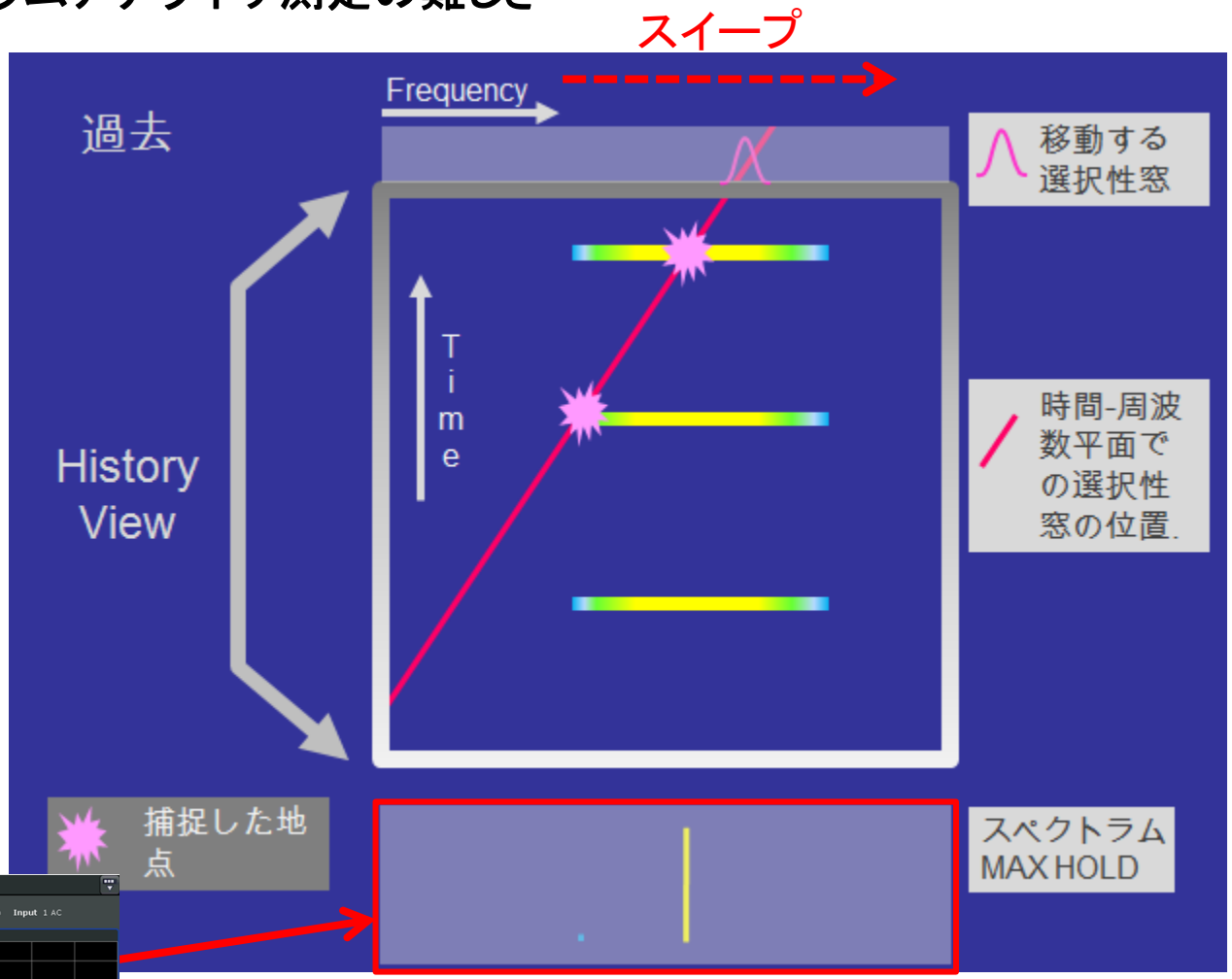
ノイズ測定においてしばしば高速掃引とMaxHoldが用いられる

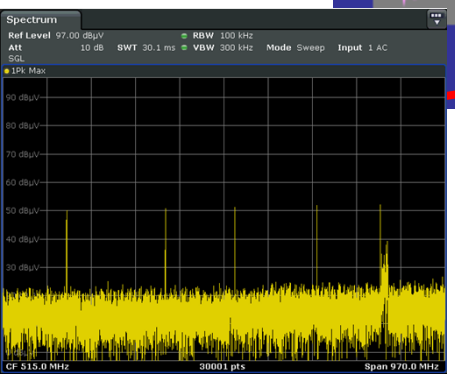


スペクトラムアナライザの構造を考えてみると。。。。

パルス性広帯域ノイズの特徴・測定の難しさ

スペクトラムアナライザ測定の難しさ

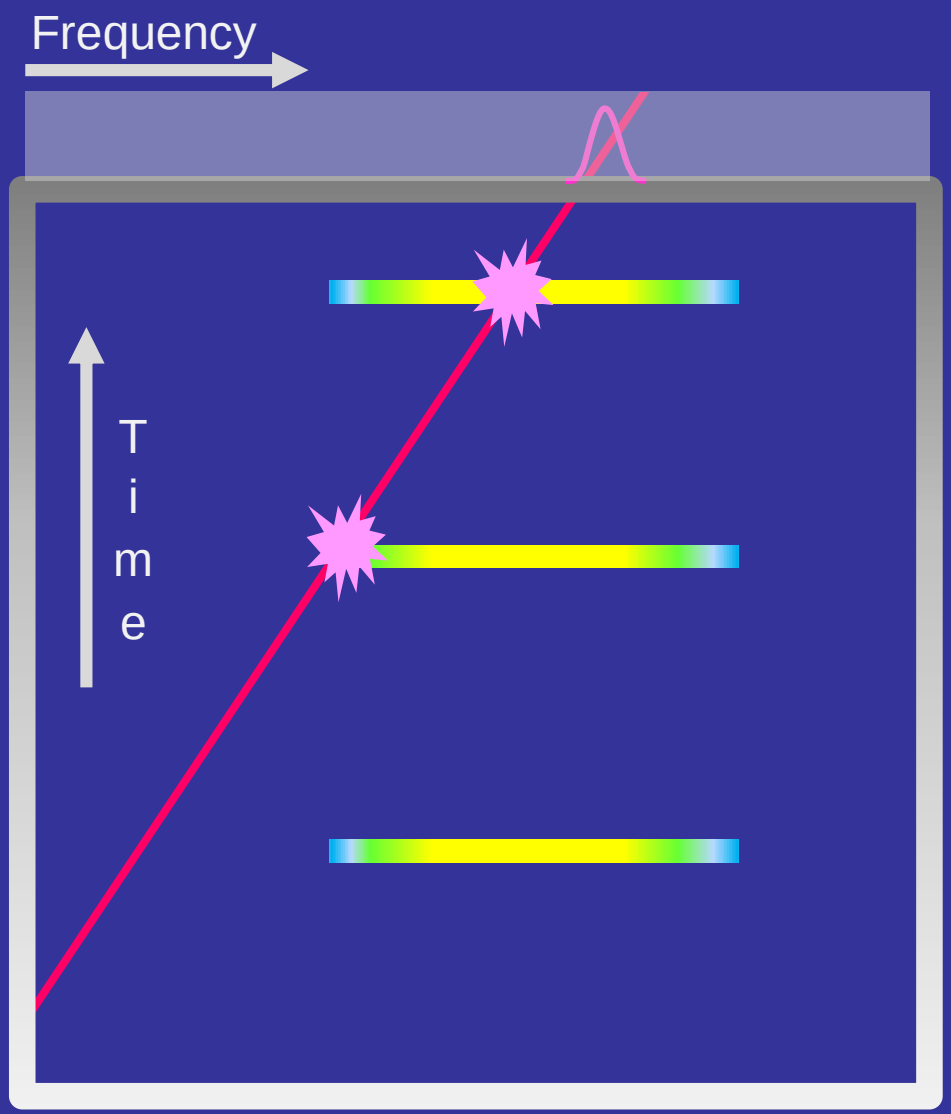




スペクトラムアナライザの画面 (MAX Hold)

過去

History View

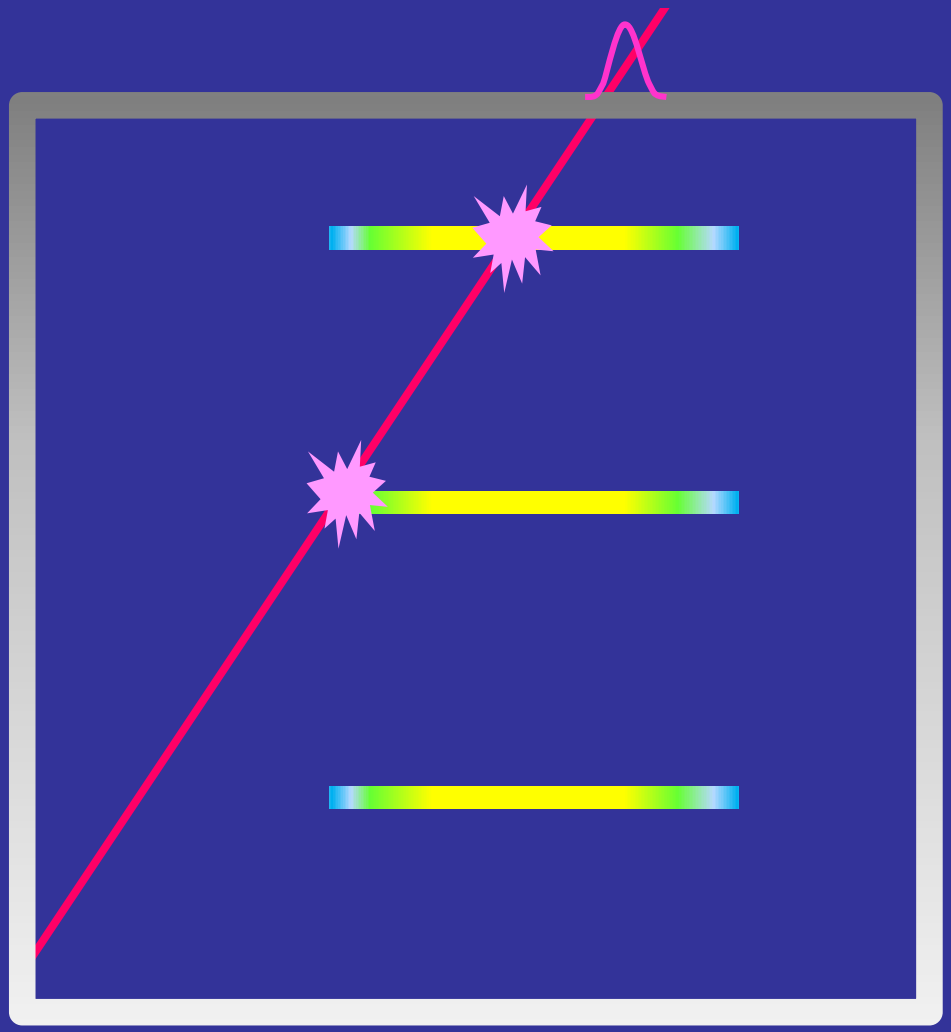


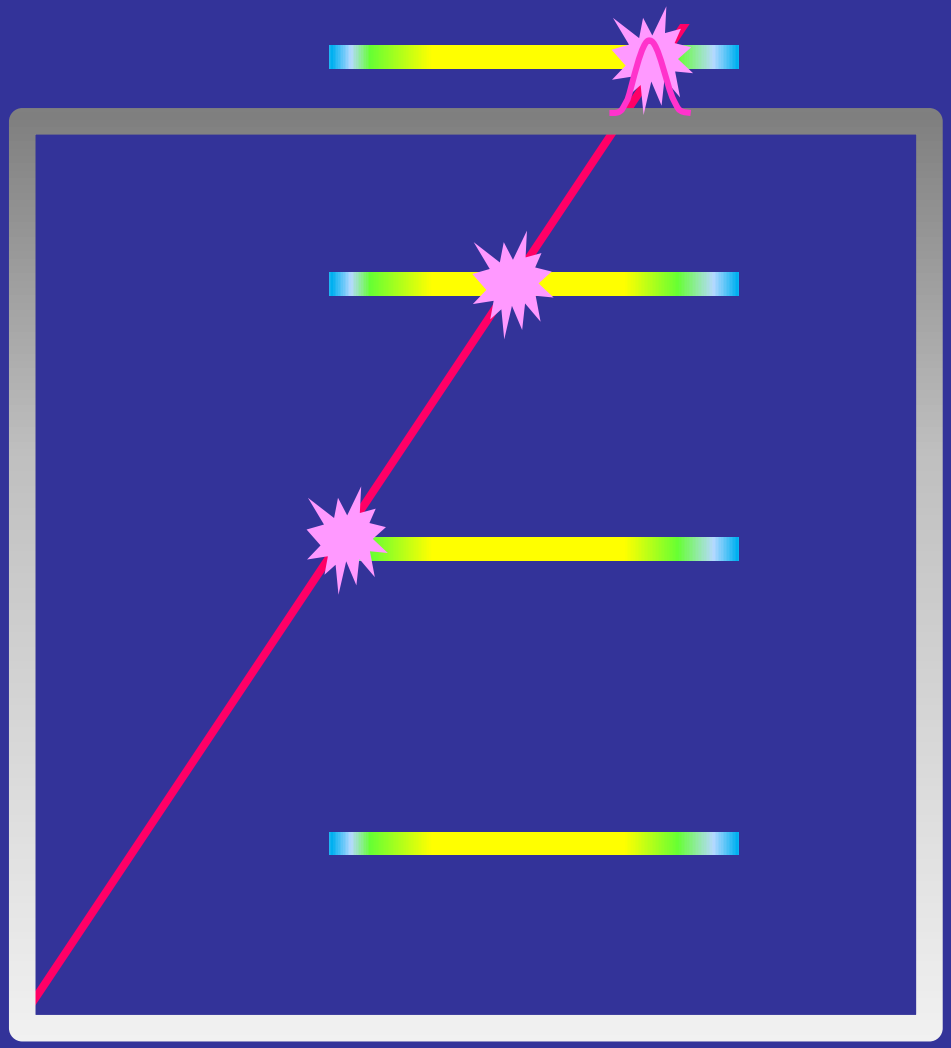
移動する選択性窓 (RBW)

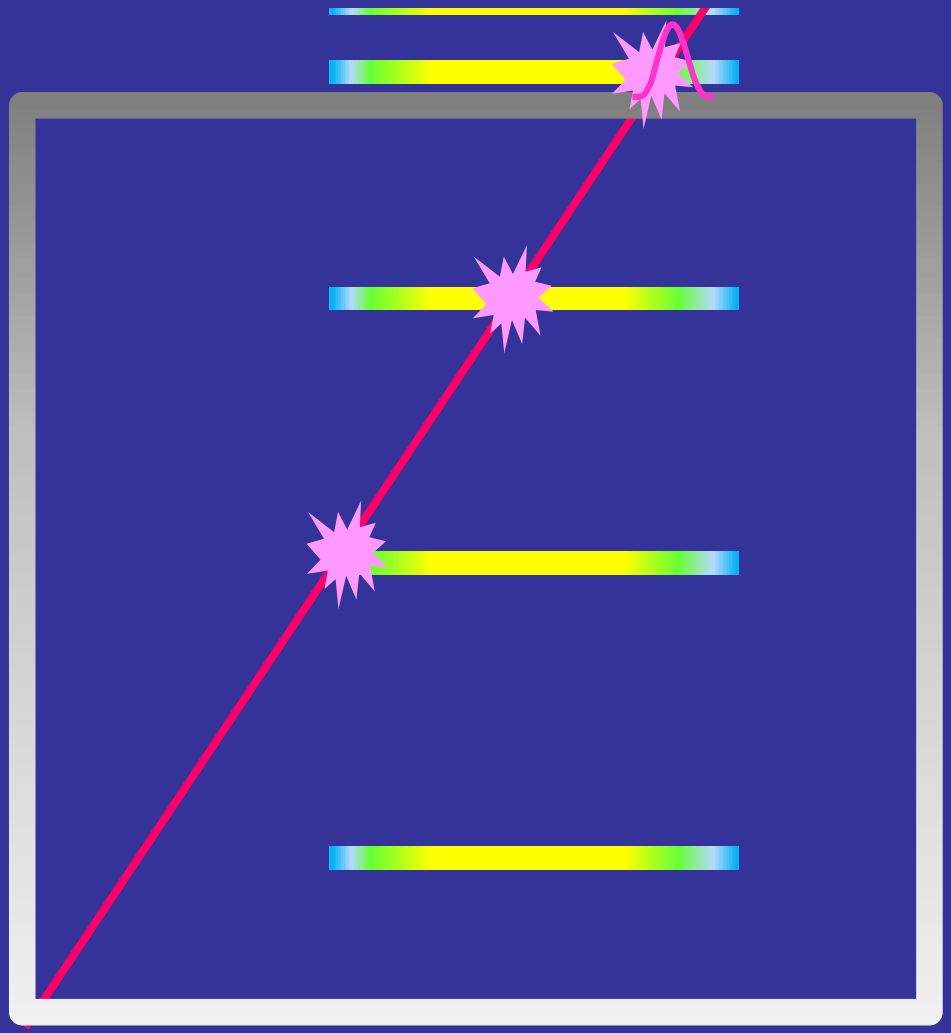
時間-周波数平面での選択性窓の位置.

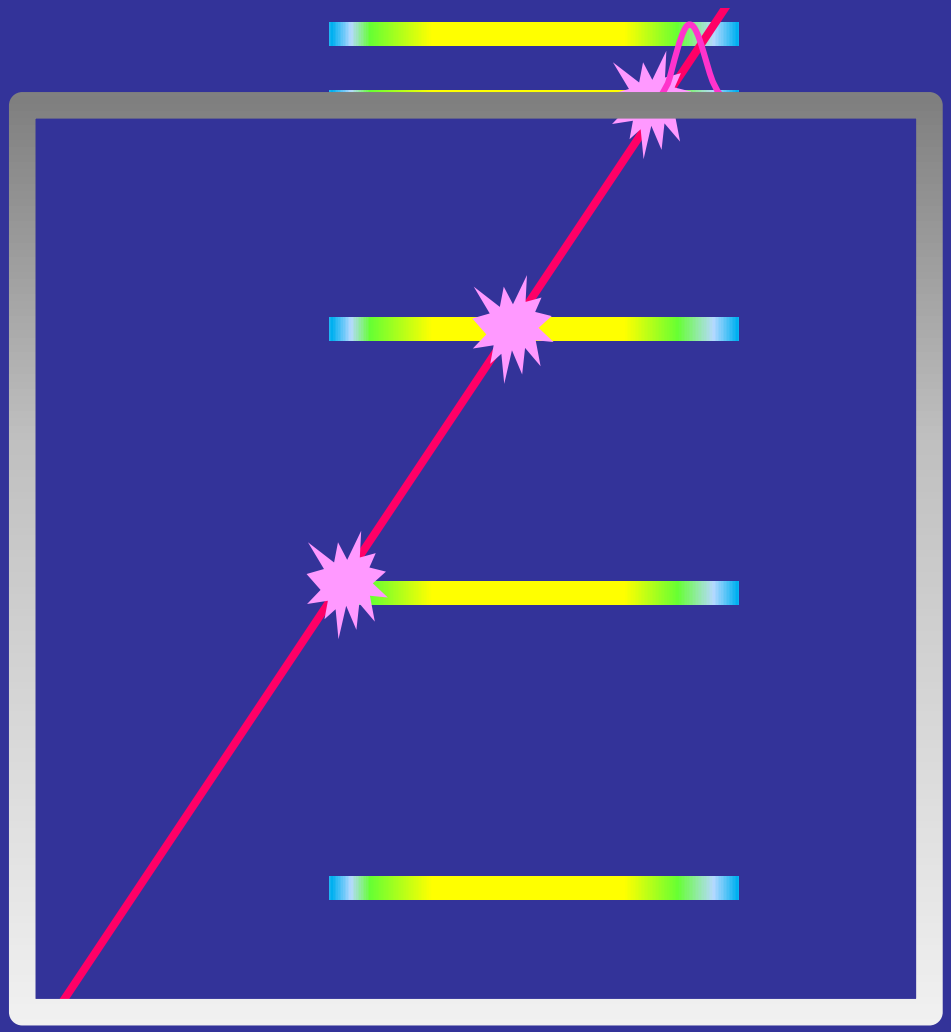
捕捉した地点

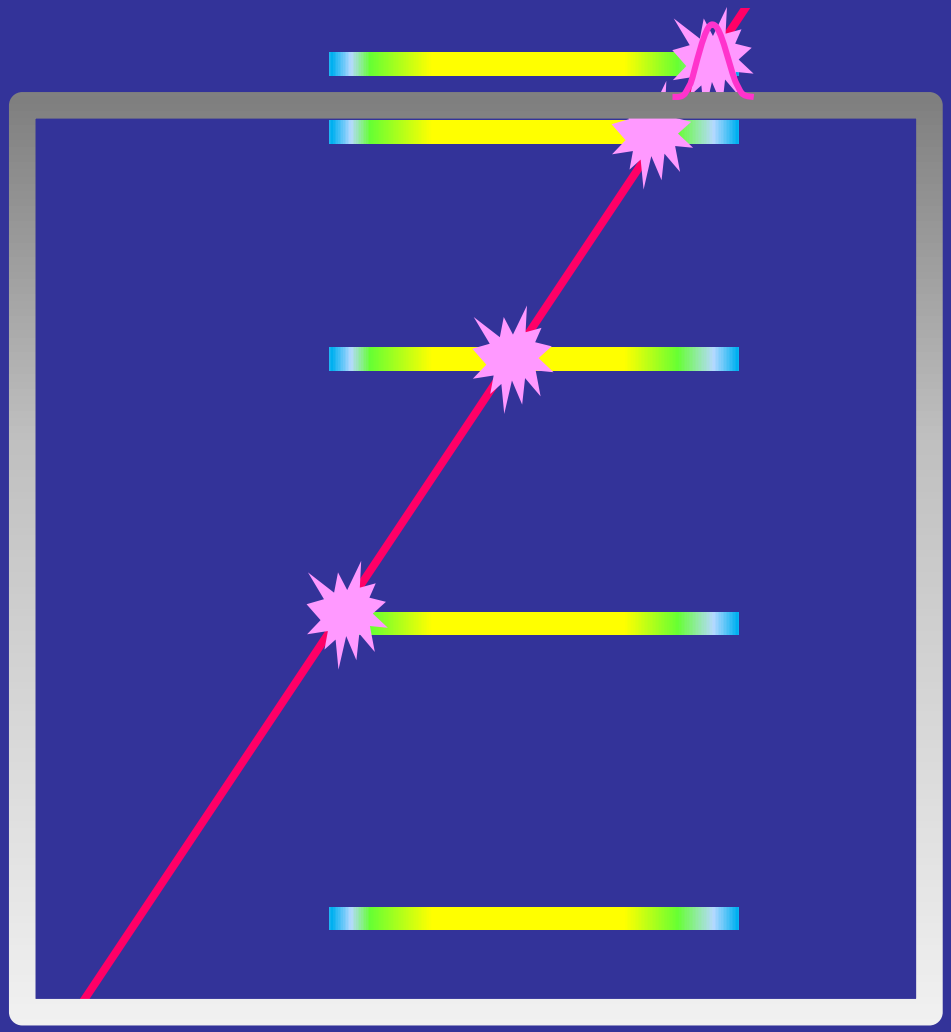
スペクトラム MAX HOLD

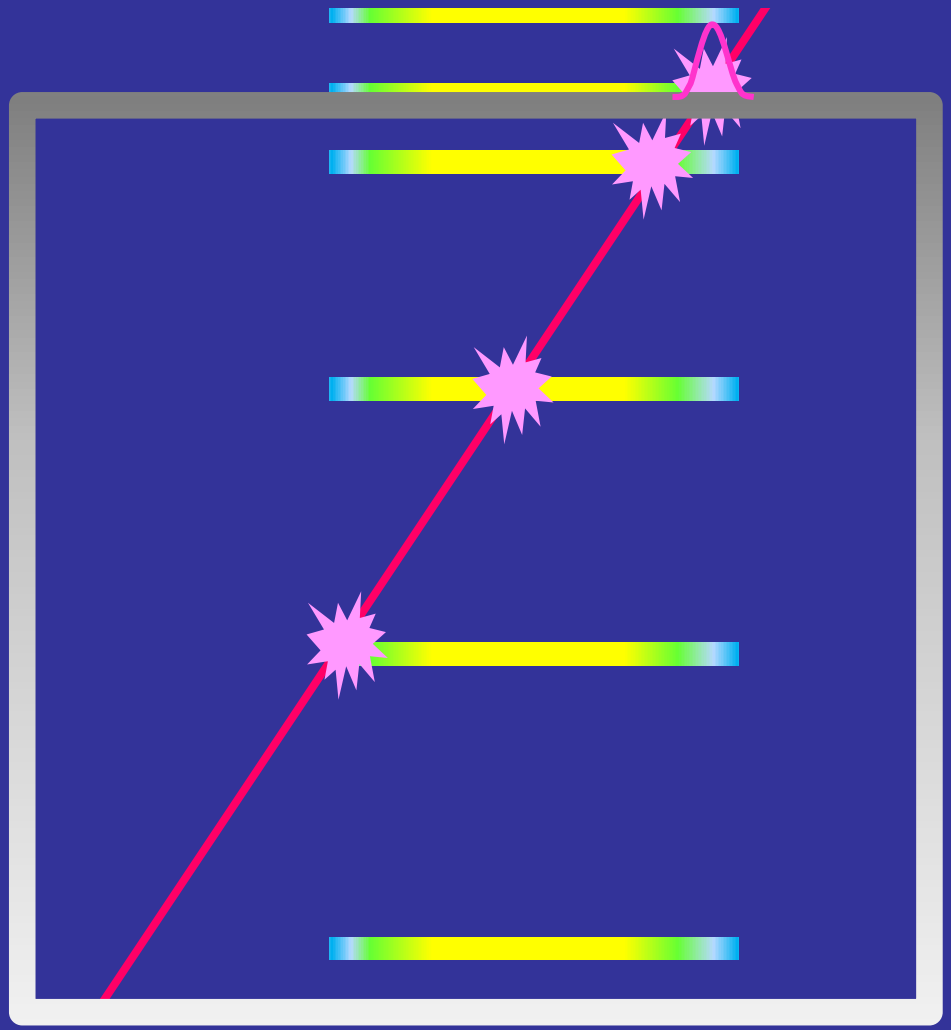


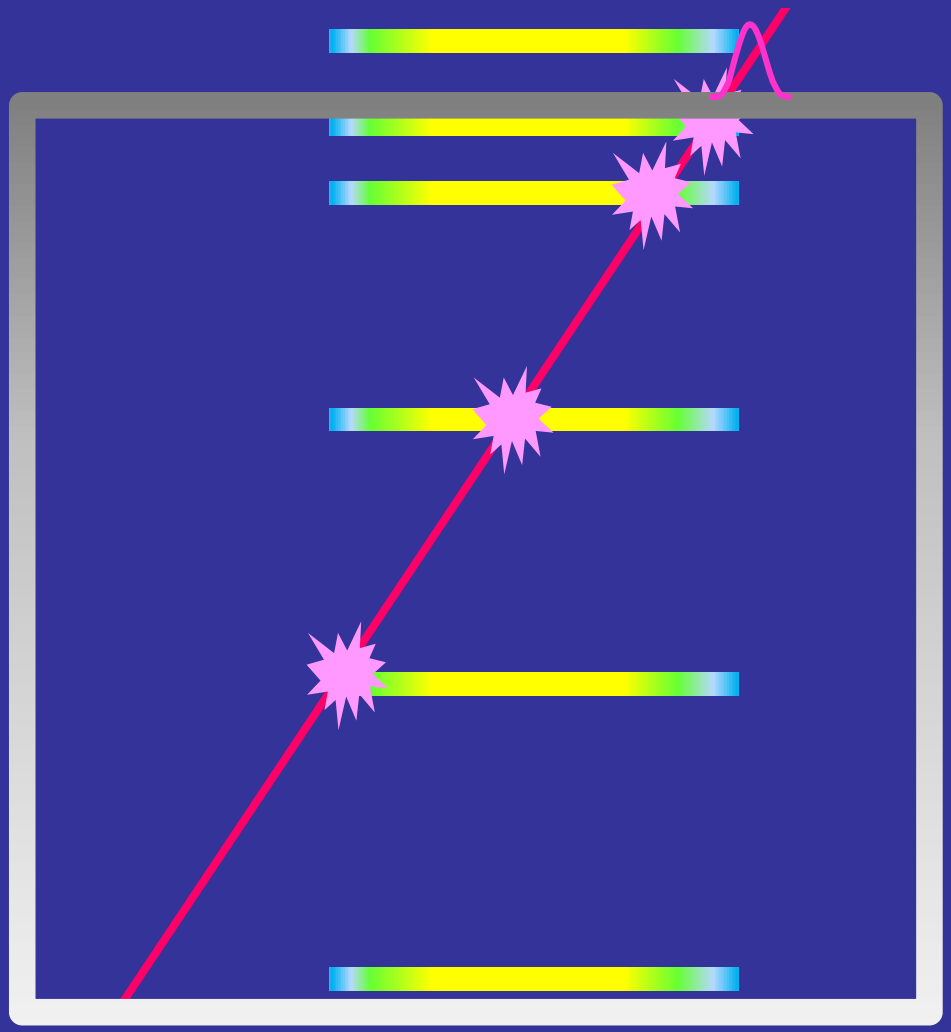


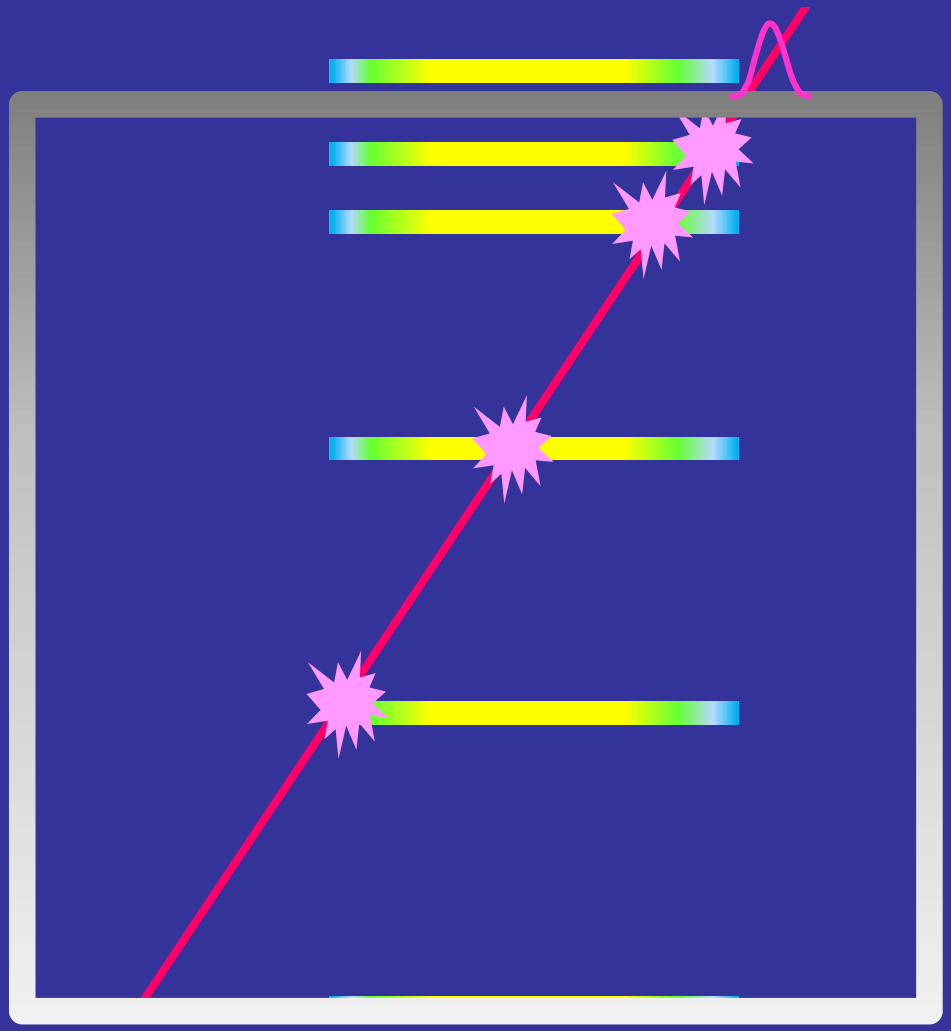


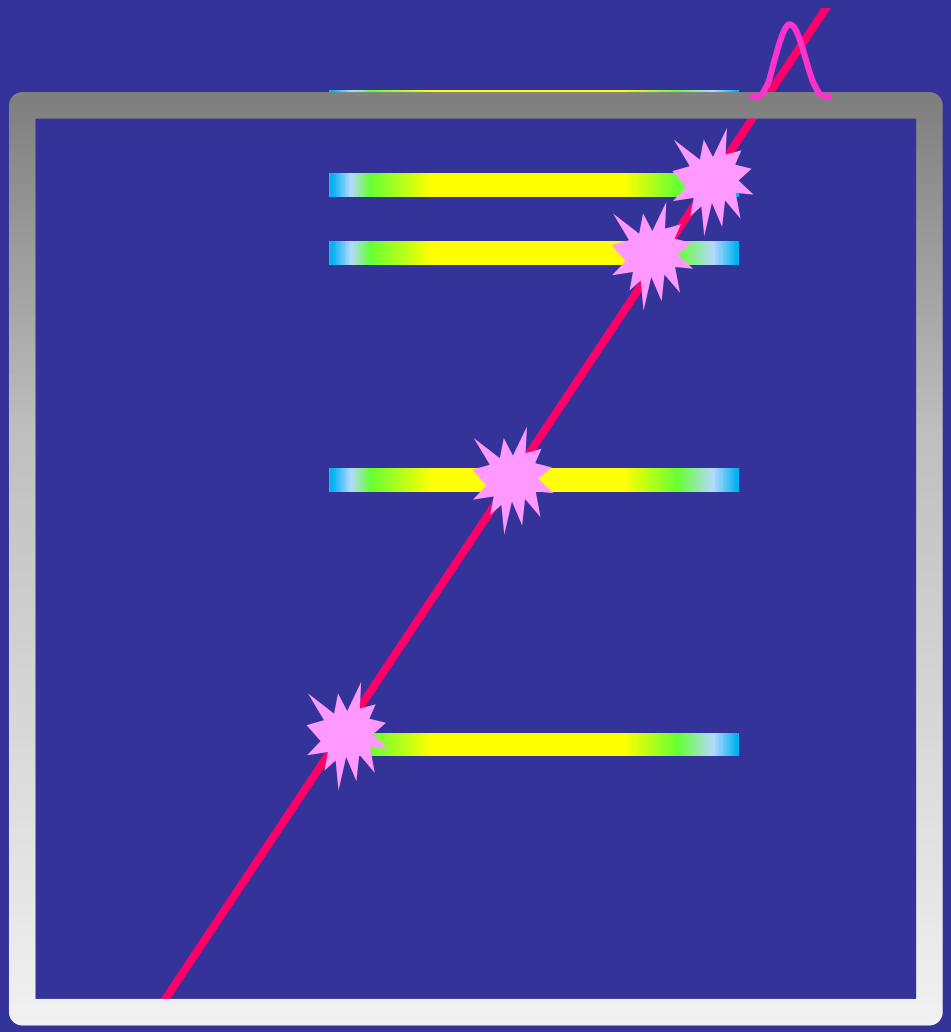


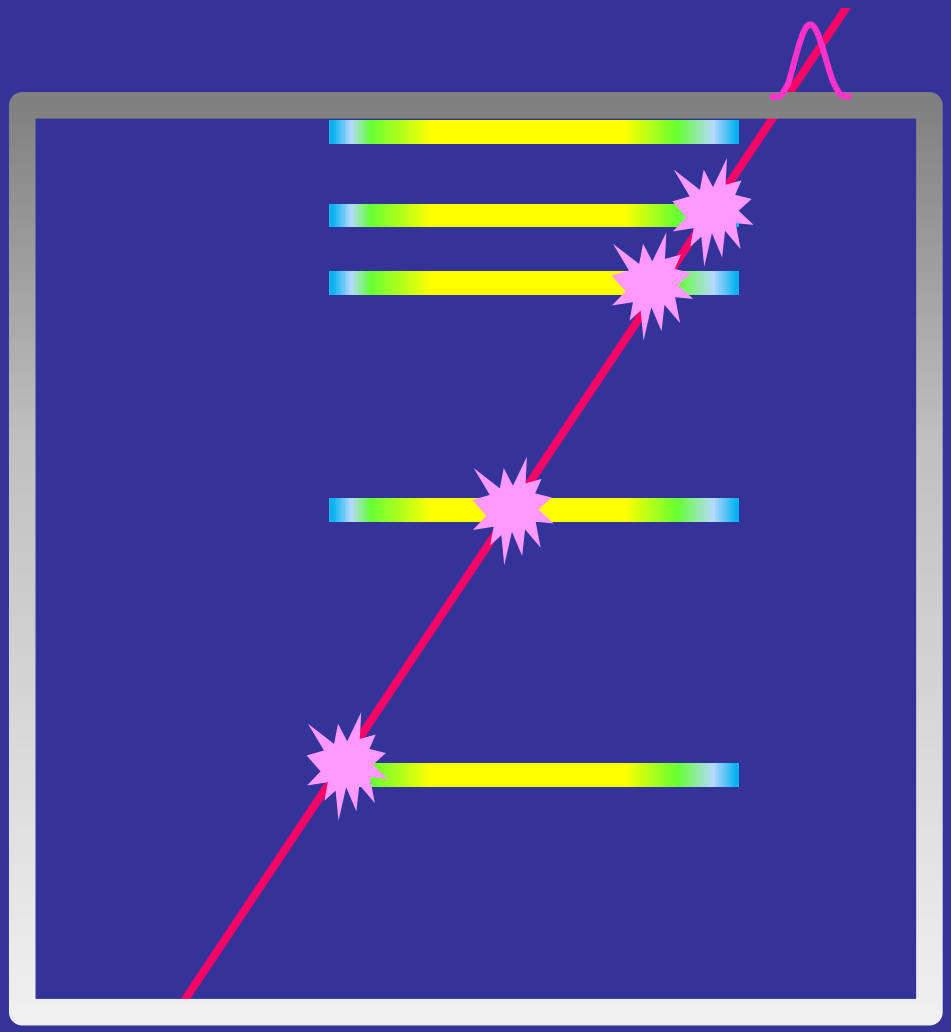


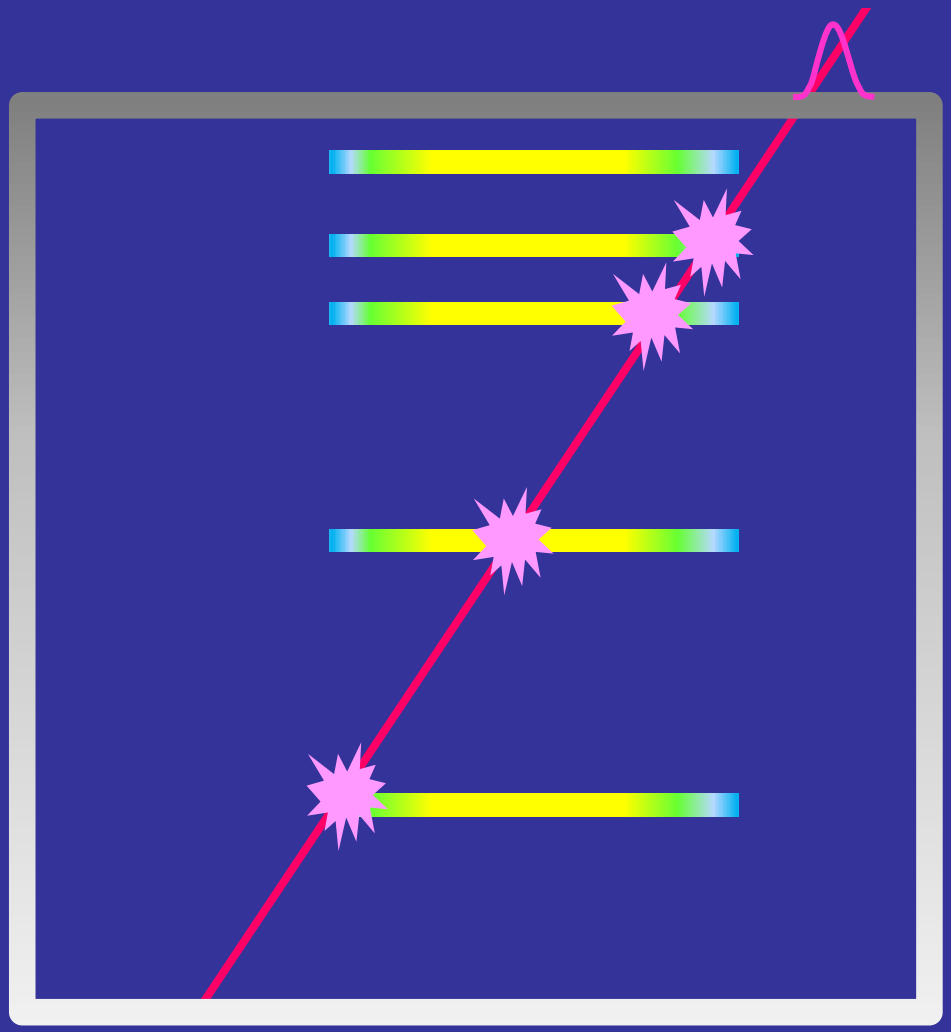


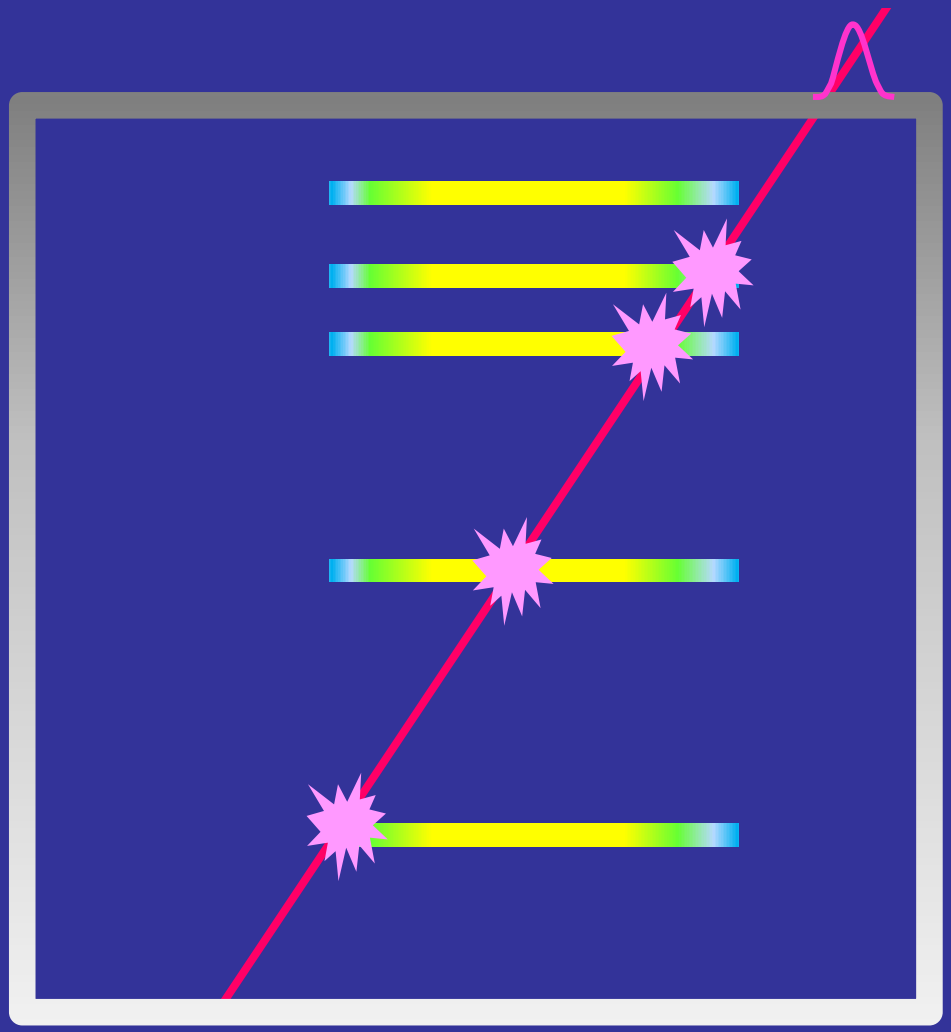


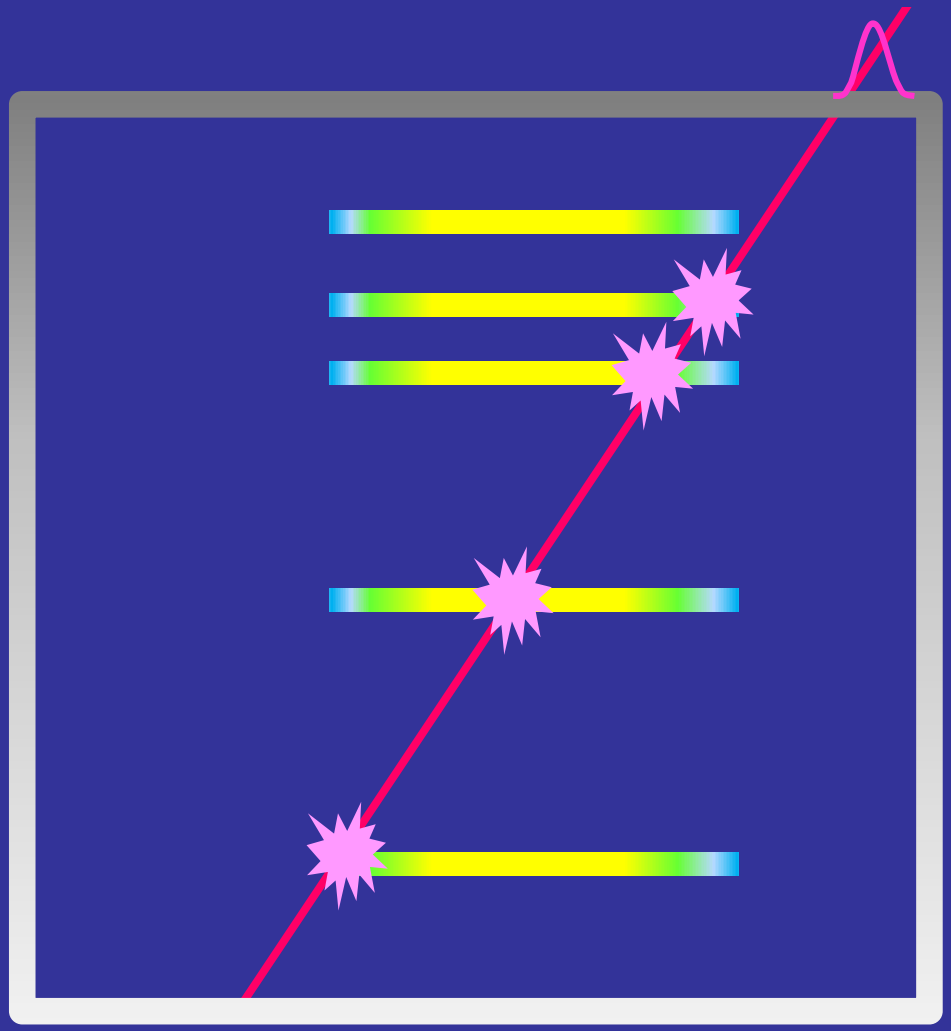


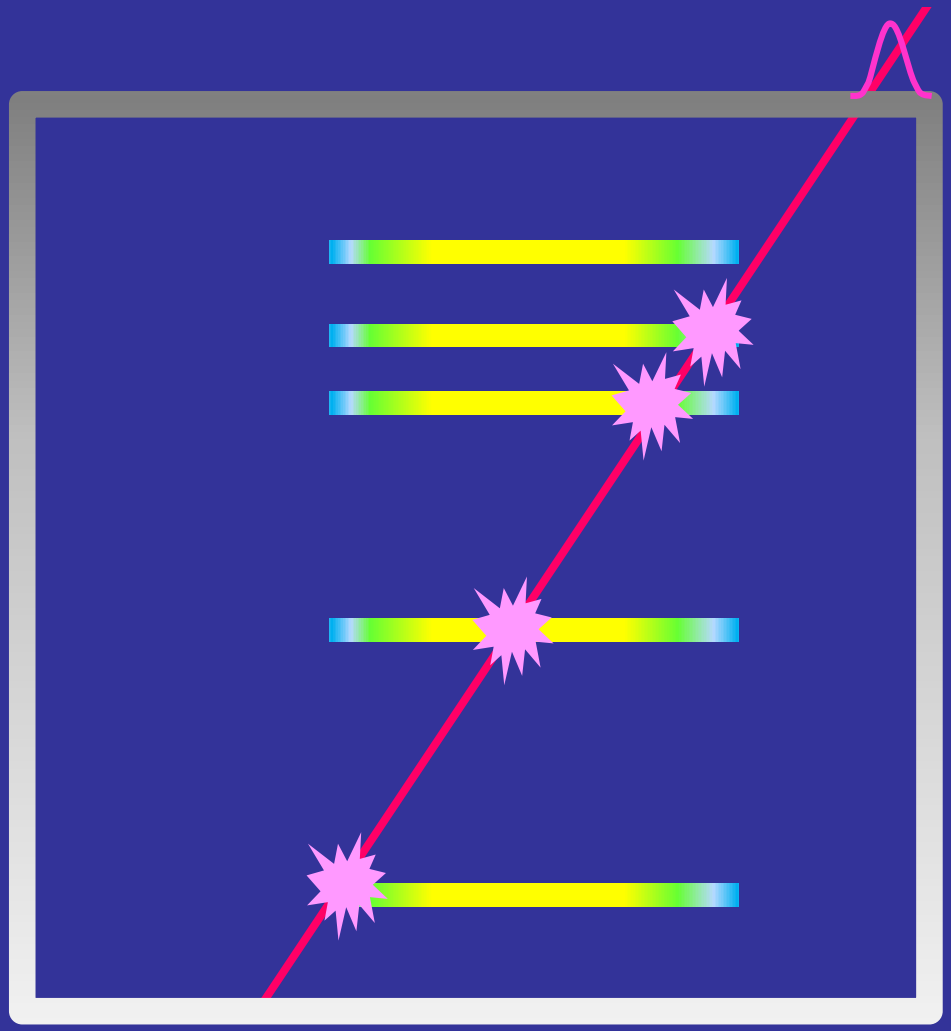


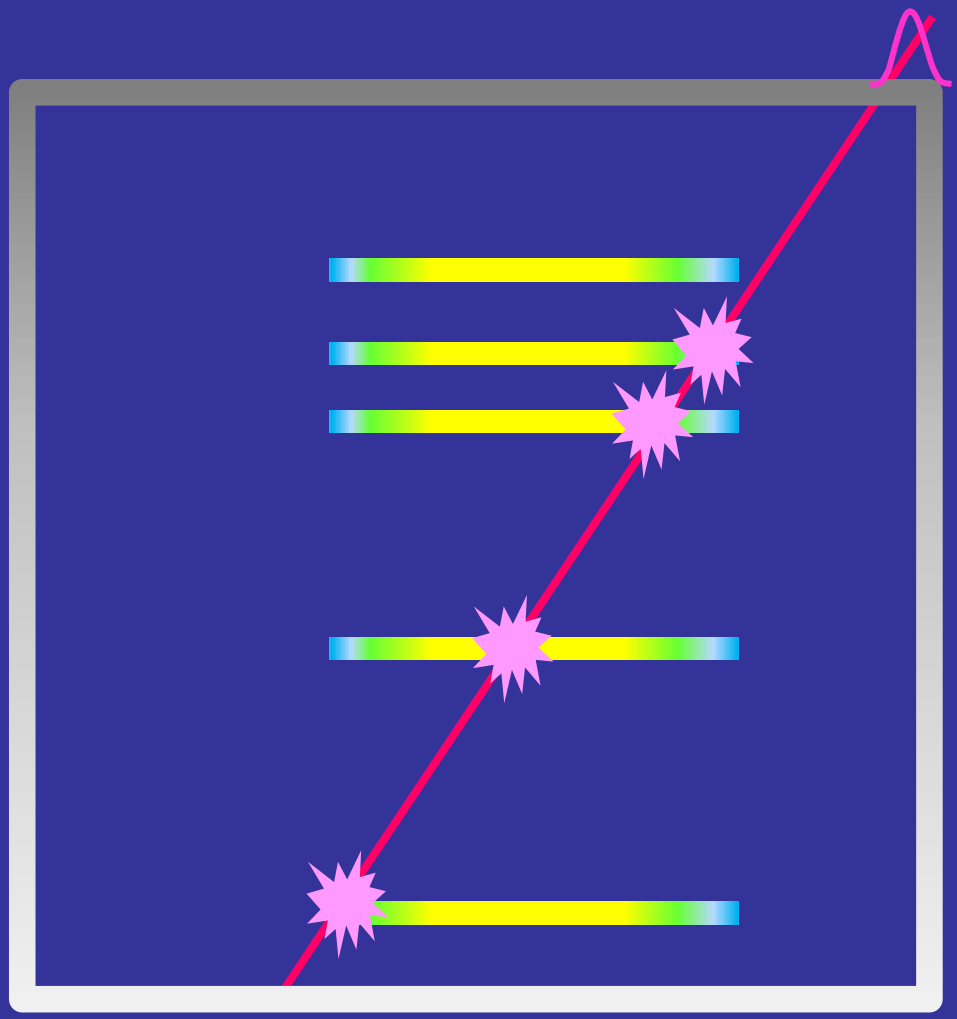


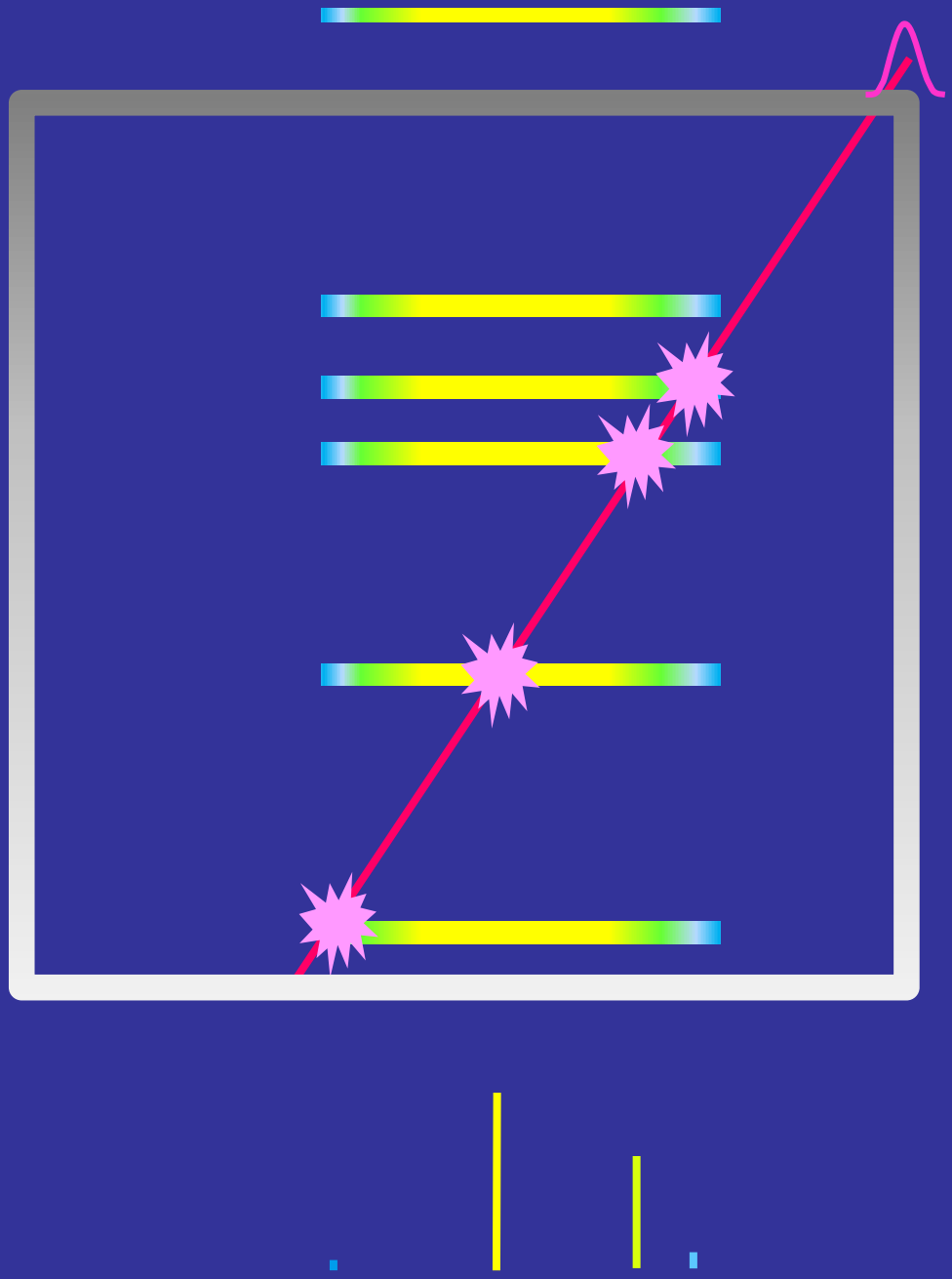


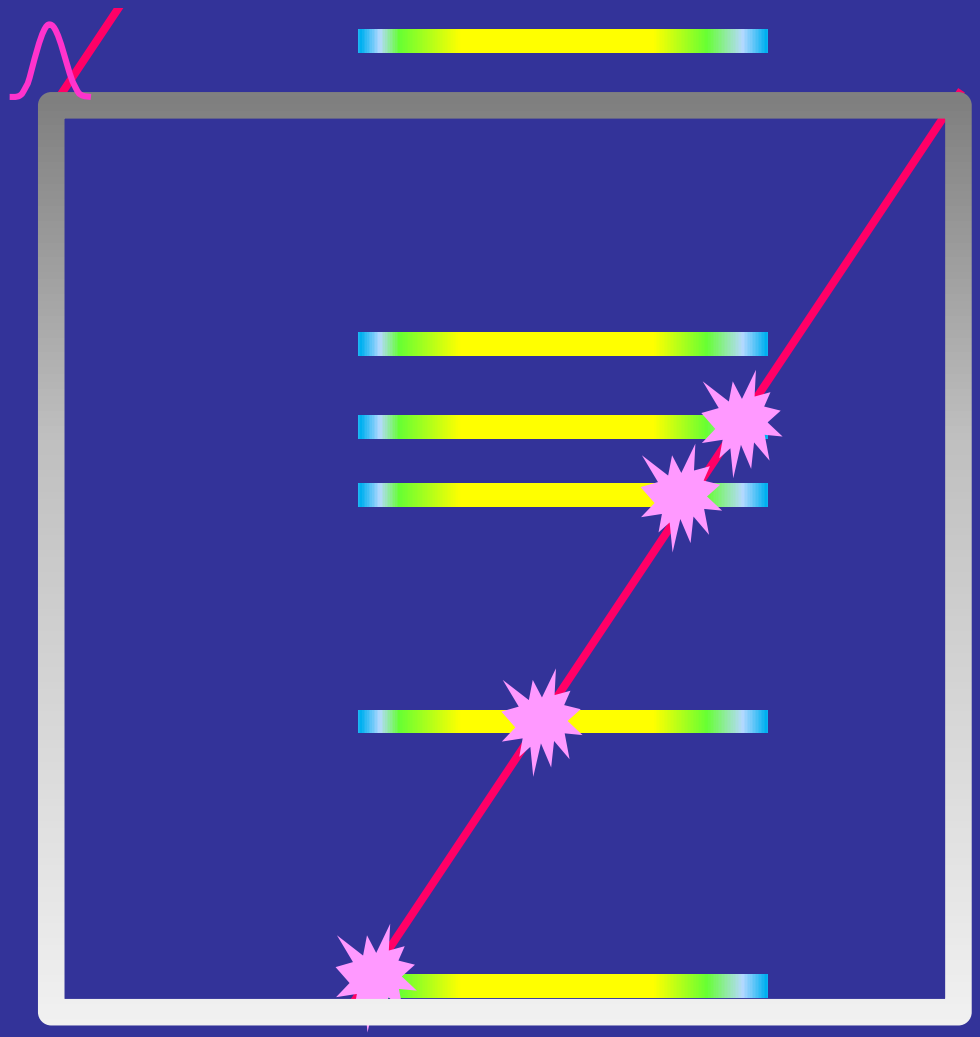


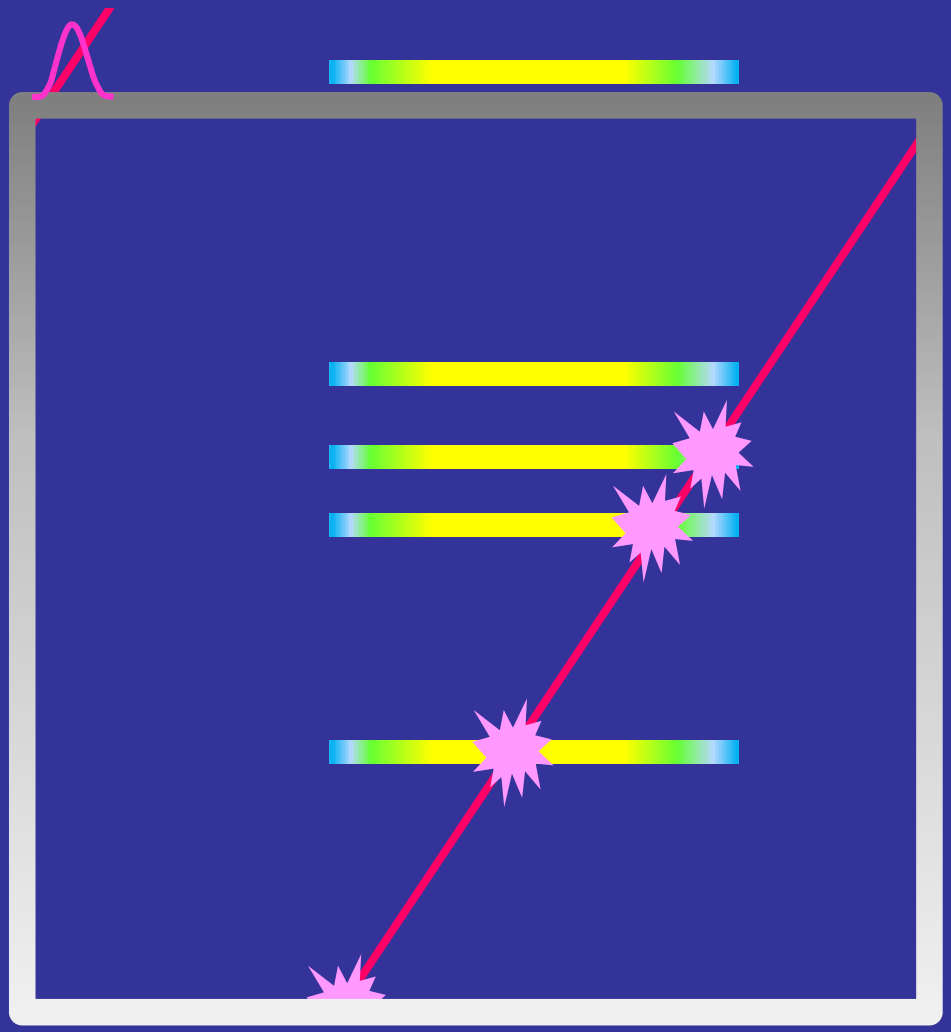


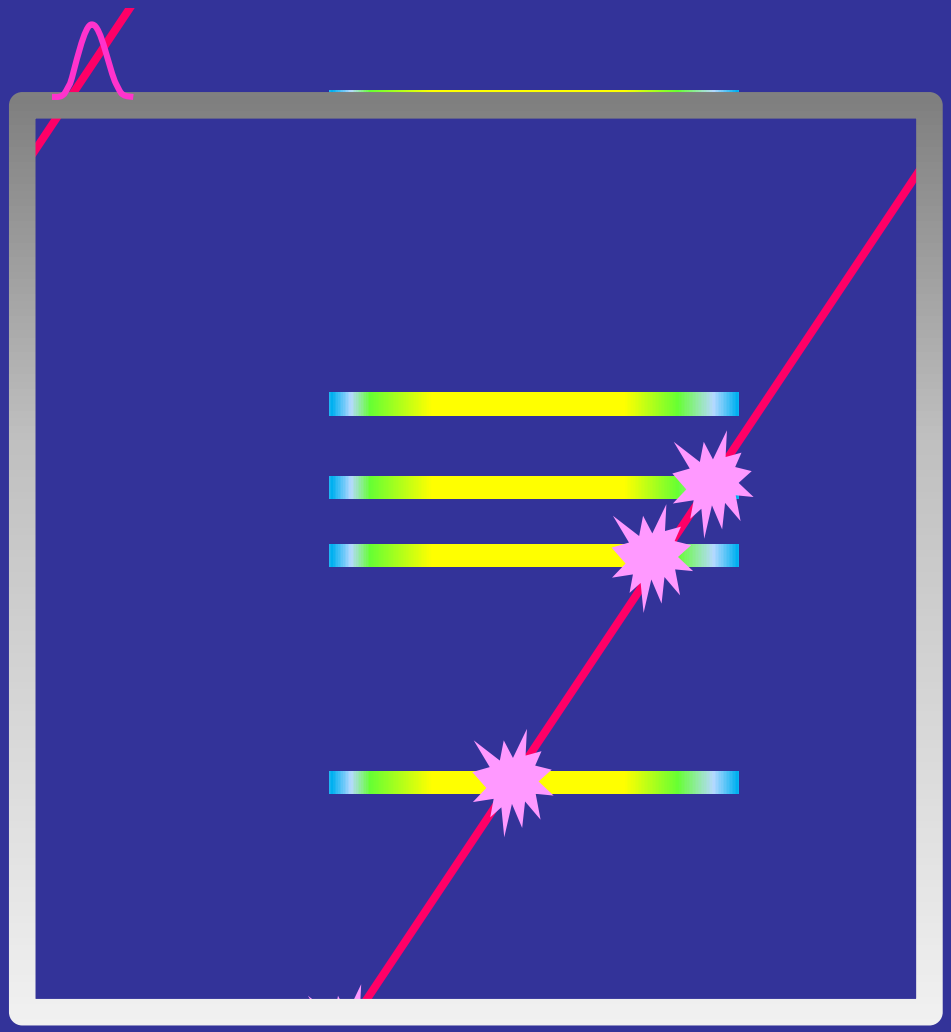


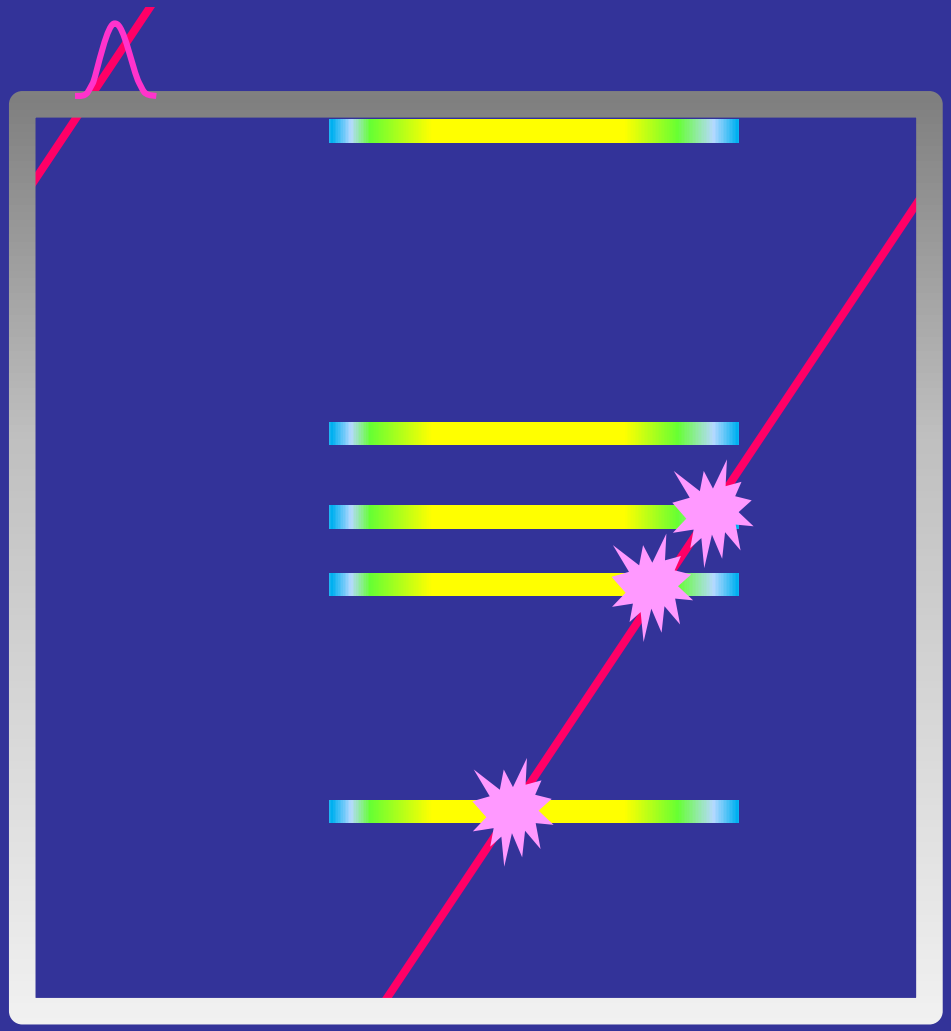


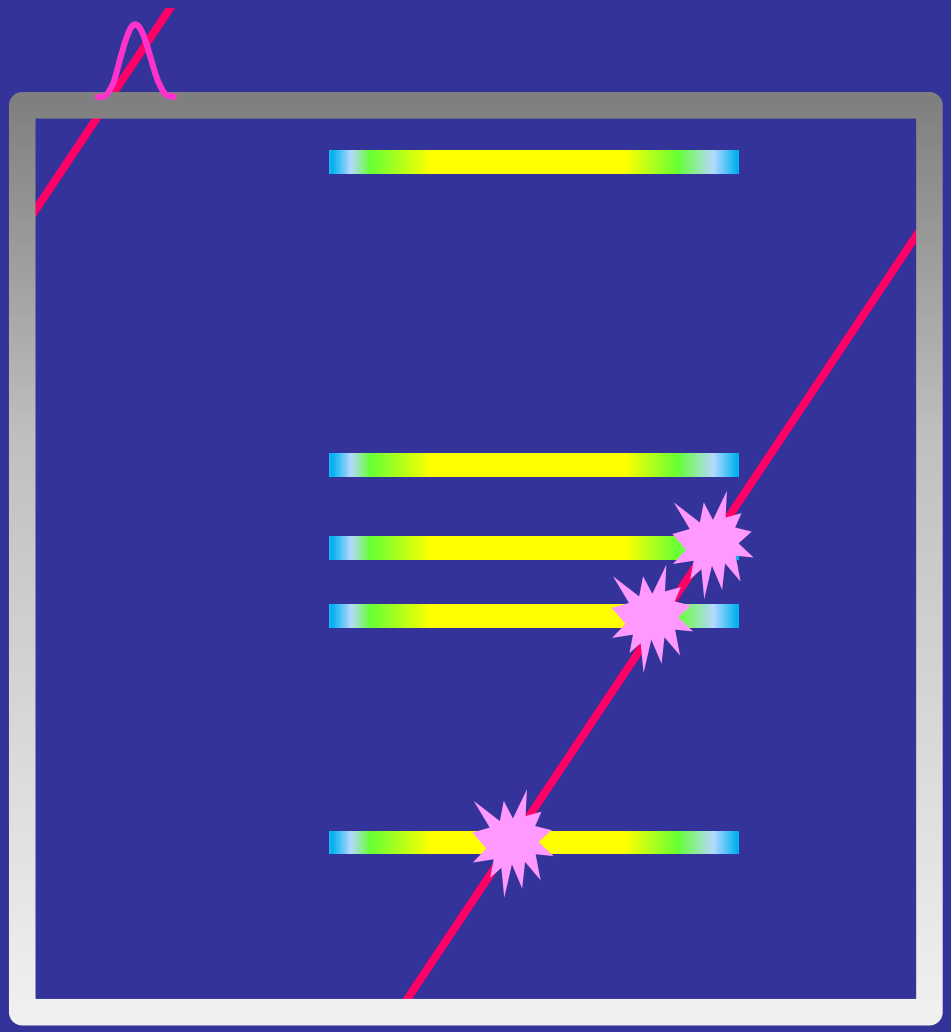


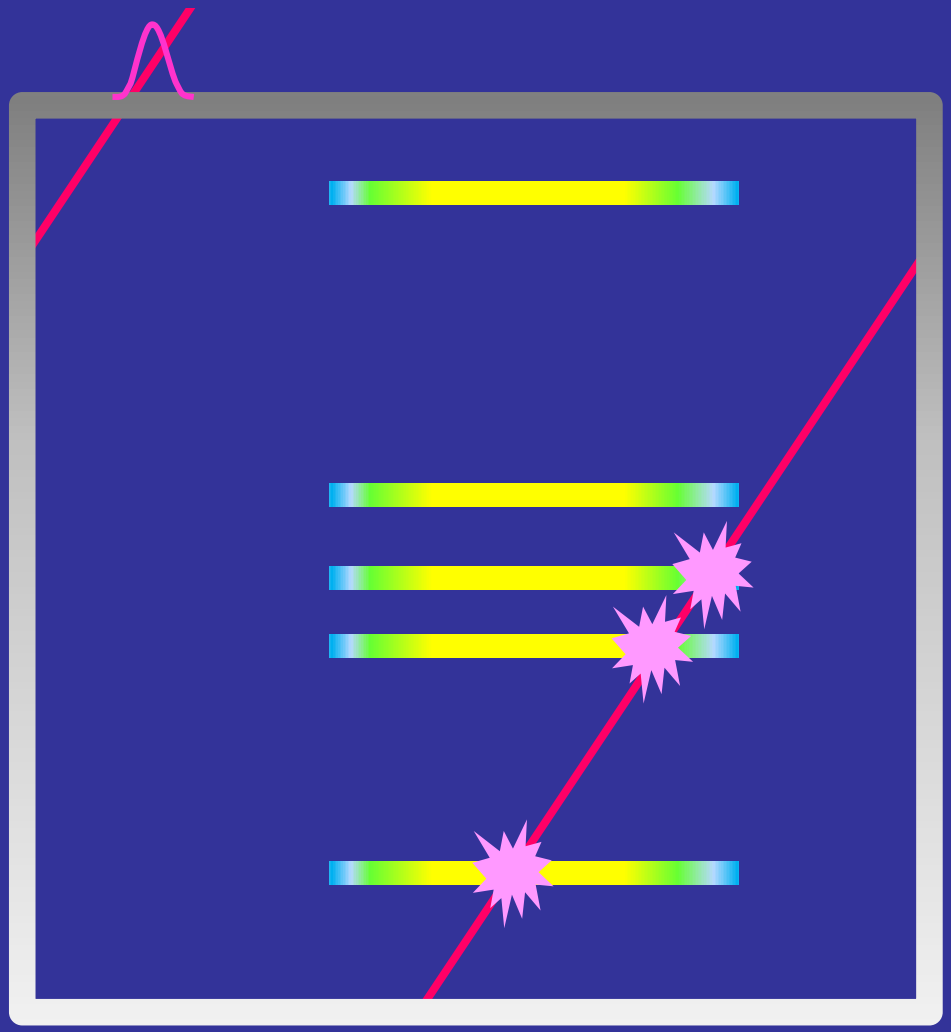


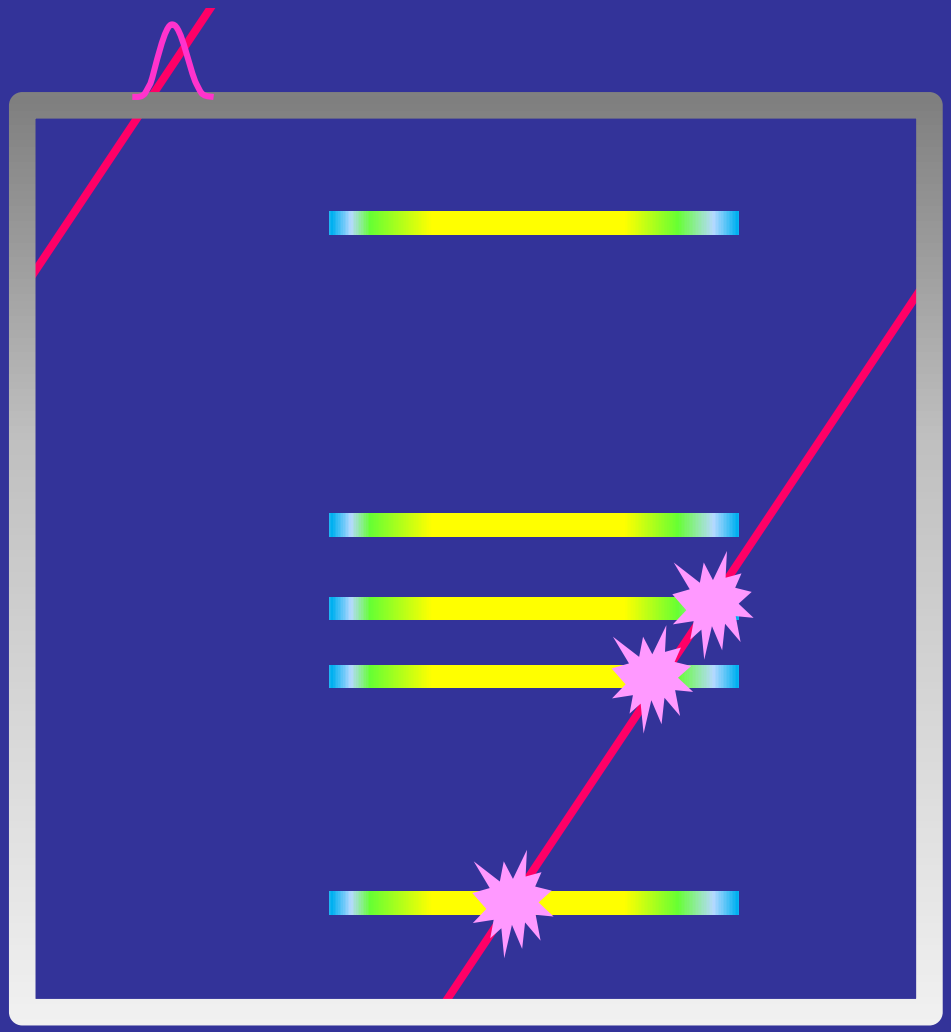


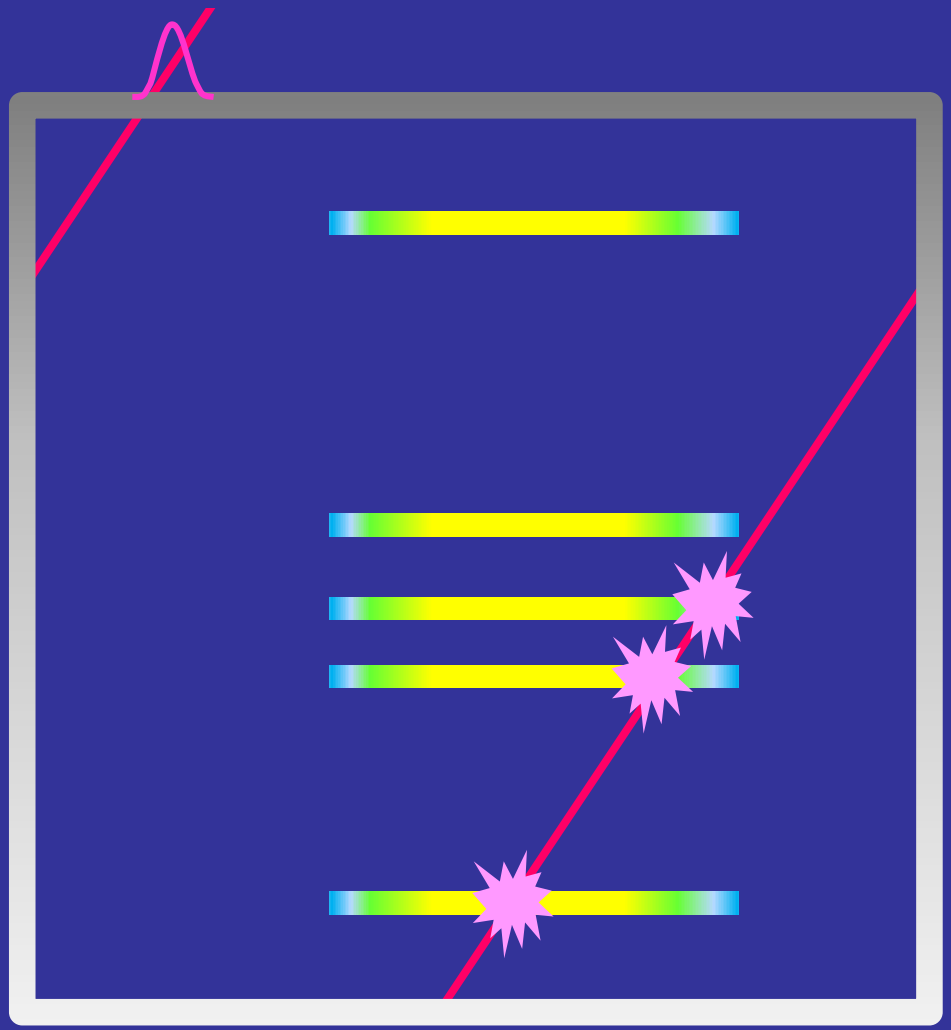


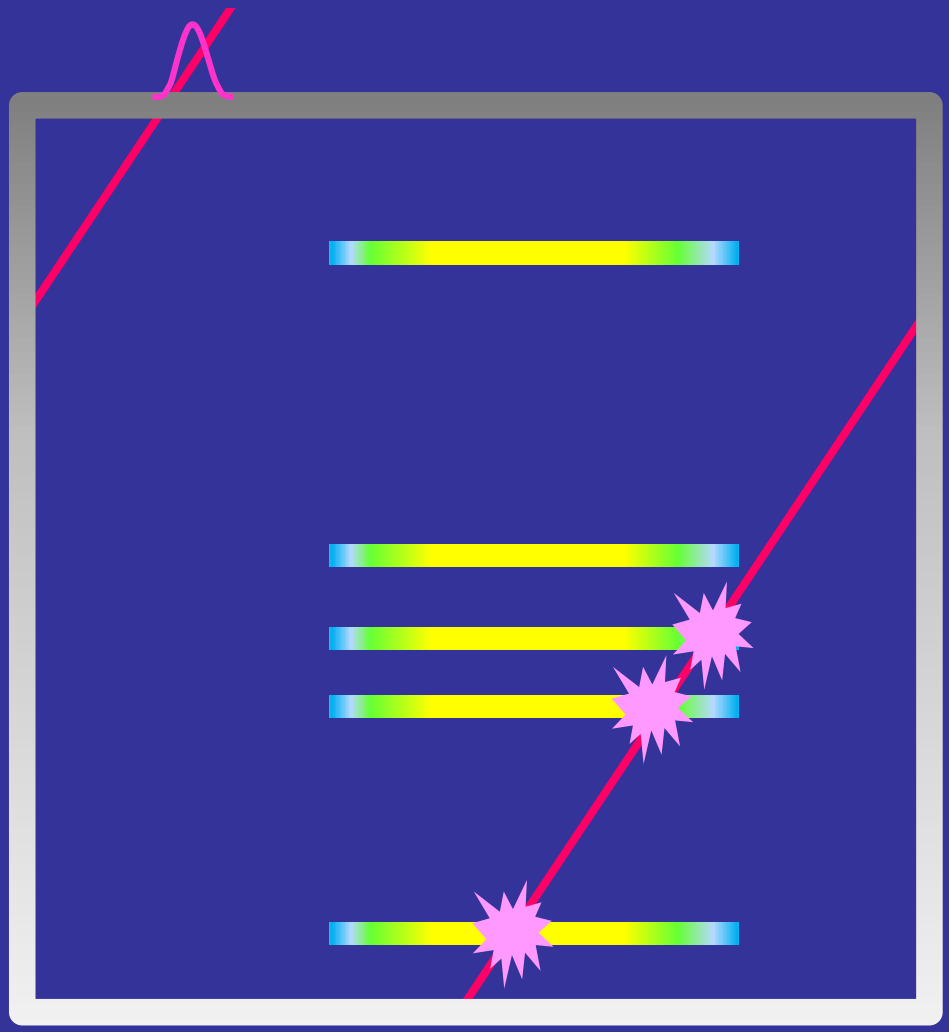


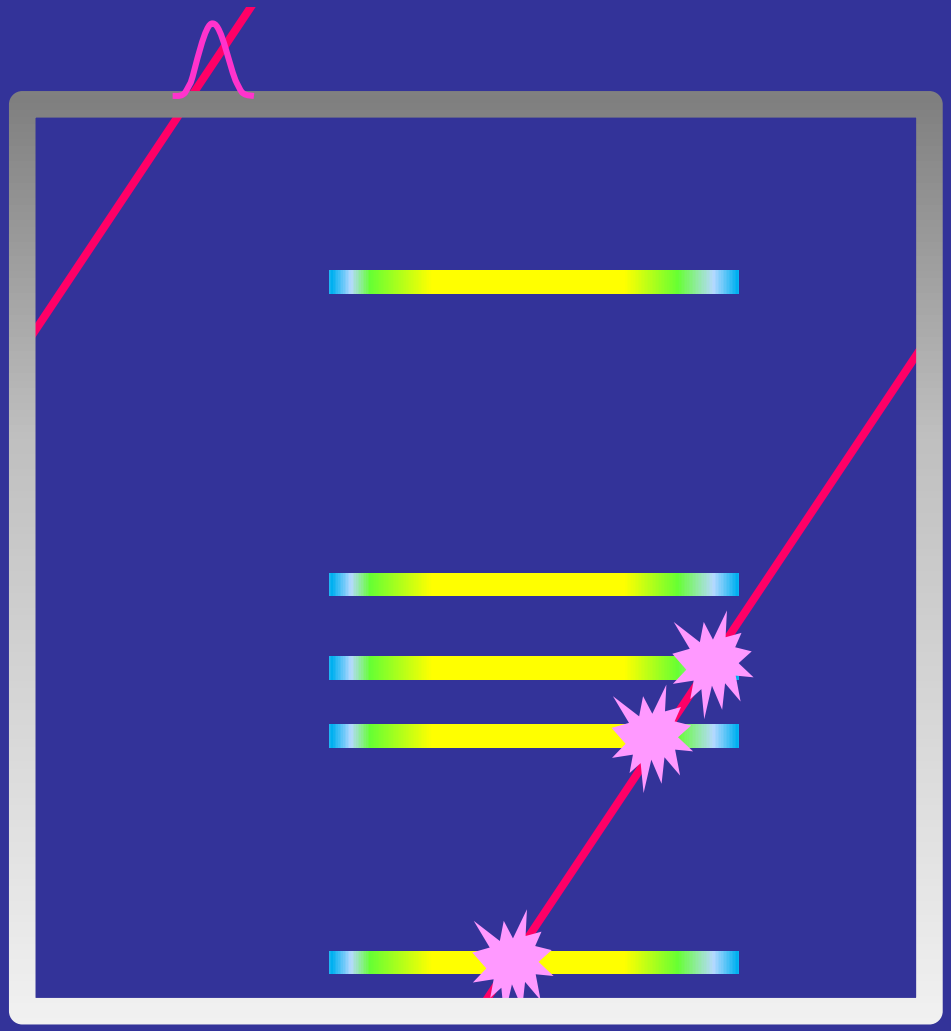


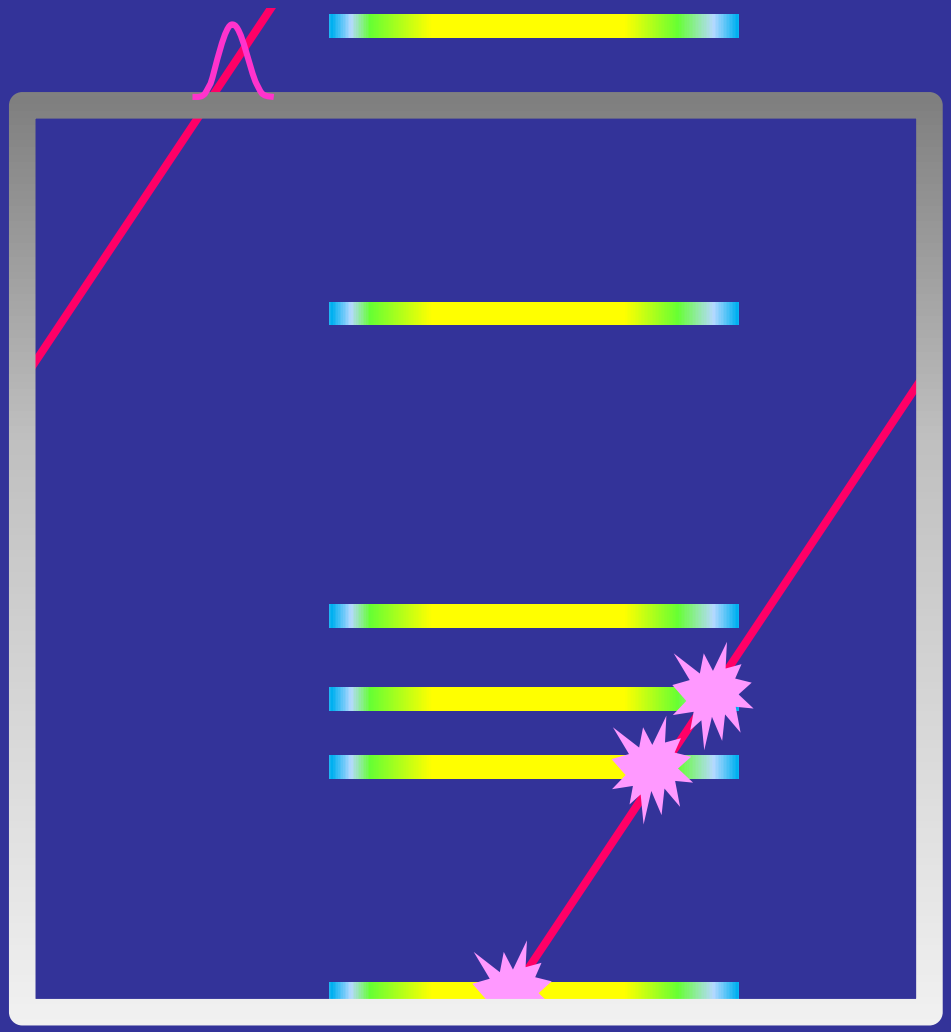


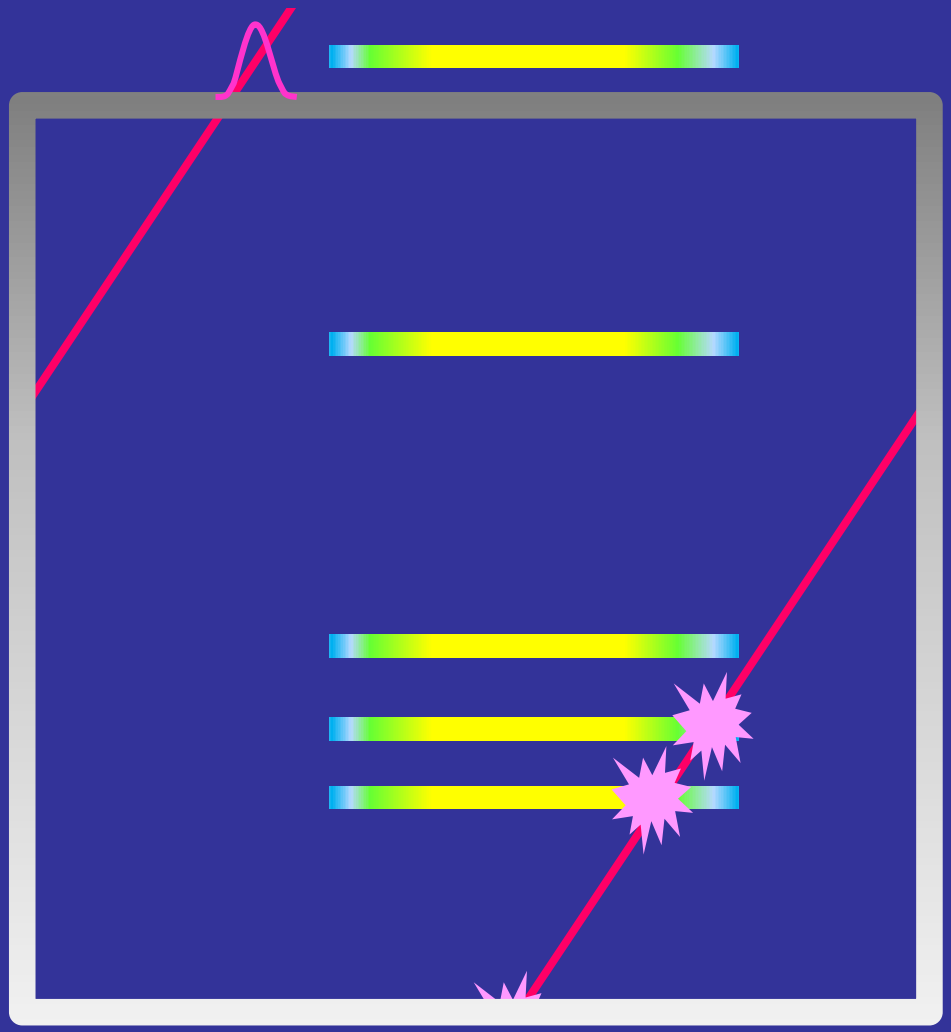


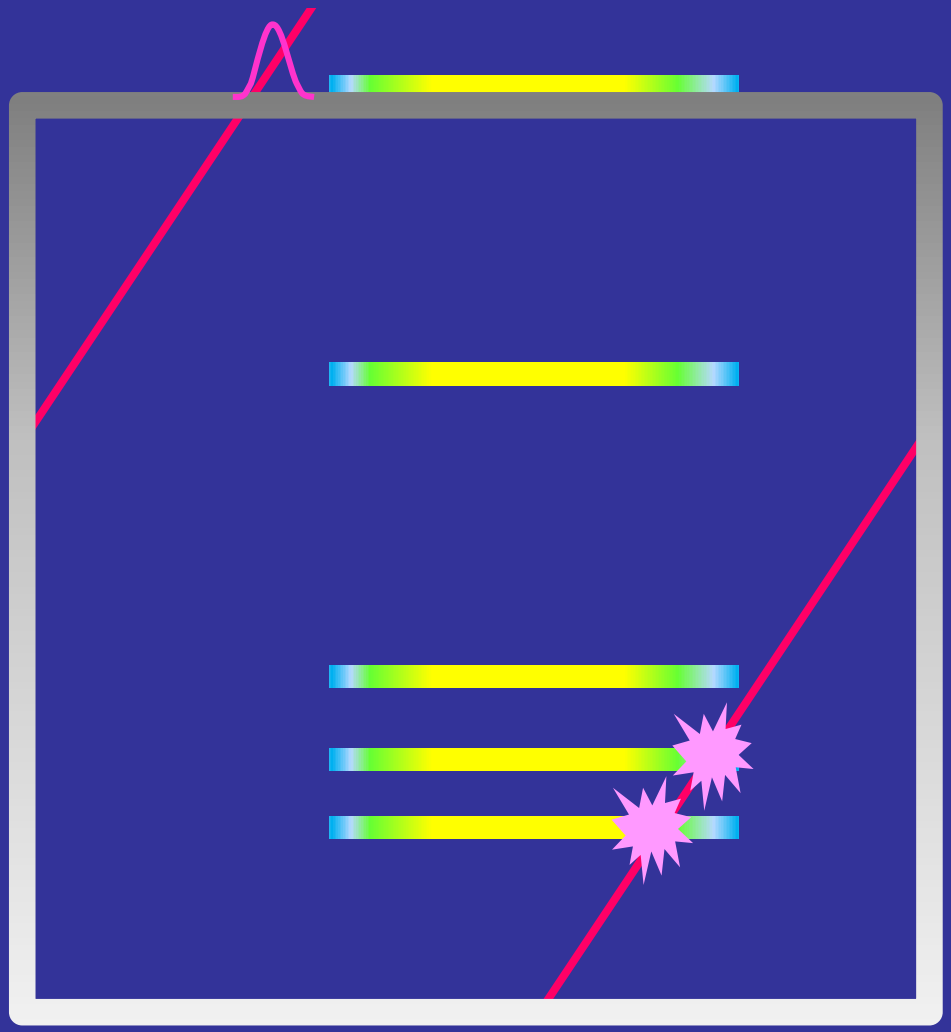


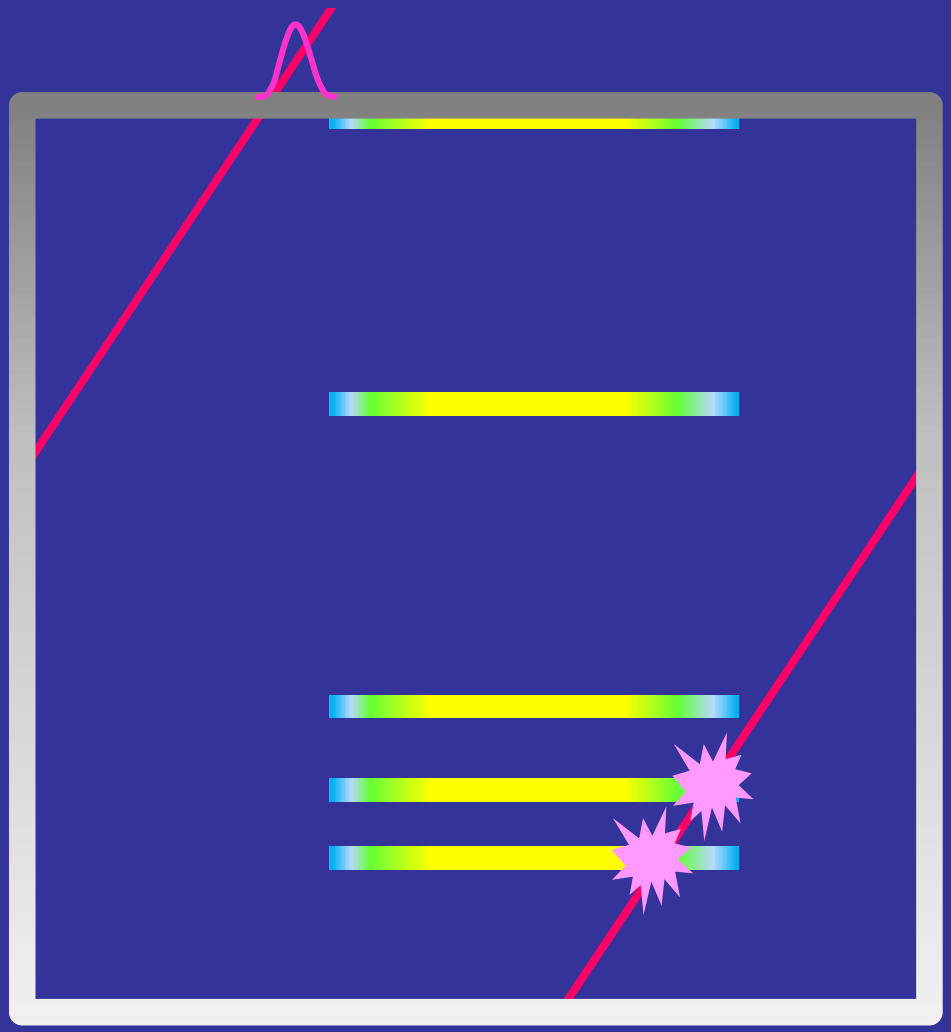


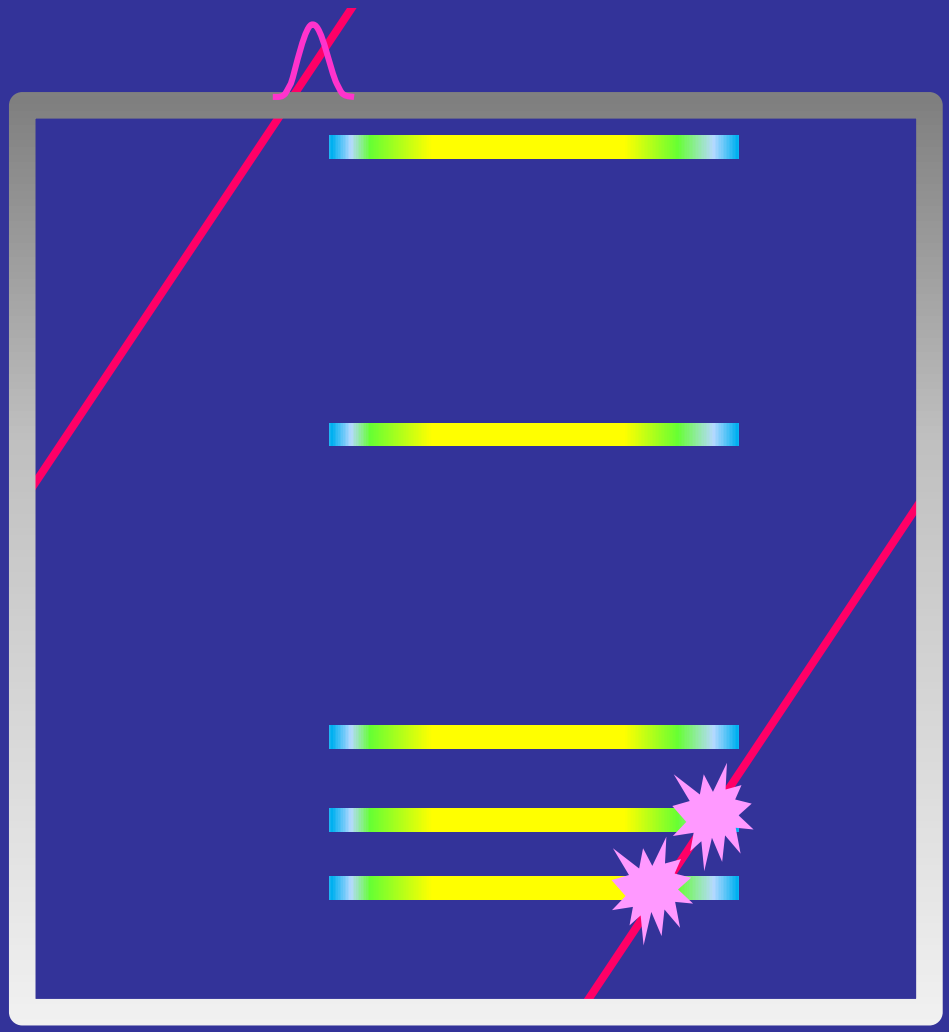


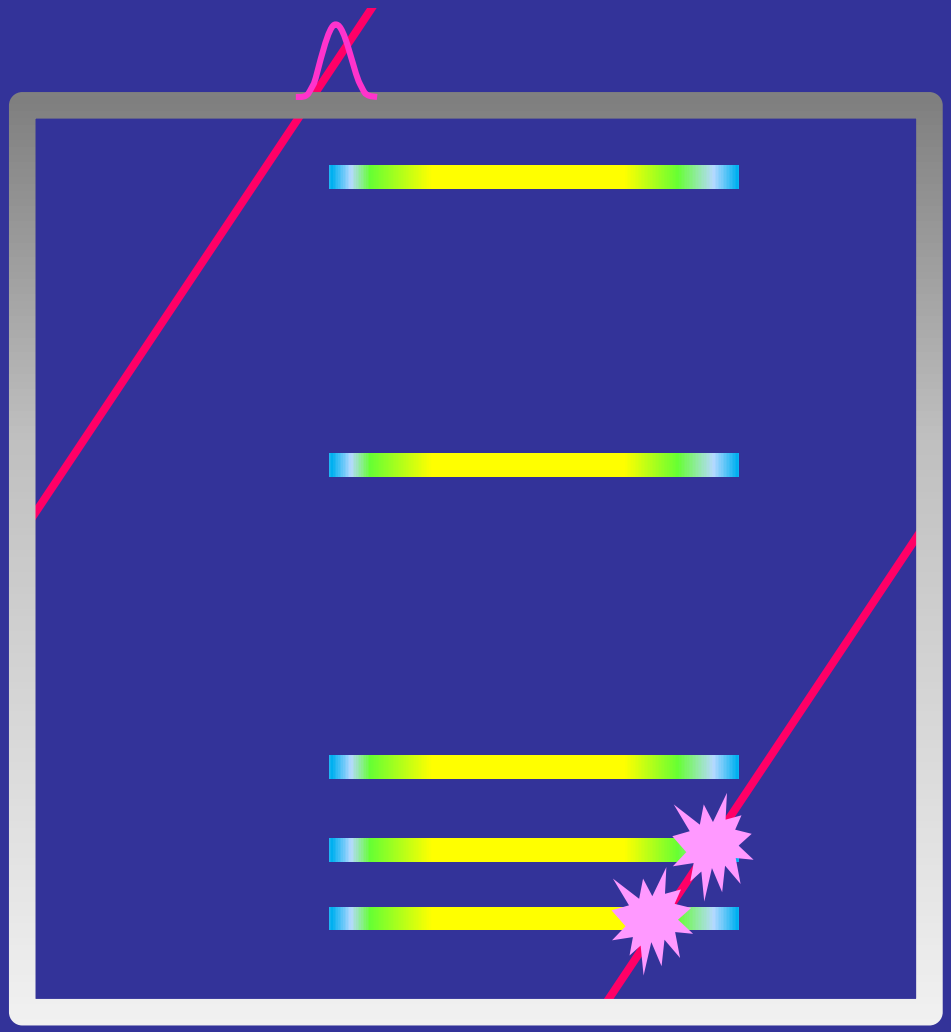


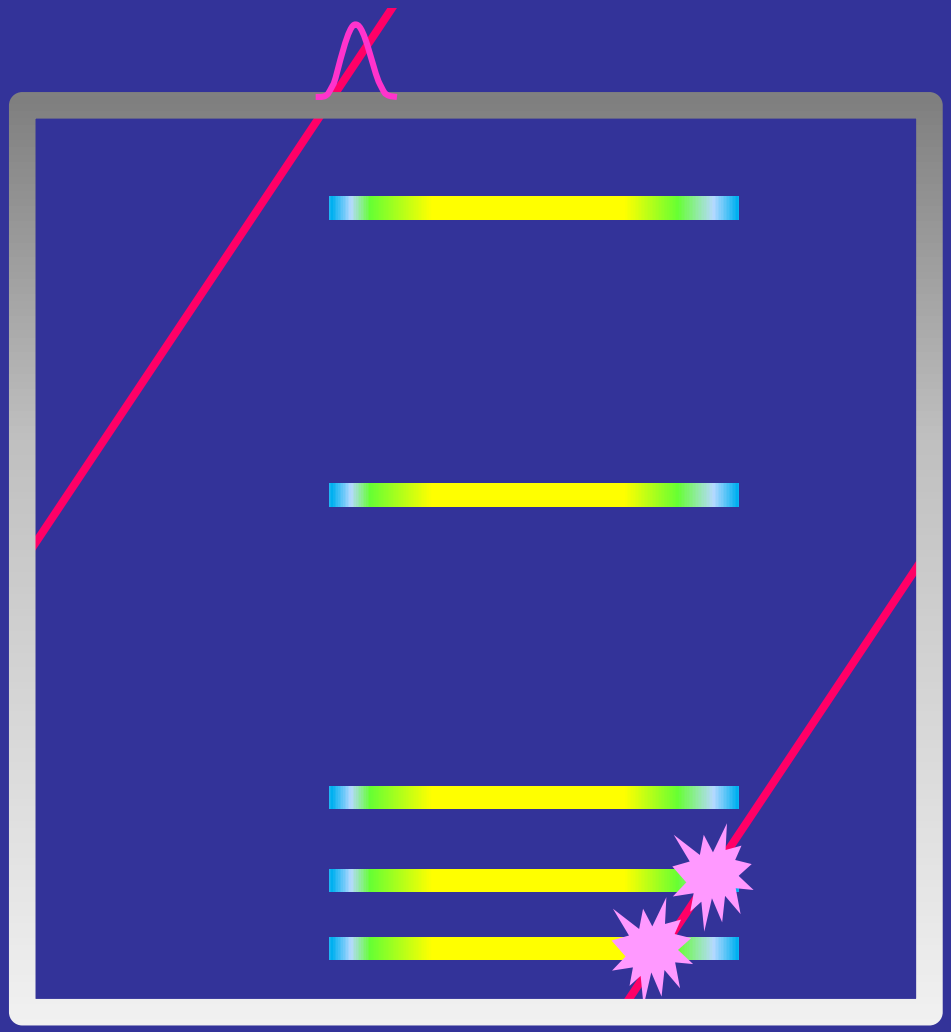


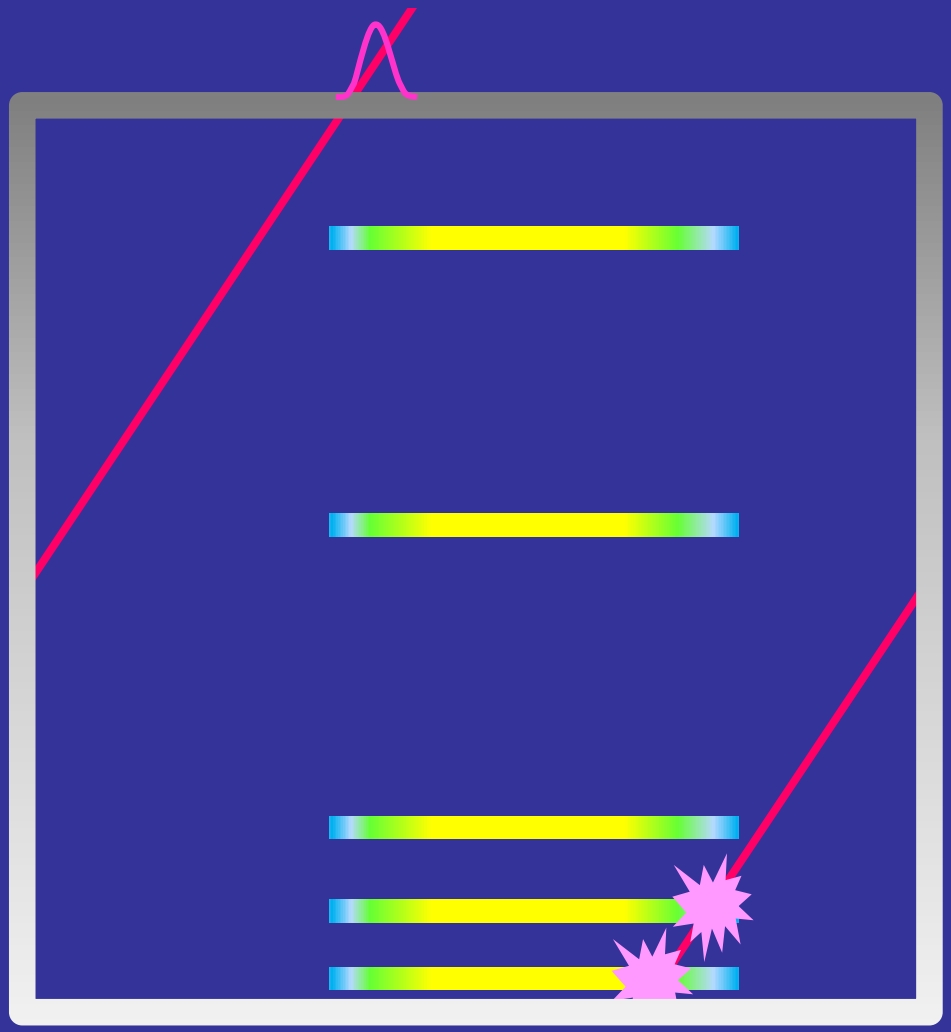


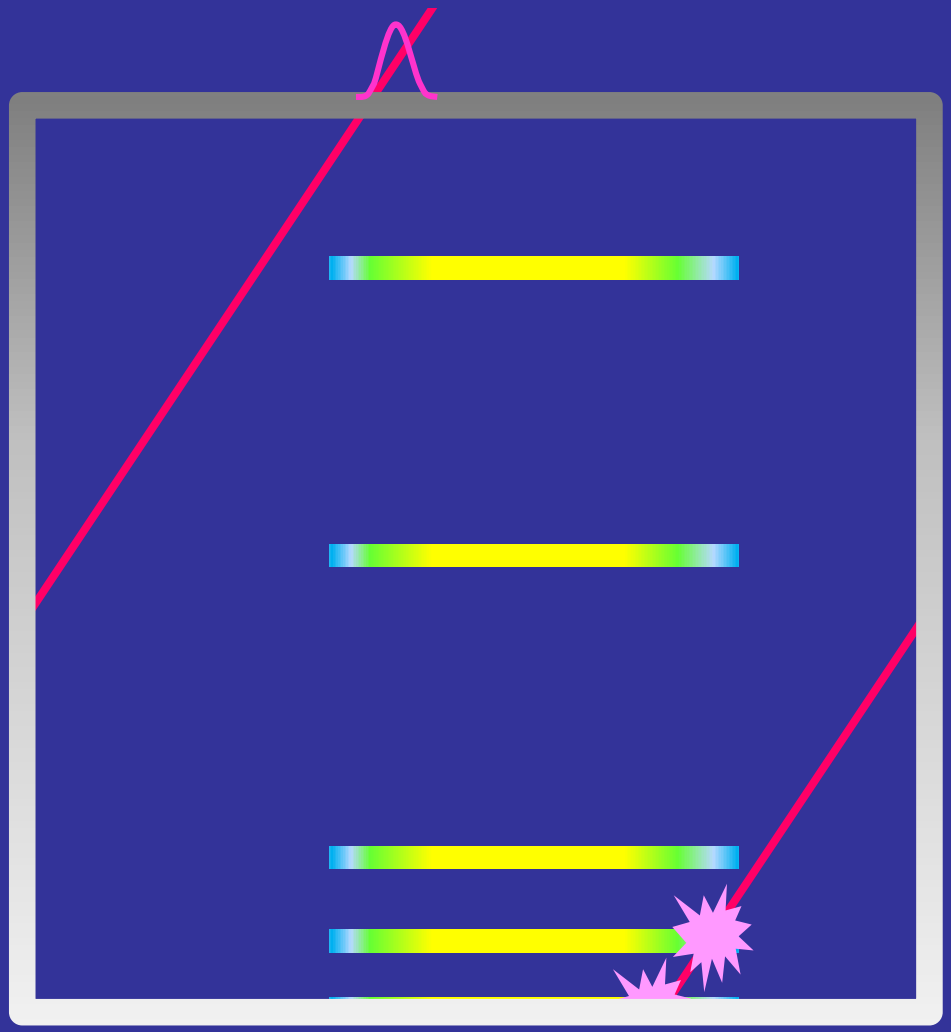


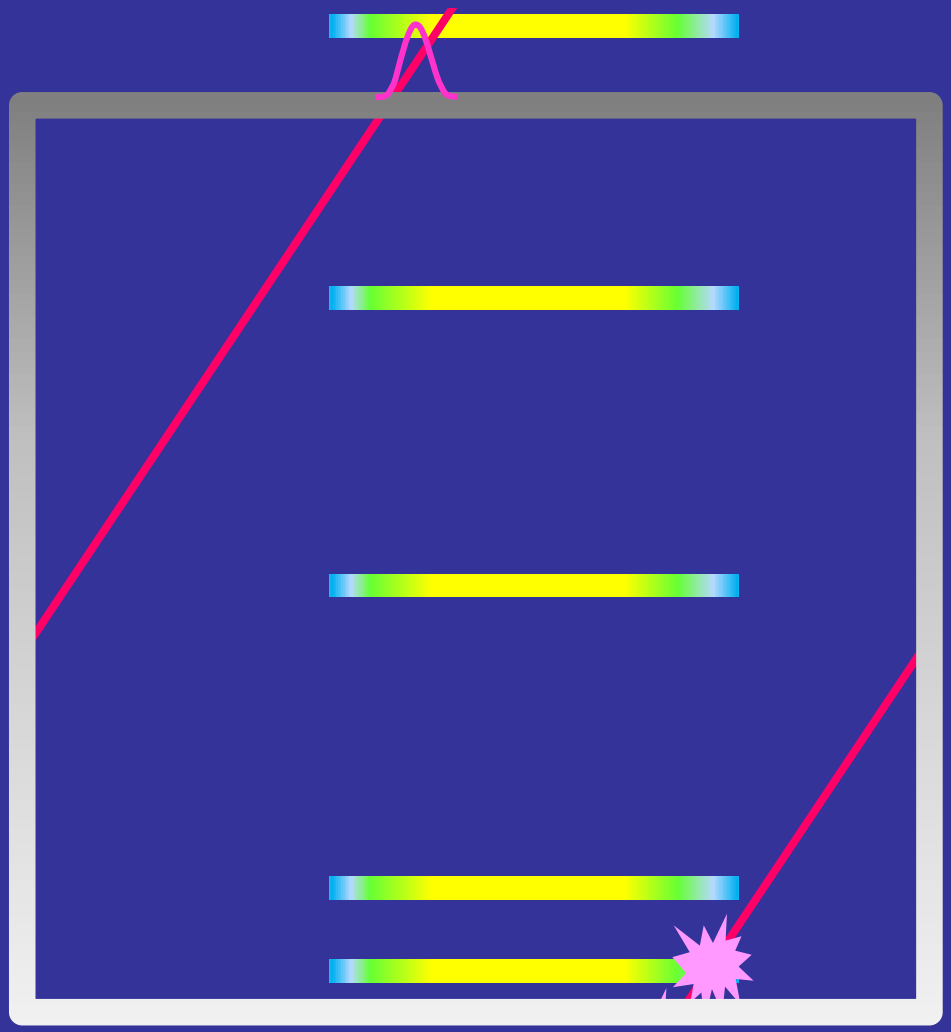


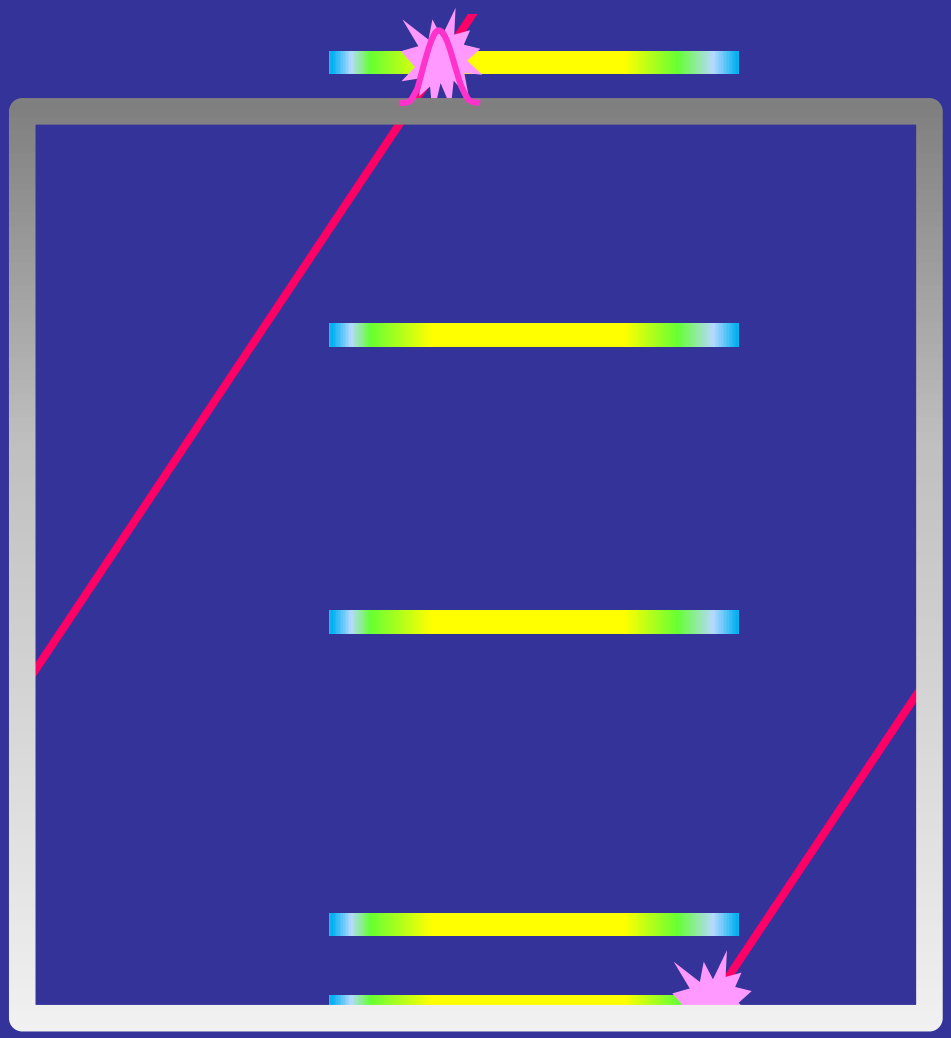


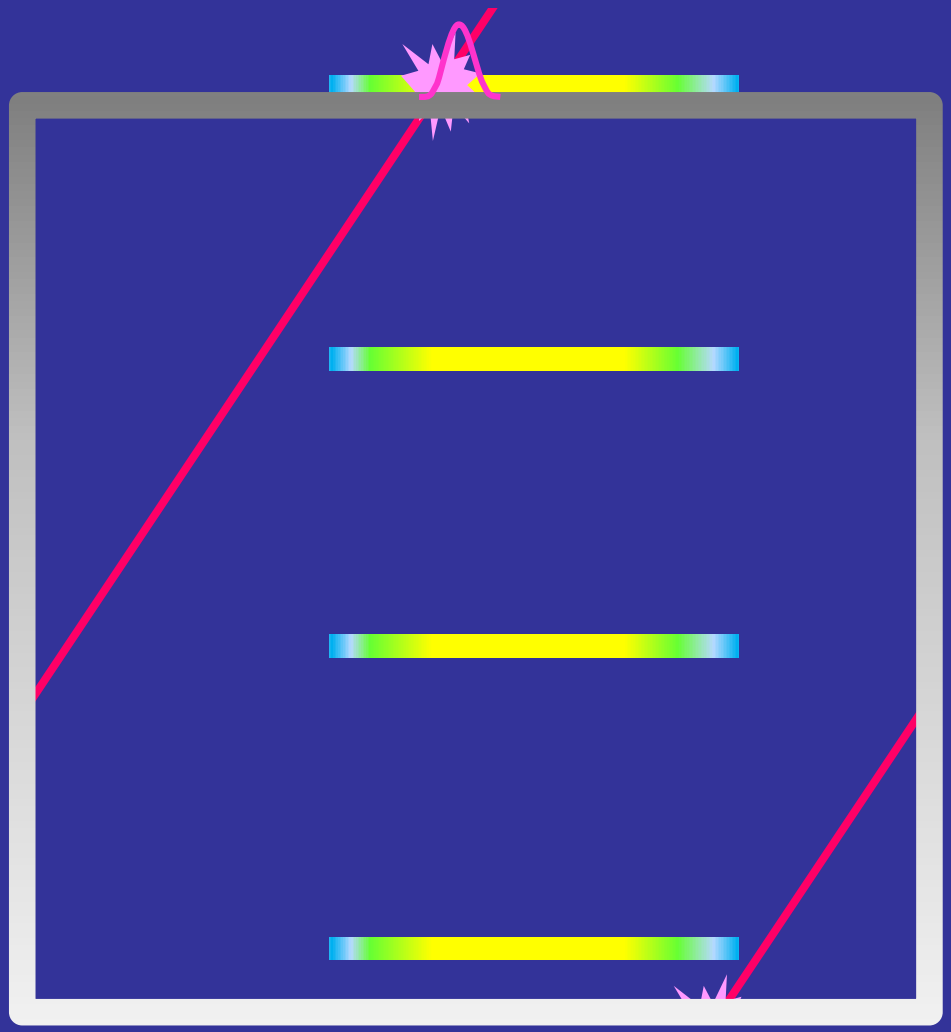


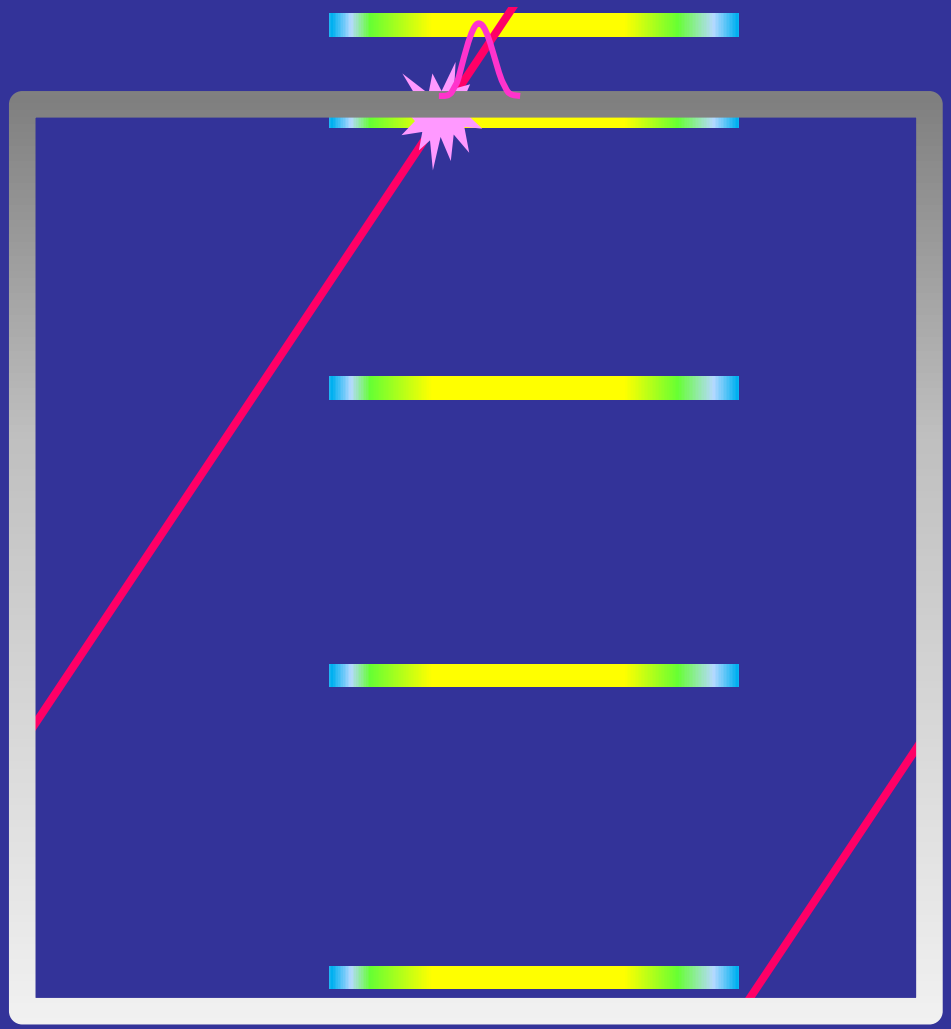


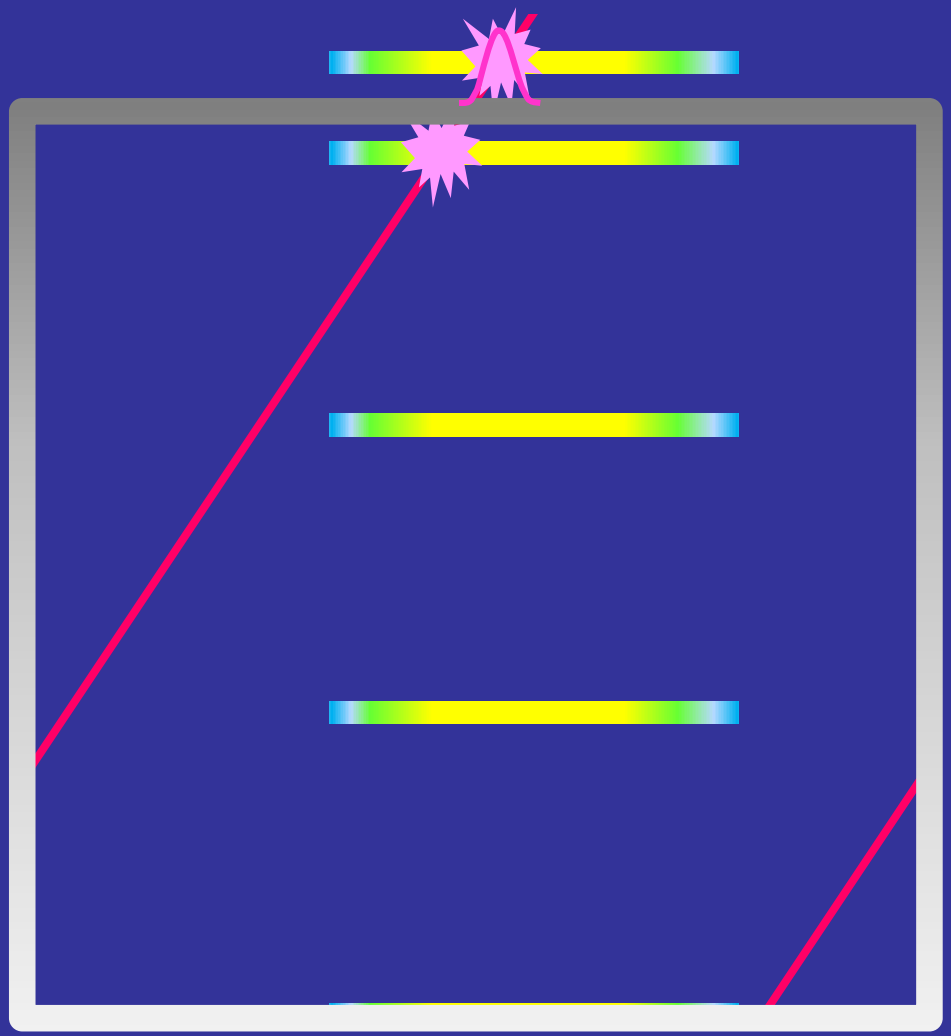


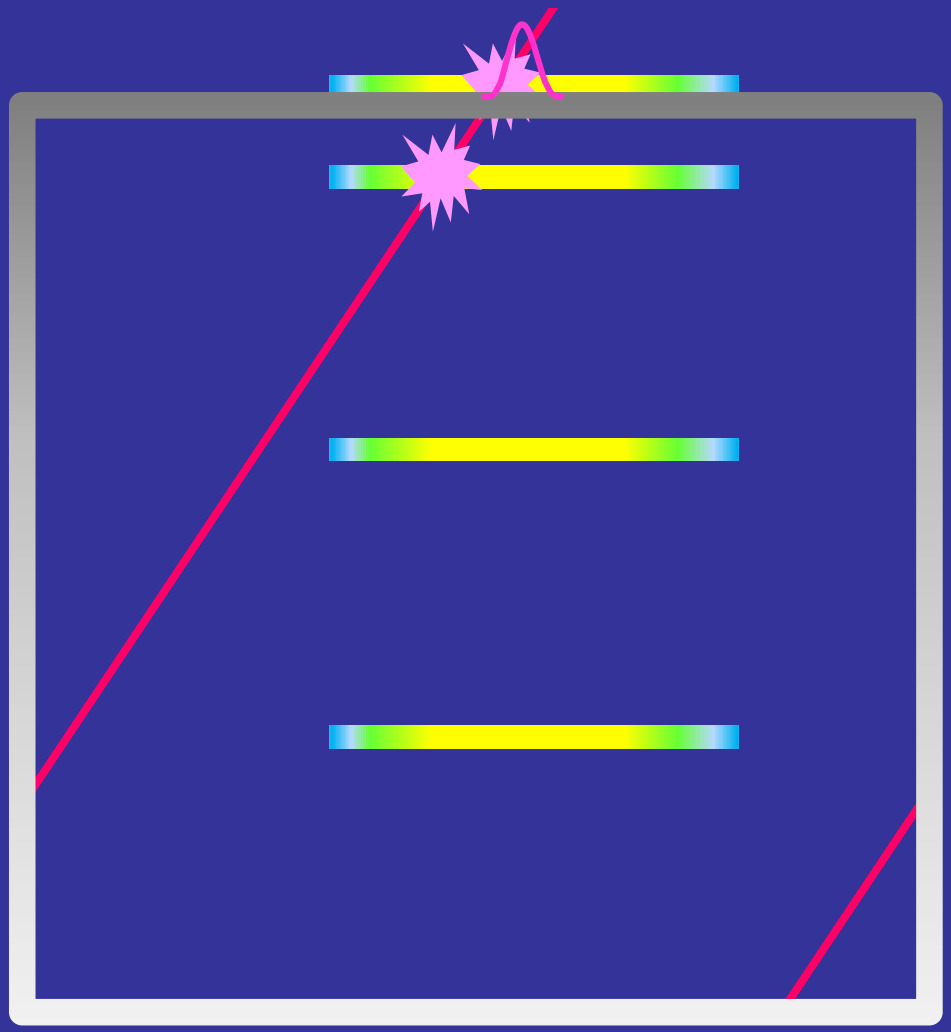


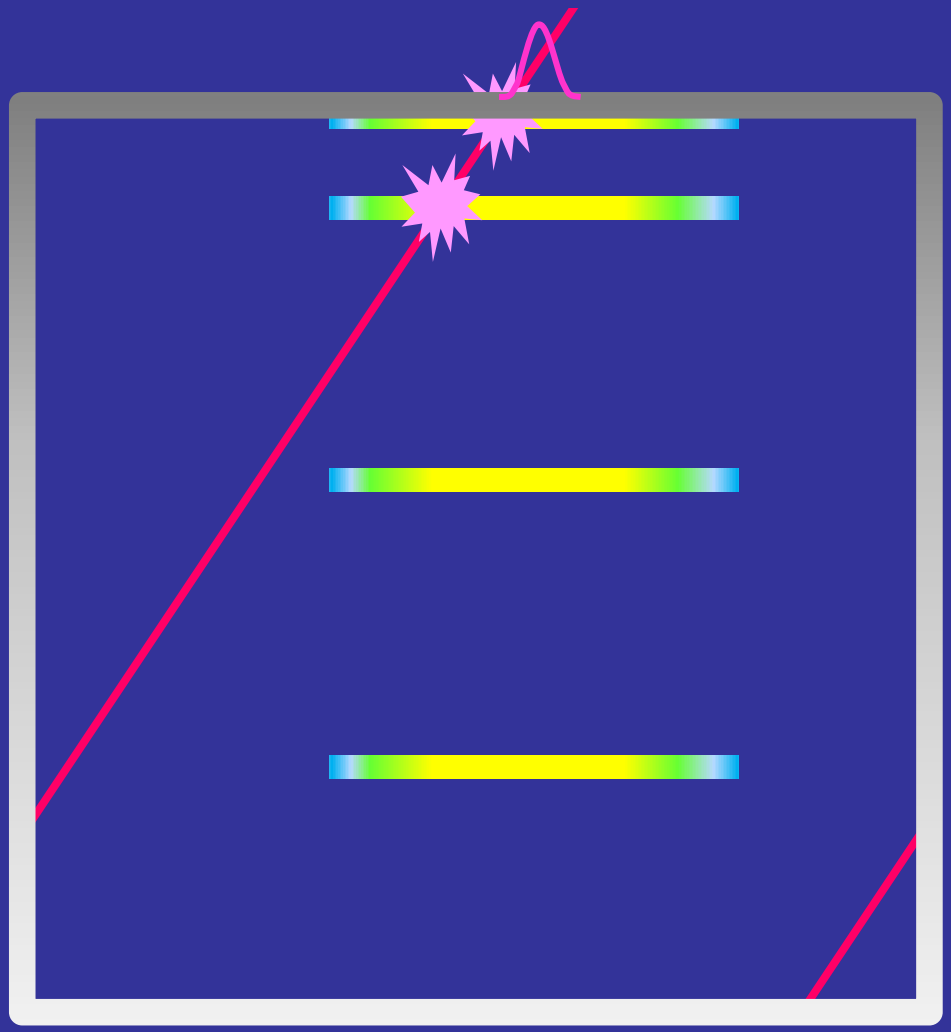


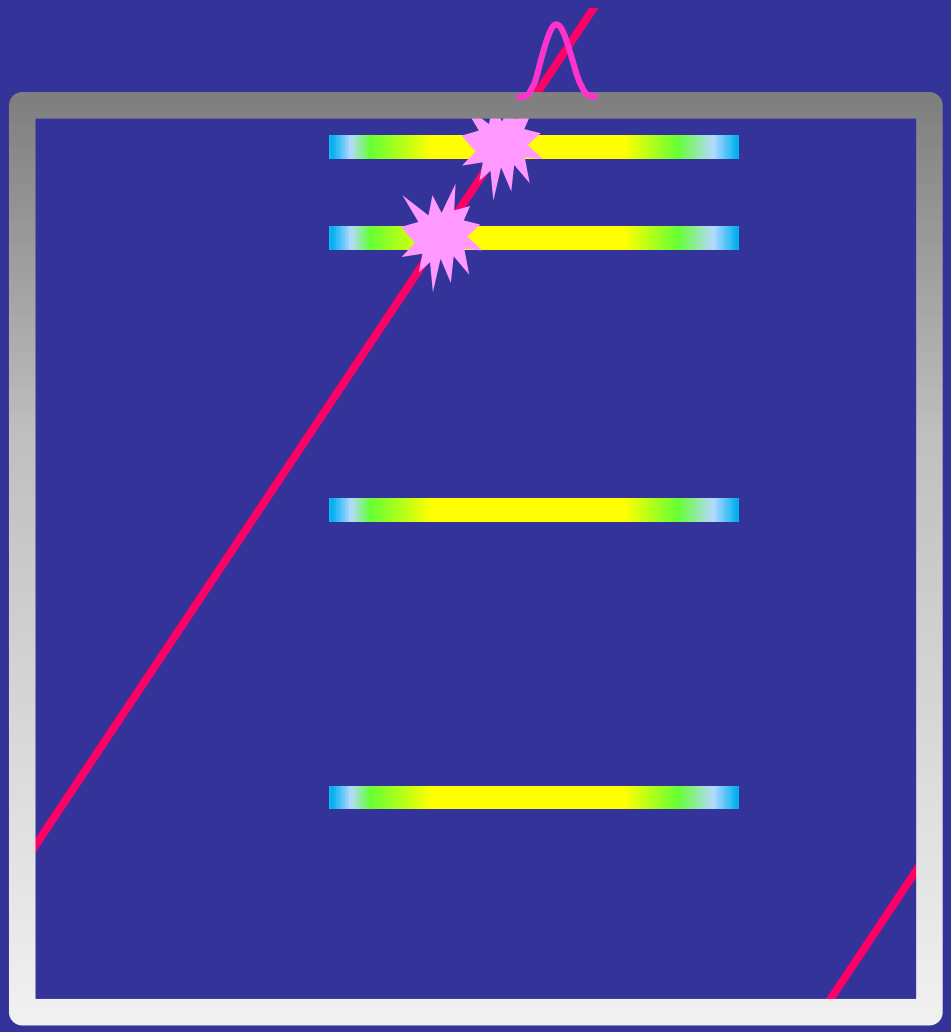


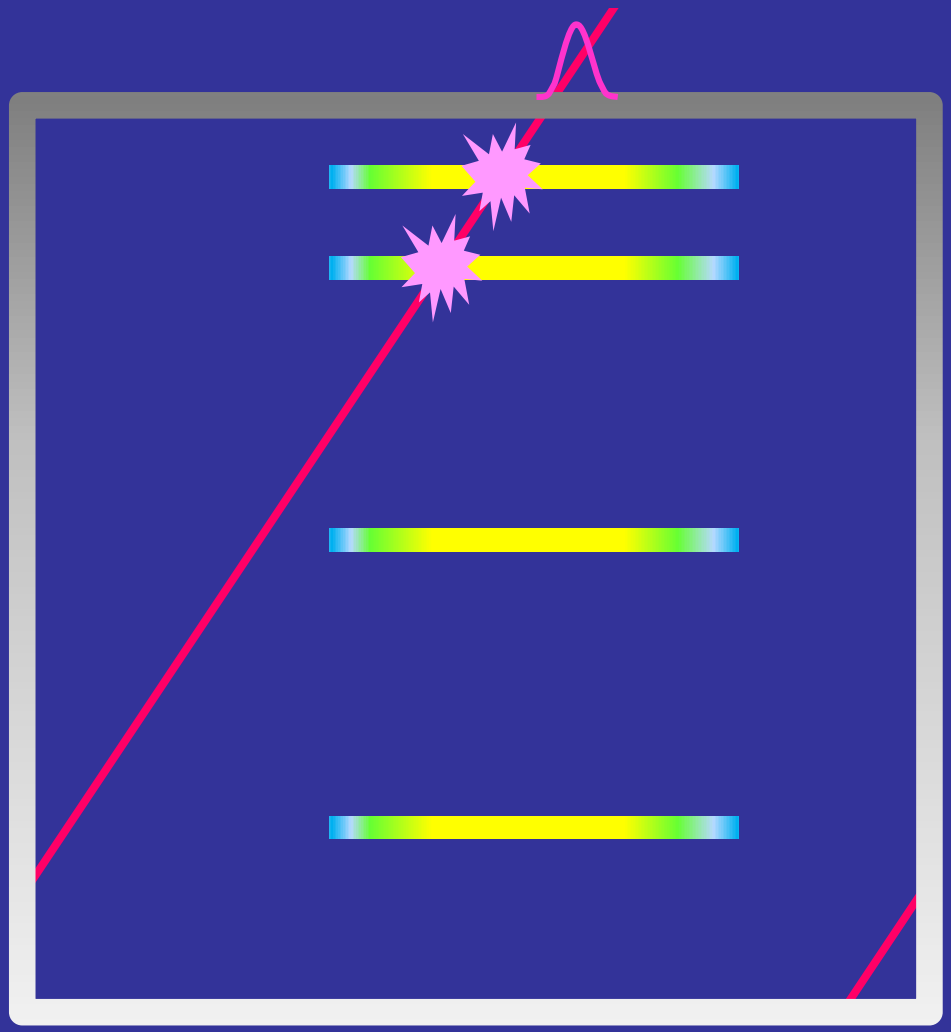


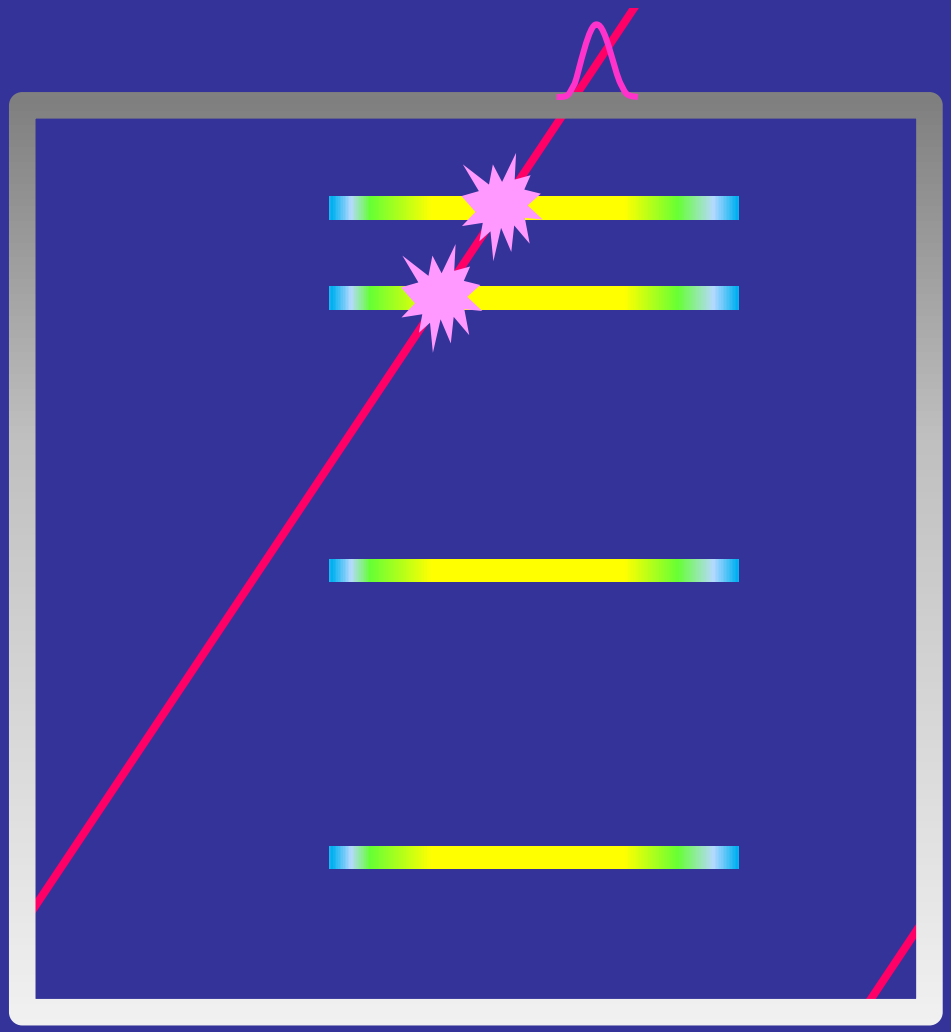


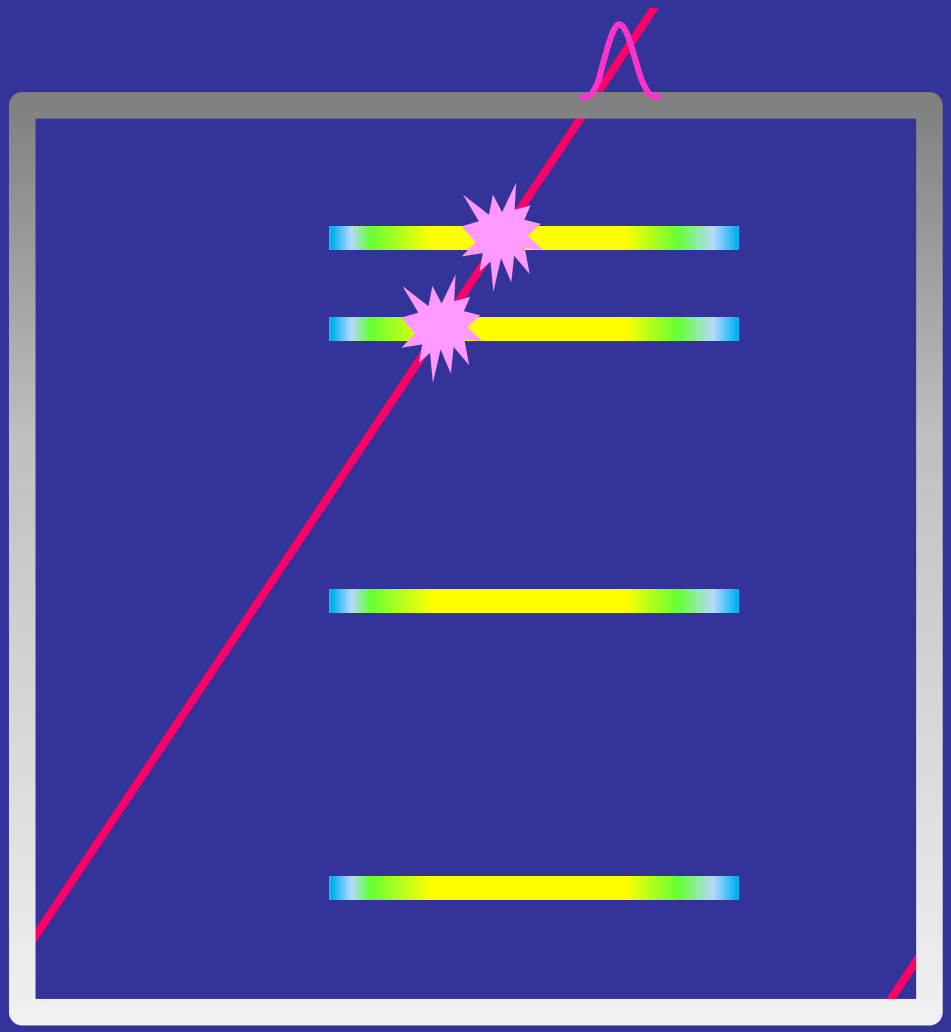


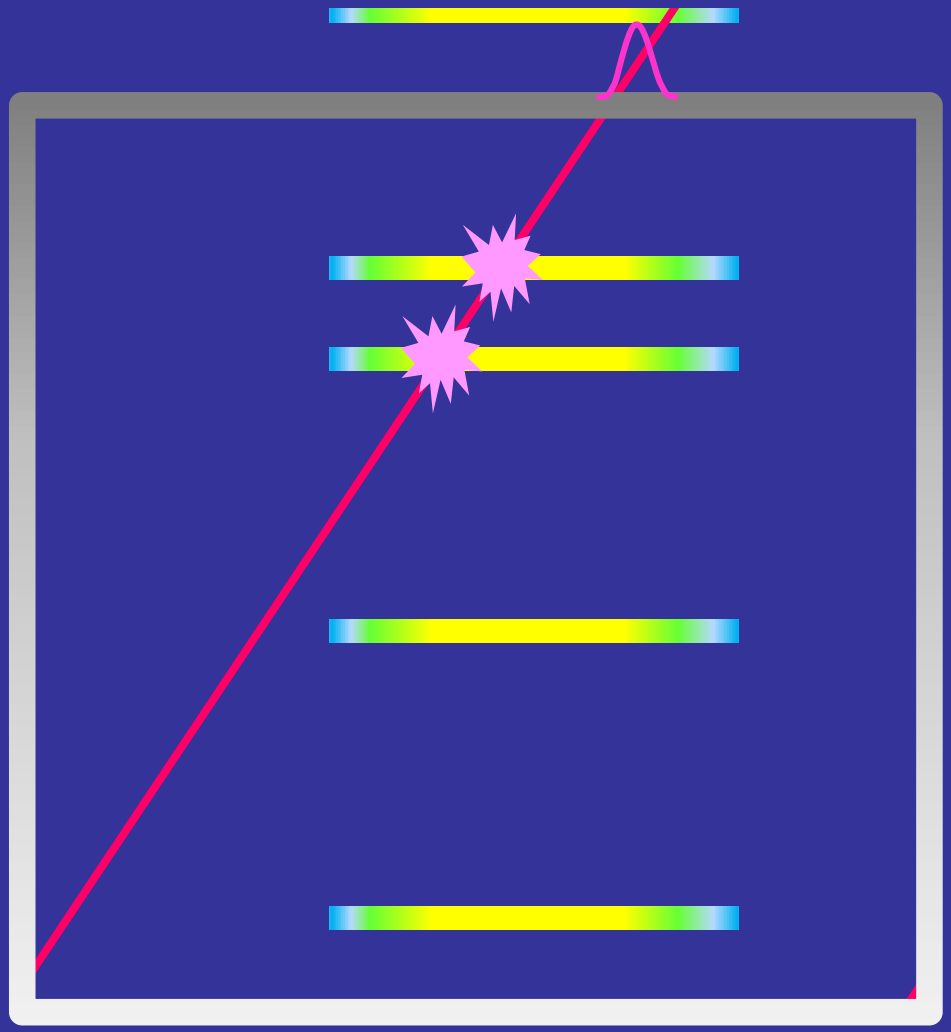


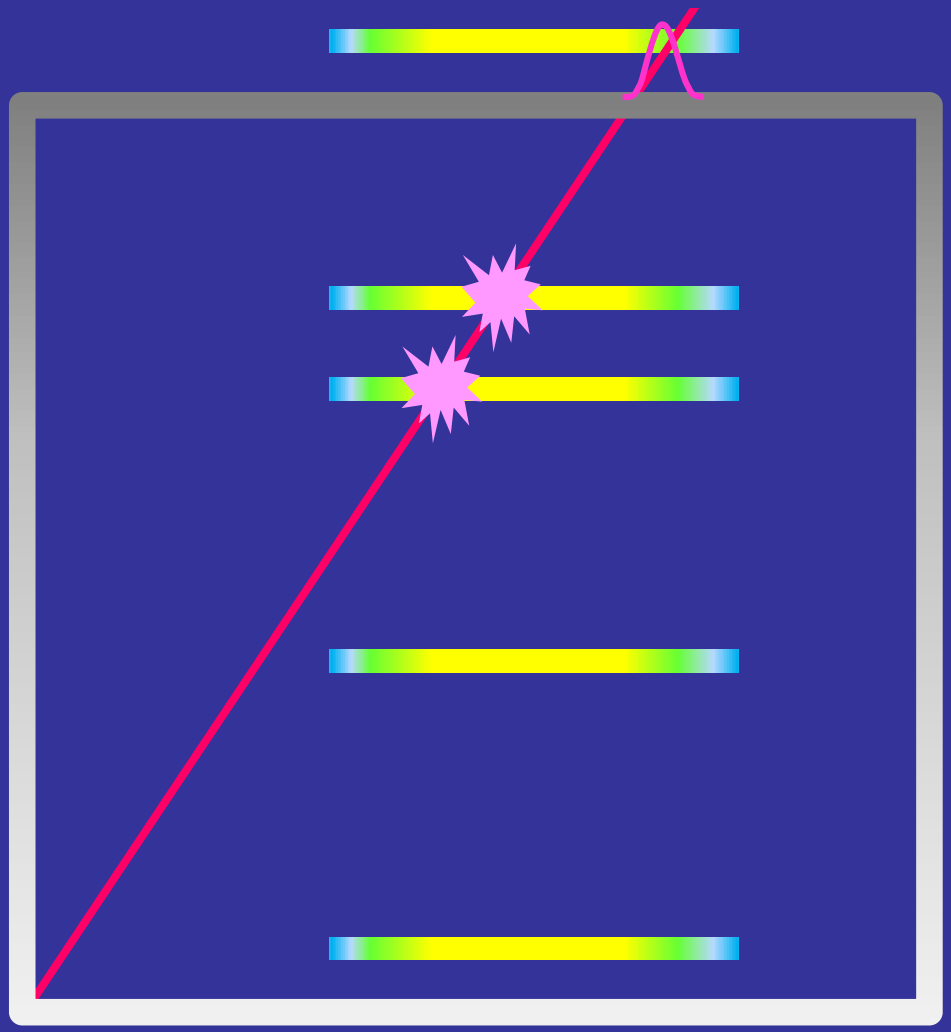


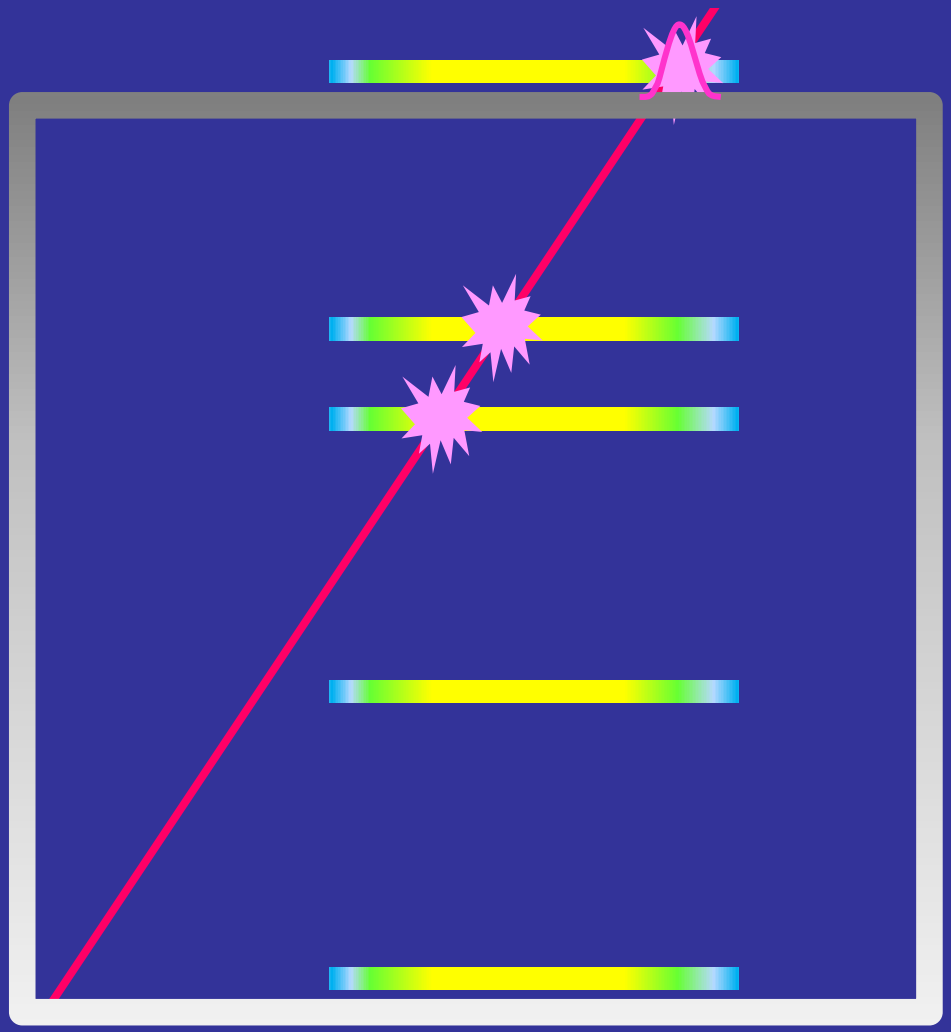


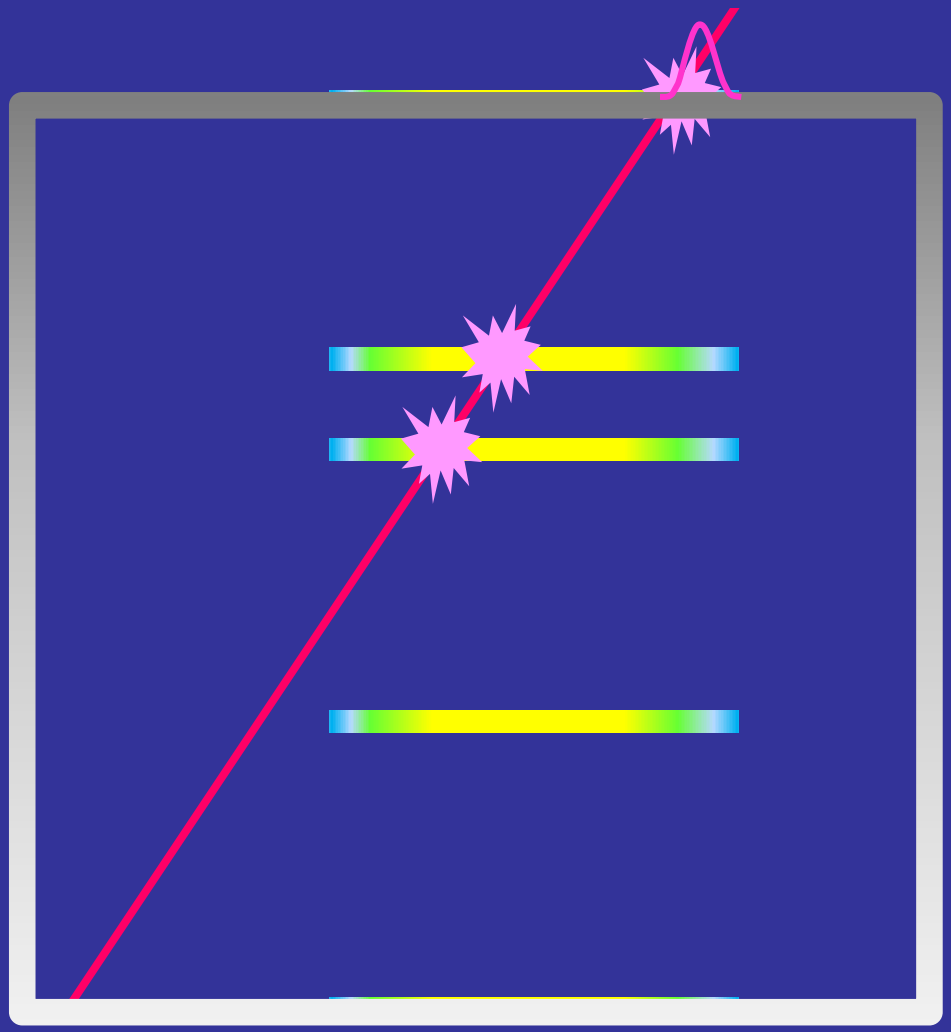


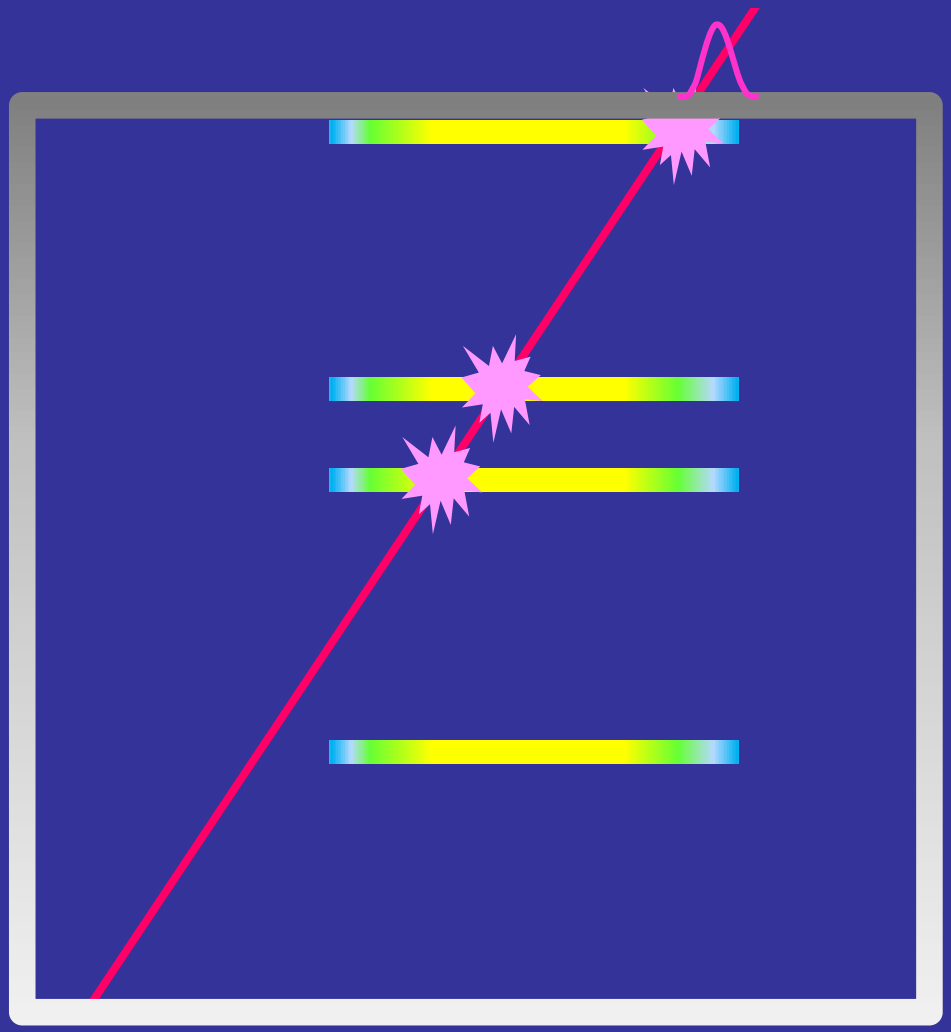


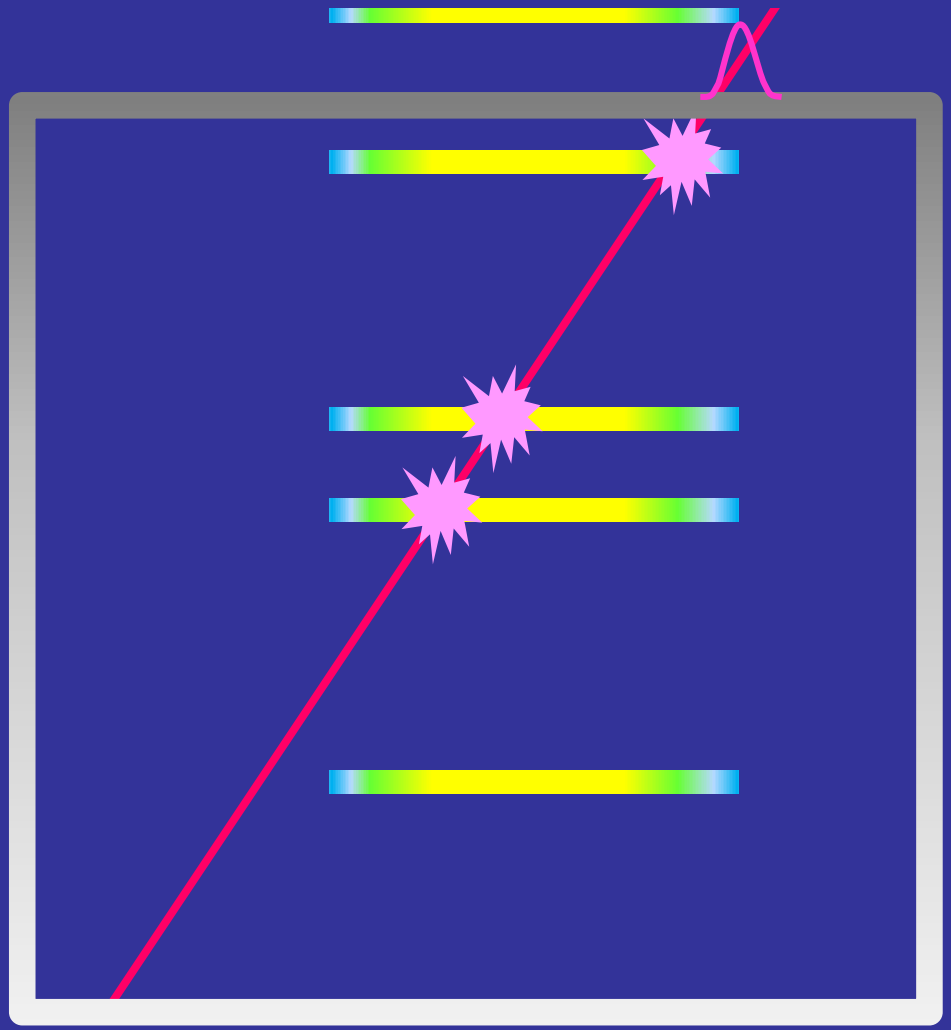


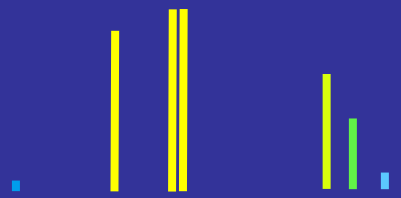


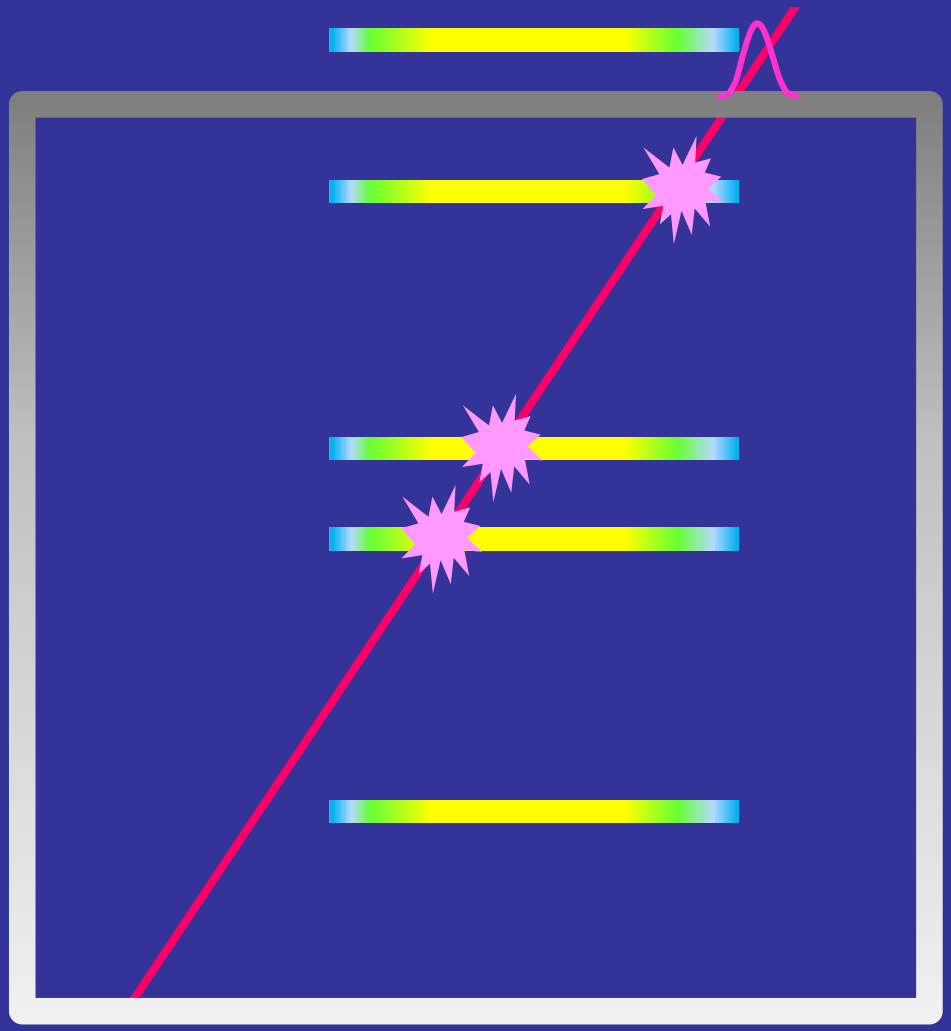


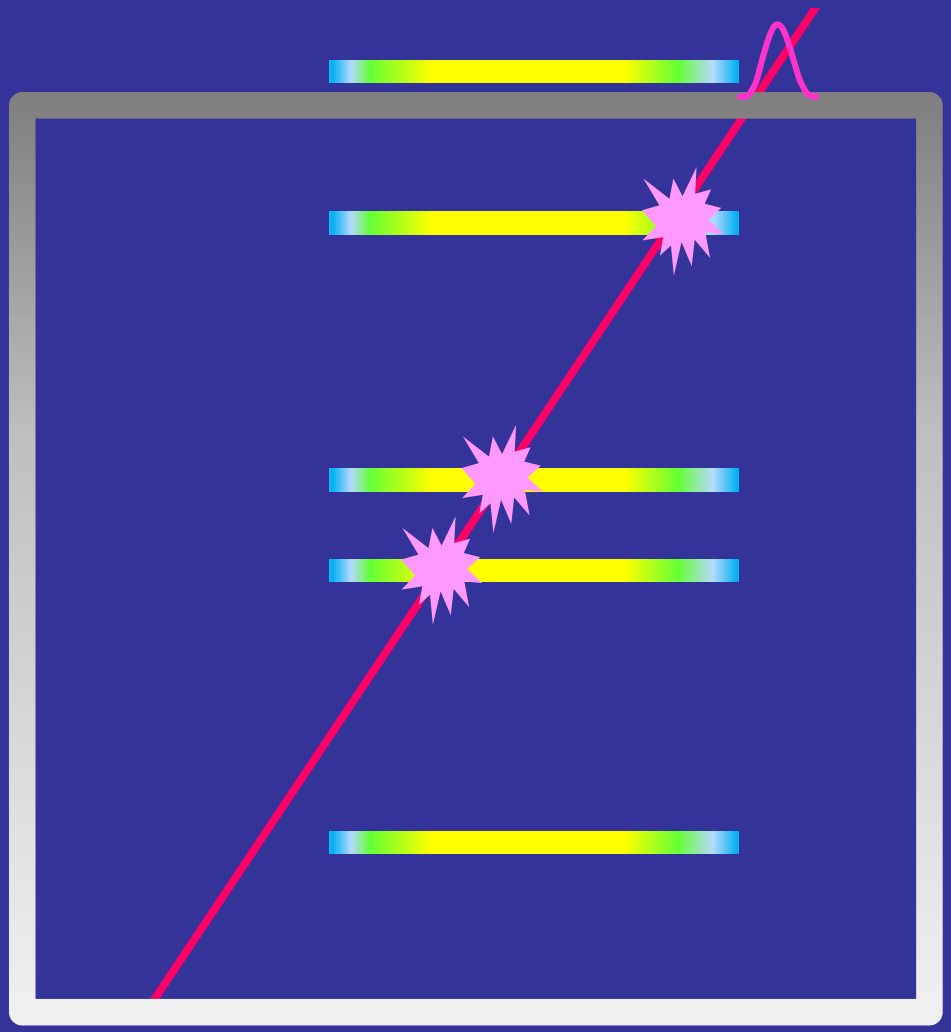


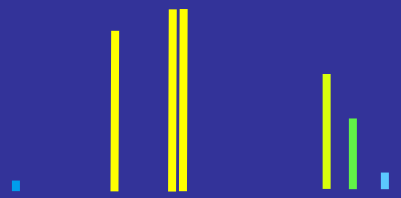


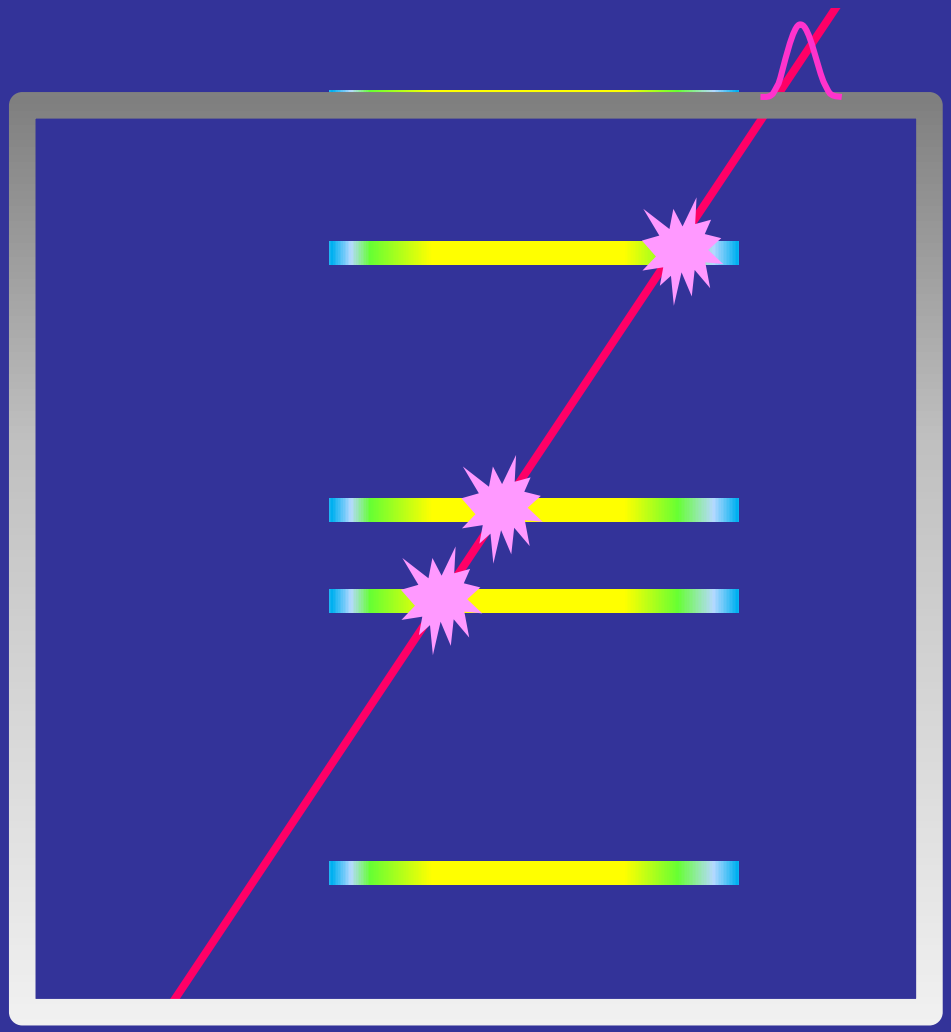


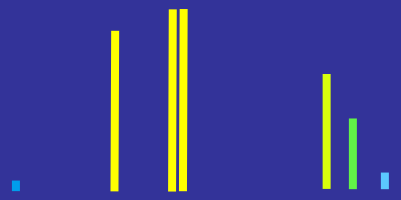


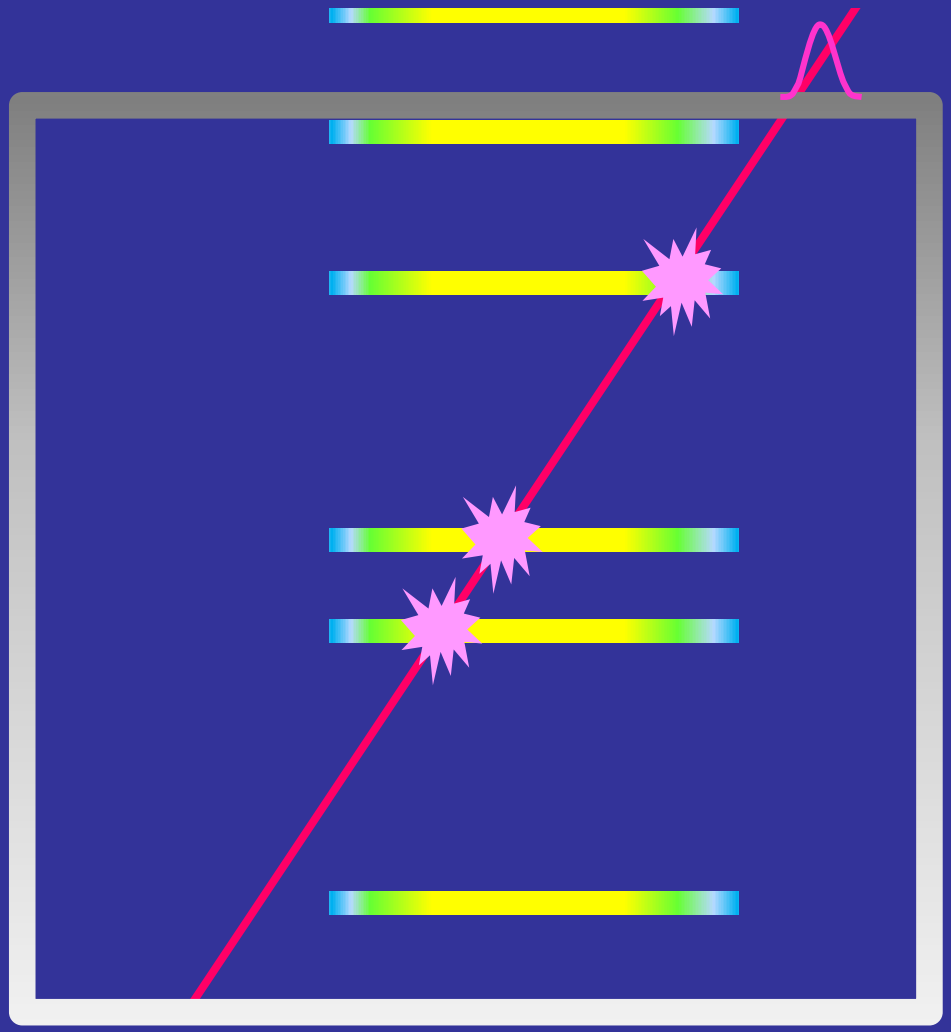


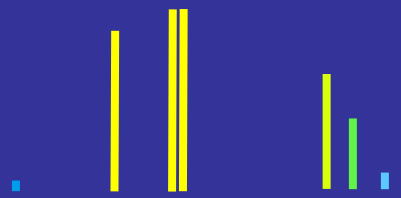


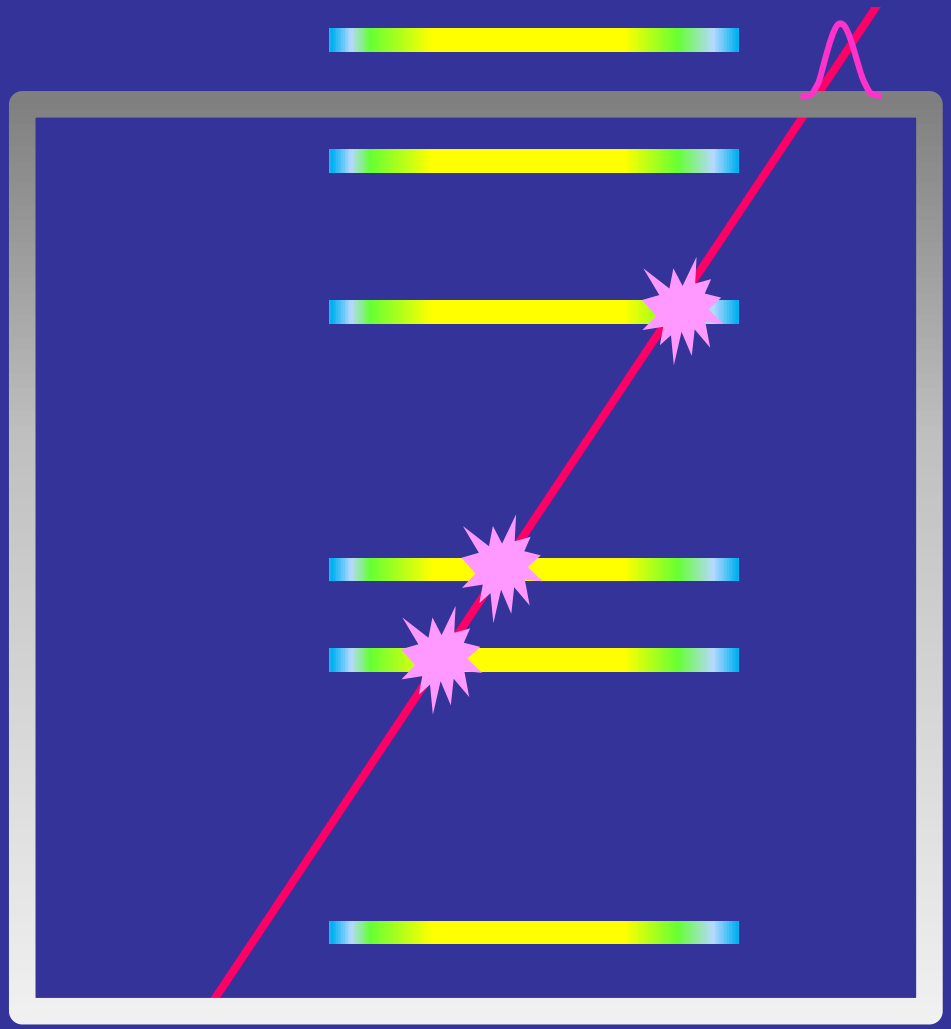


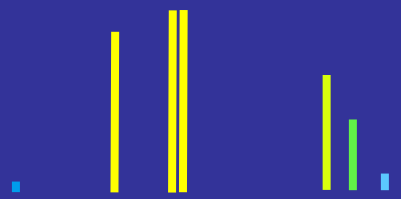


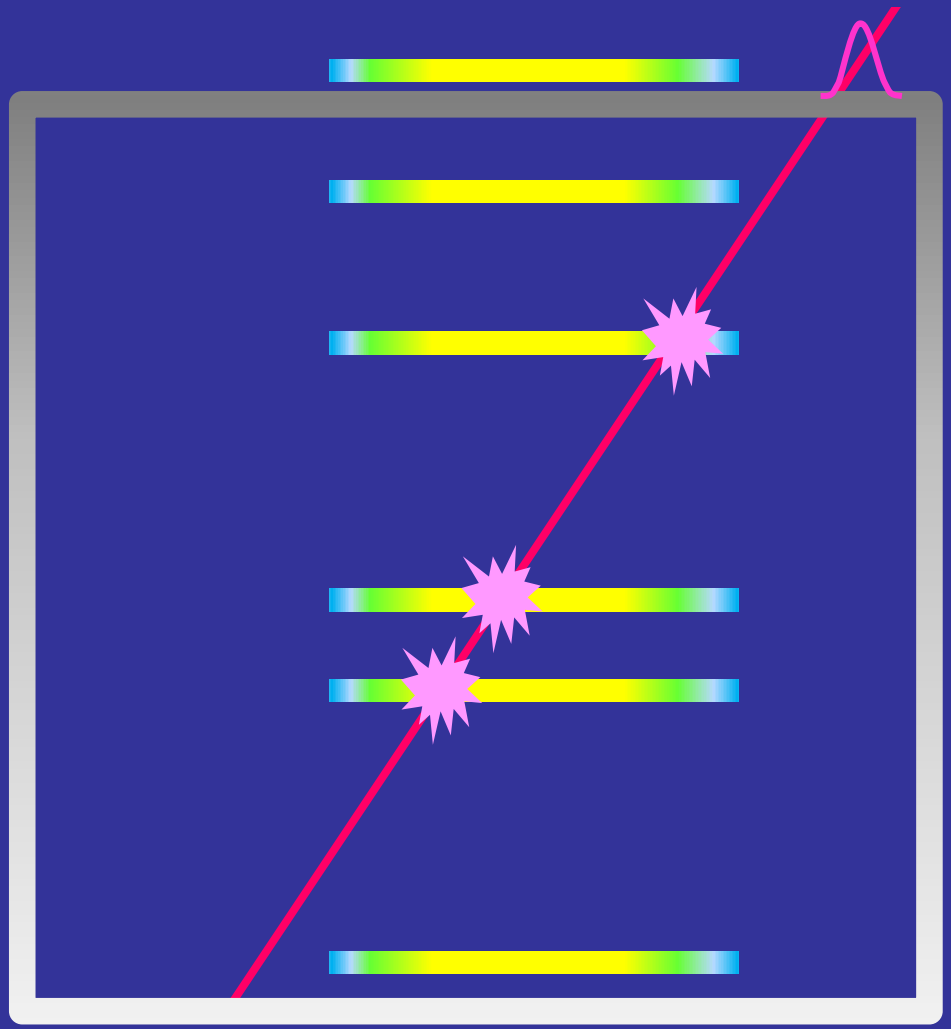


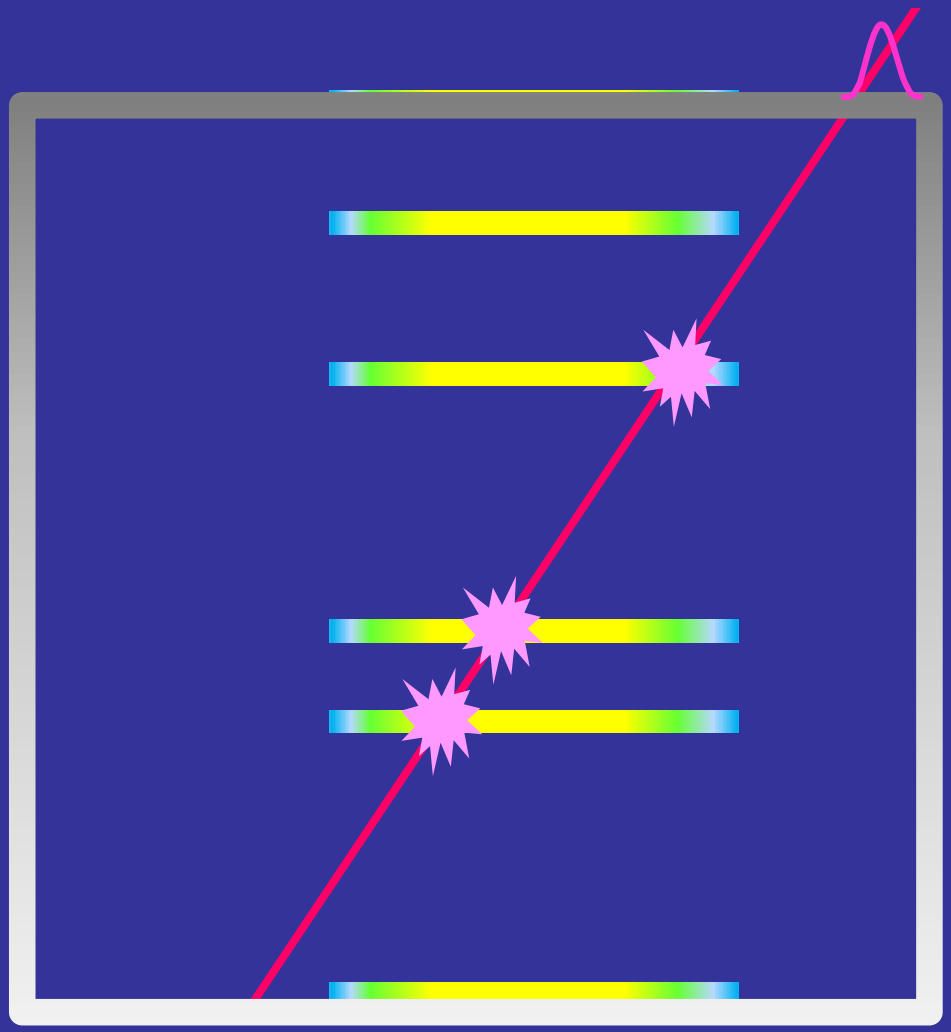


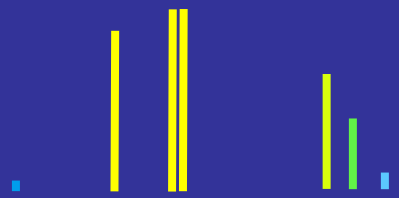


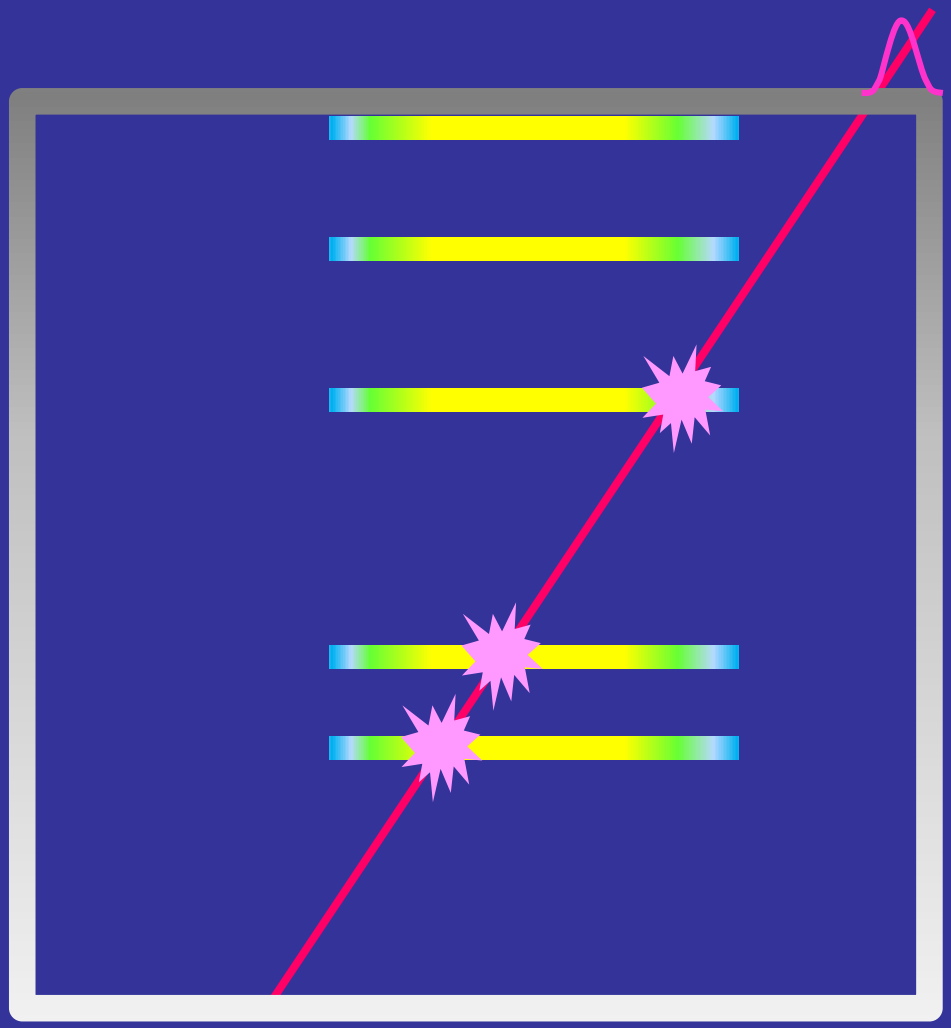


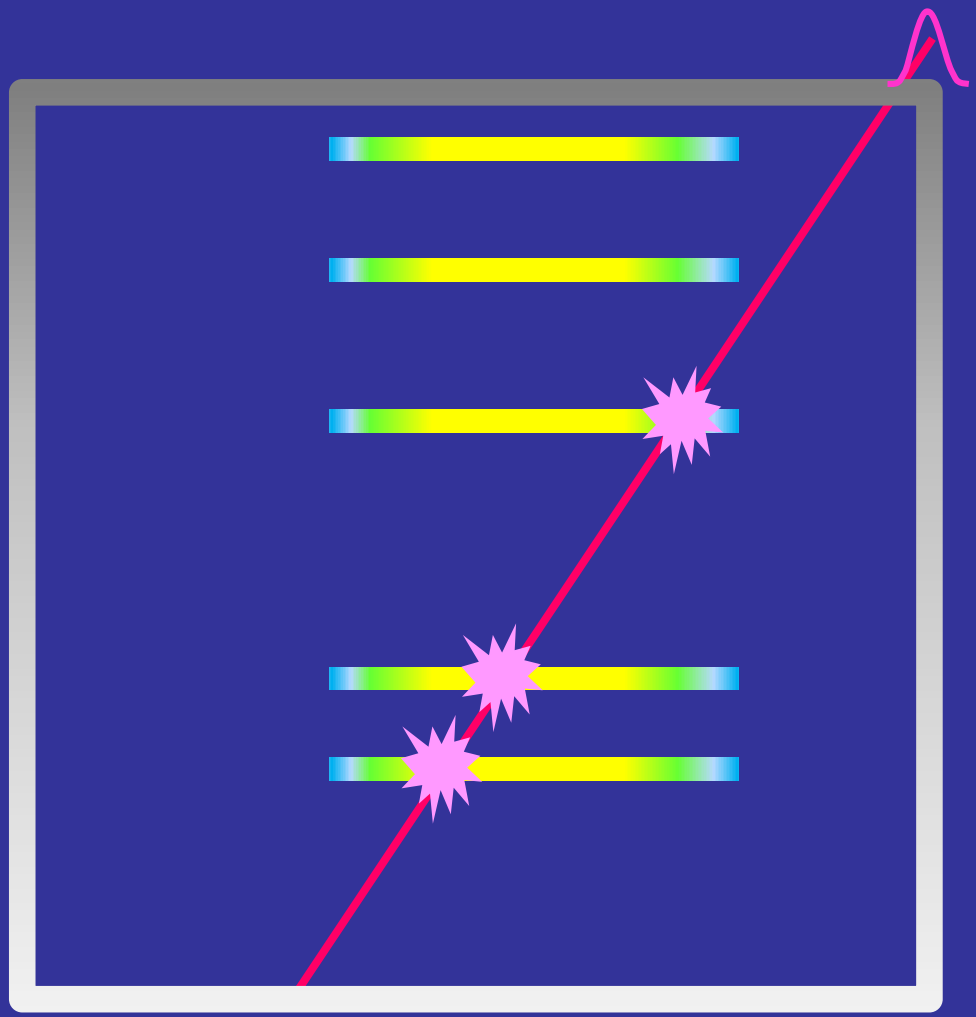


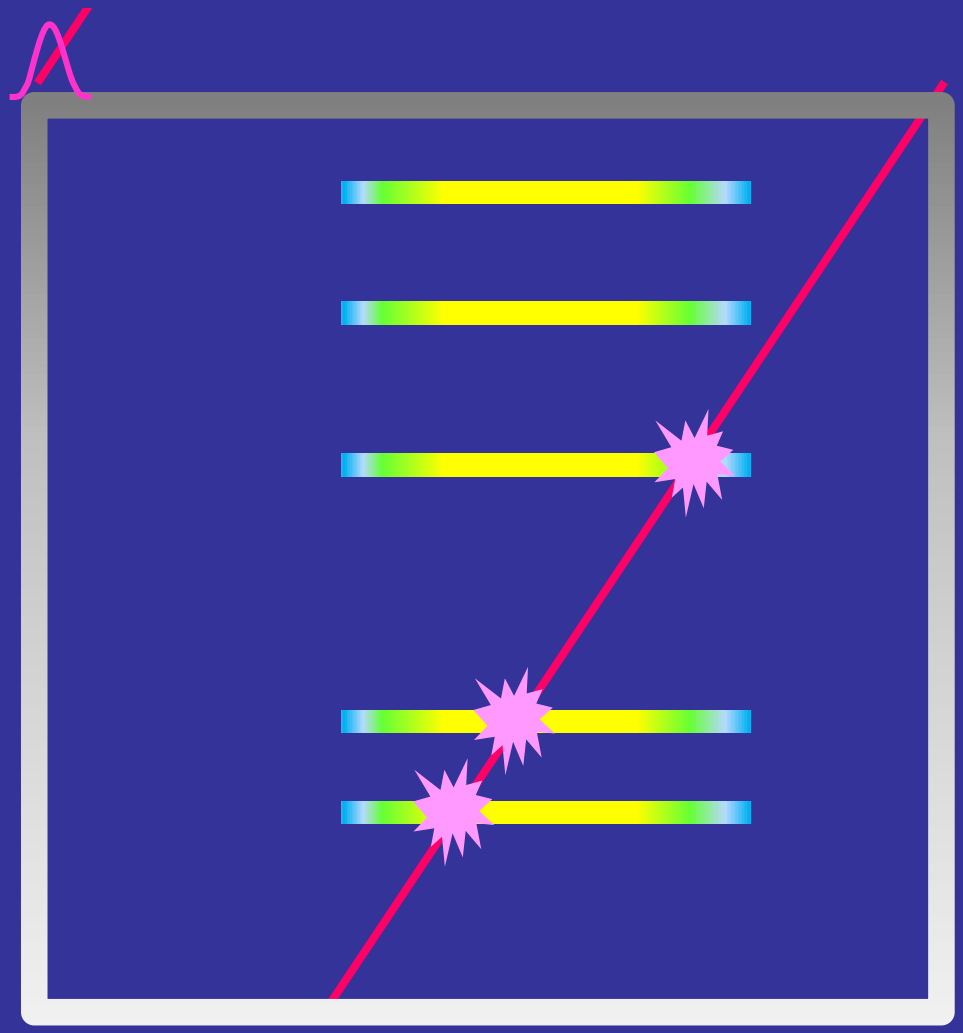


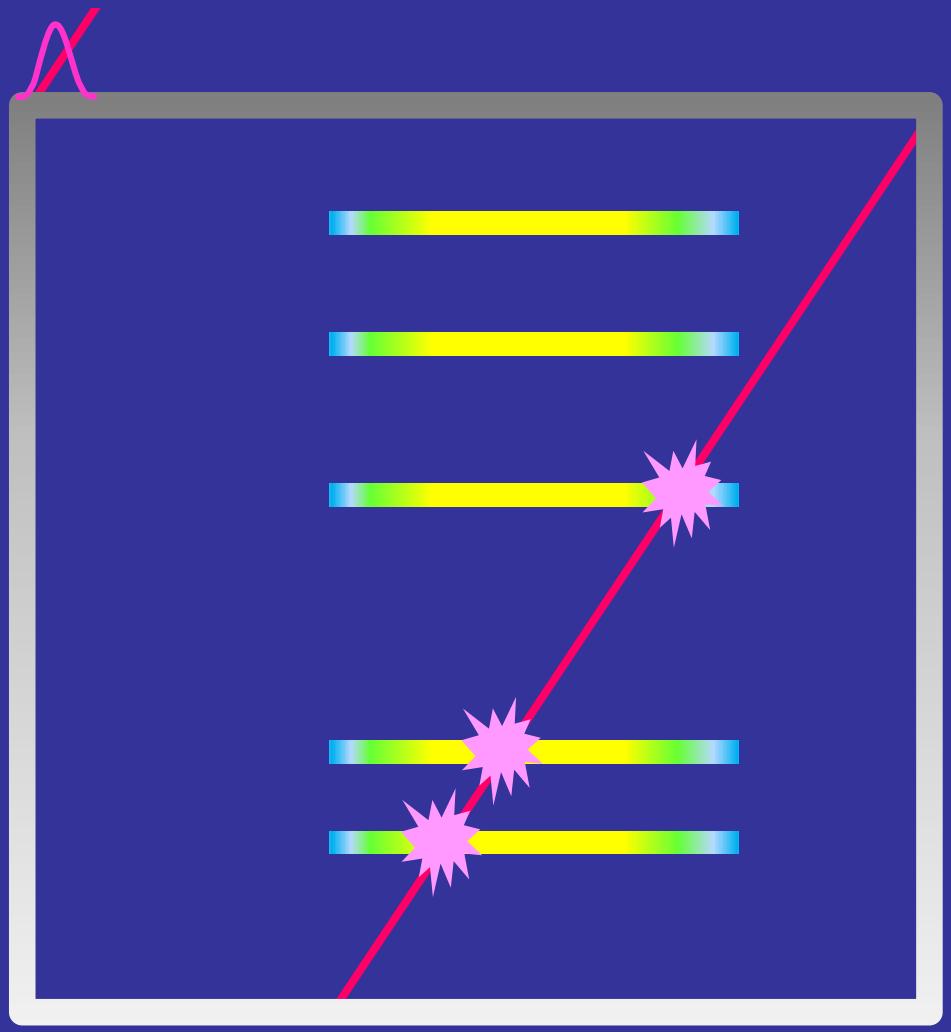


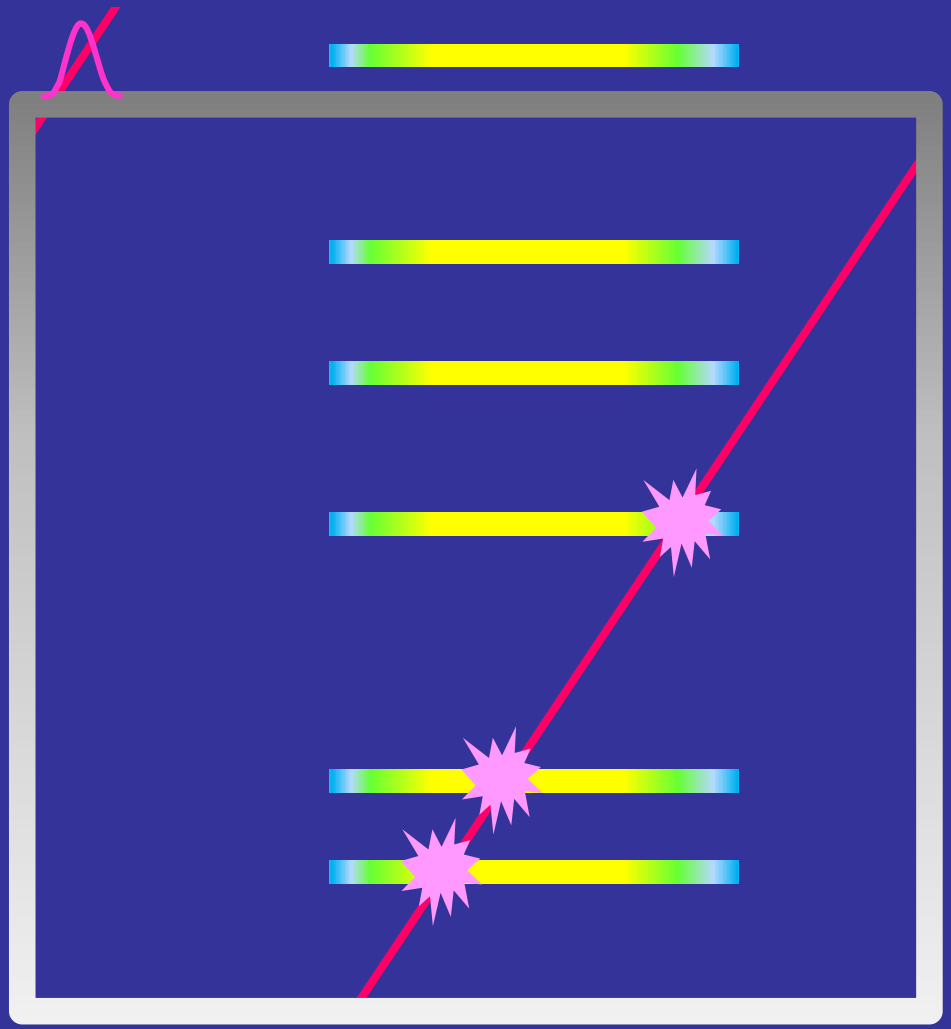


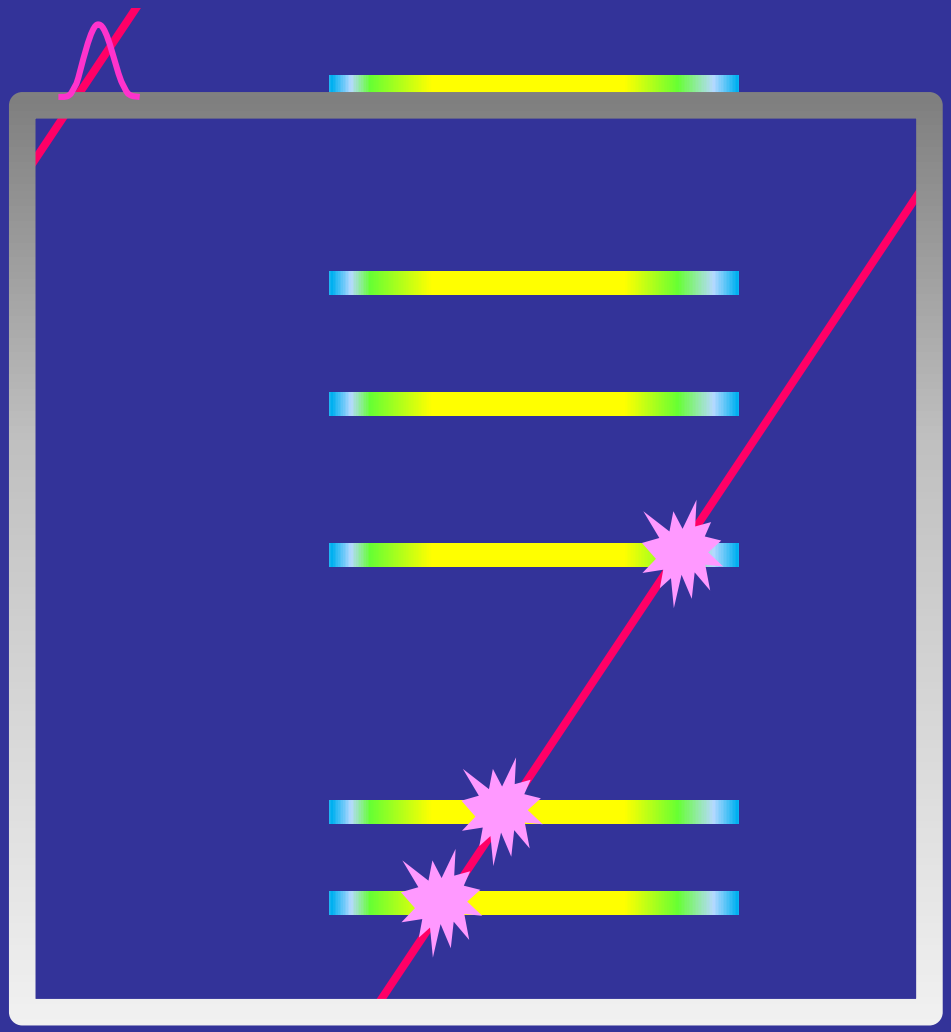


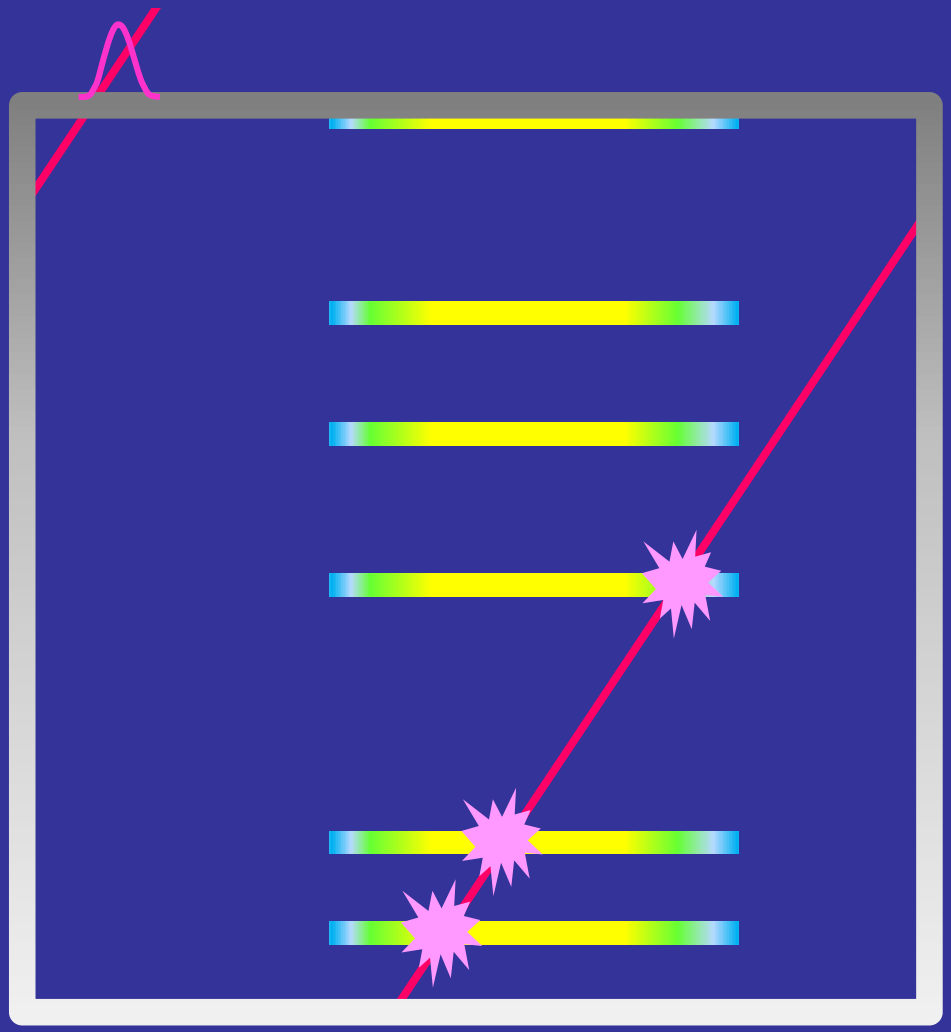


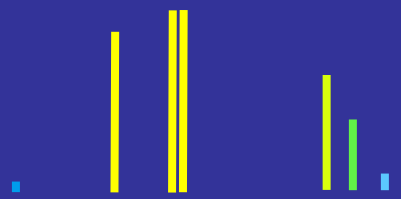


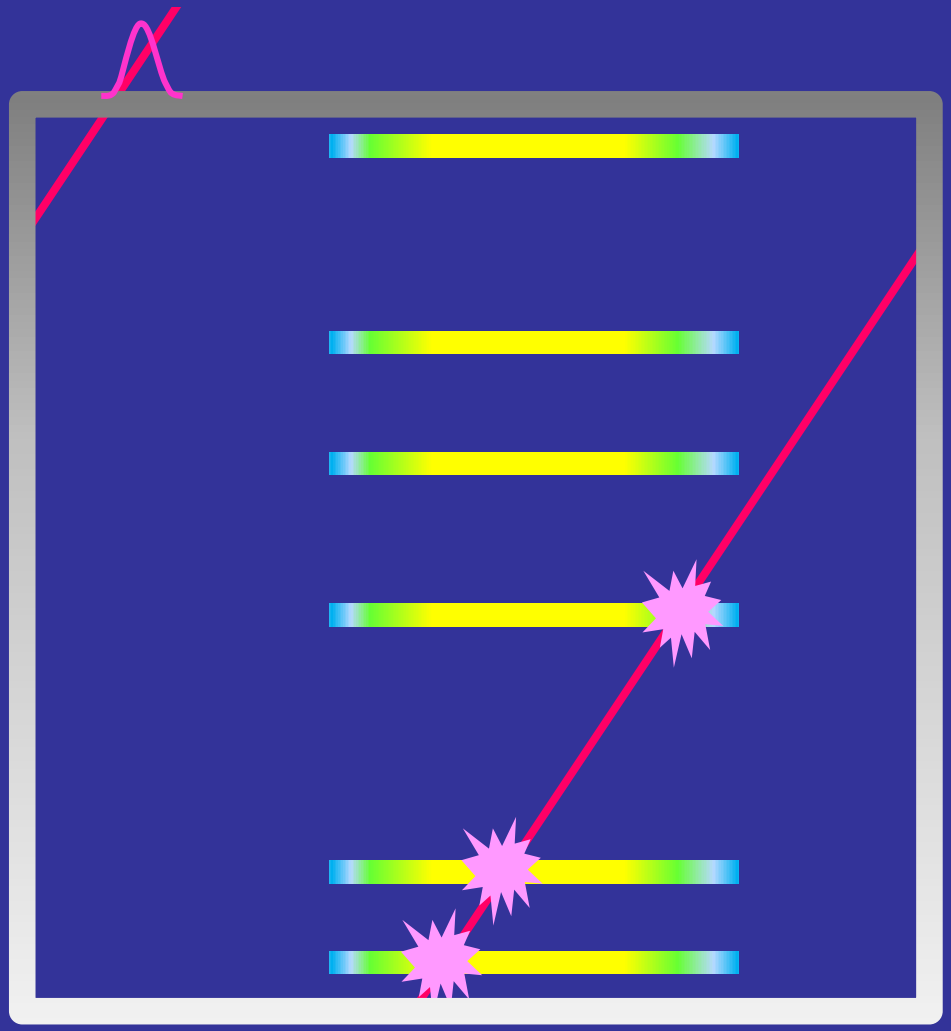


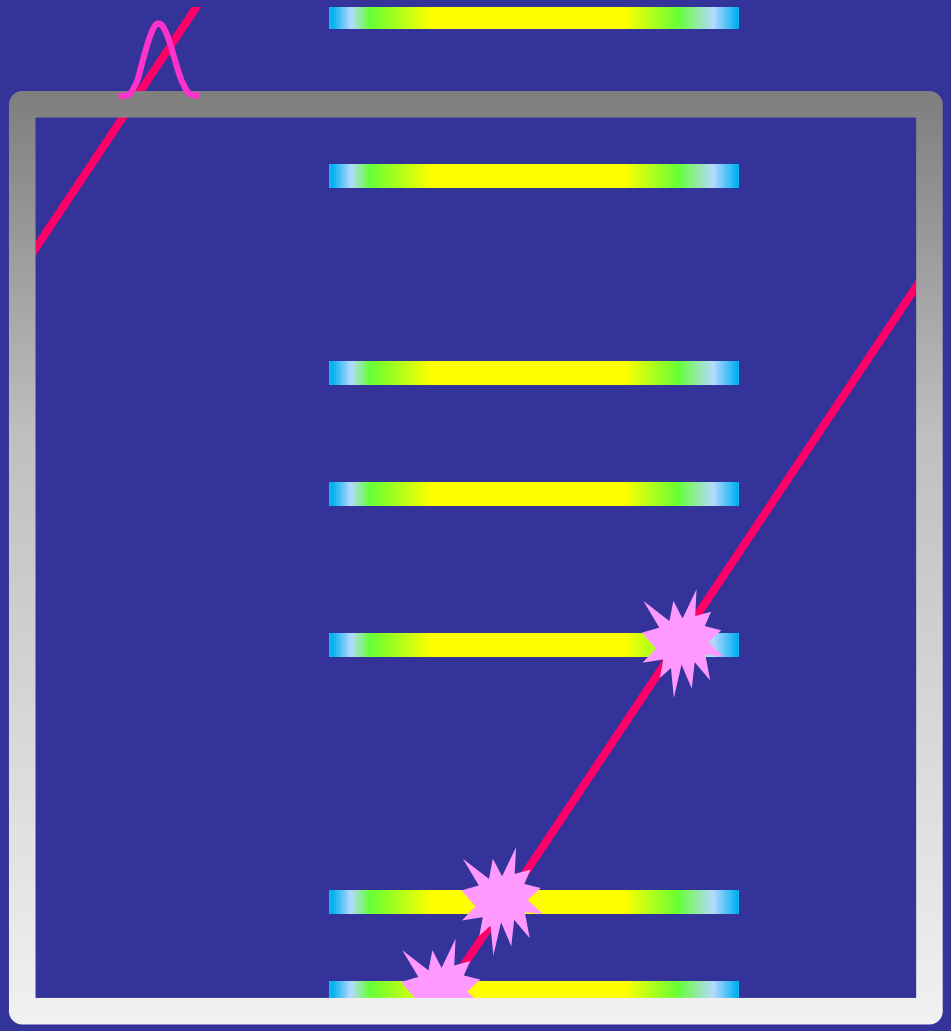


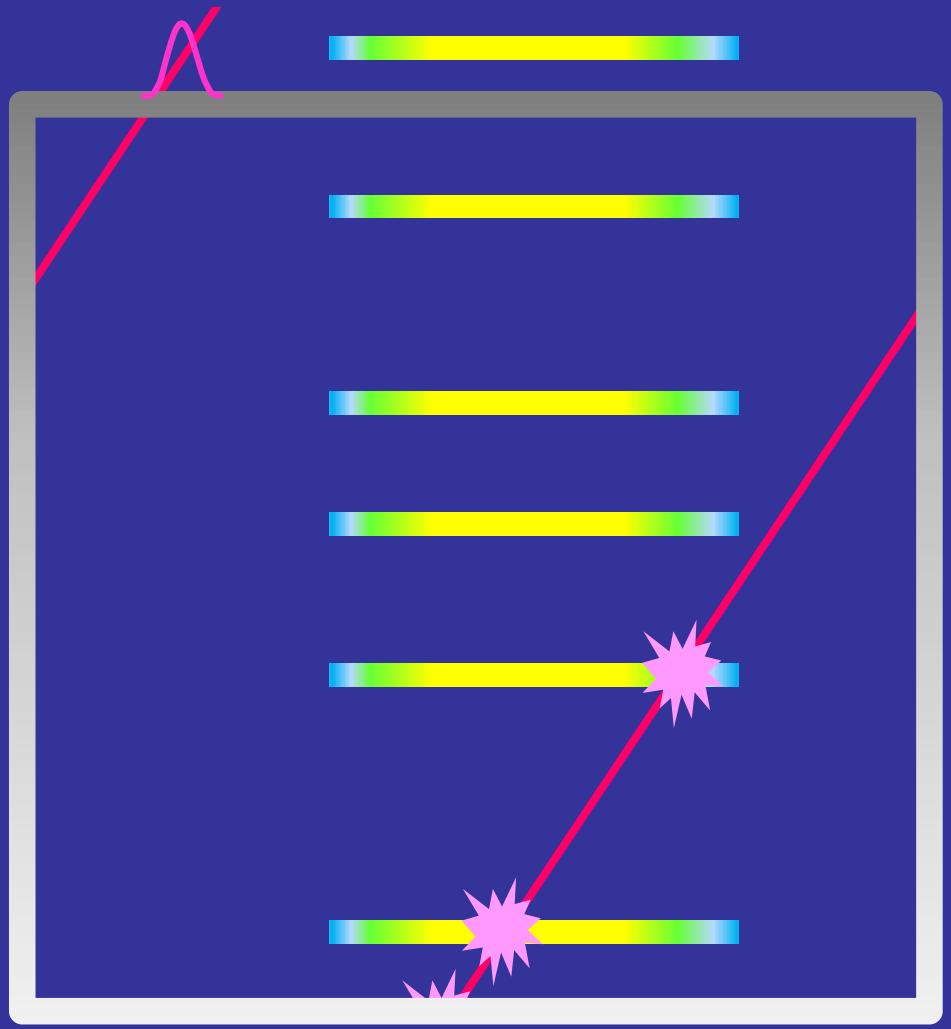


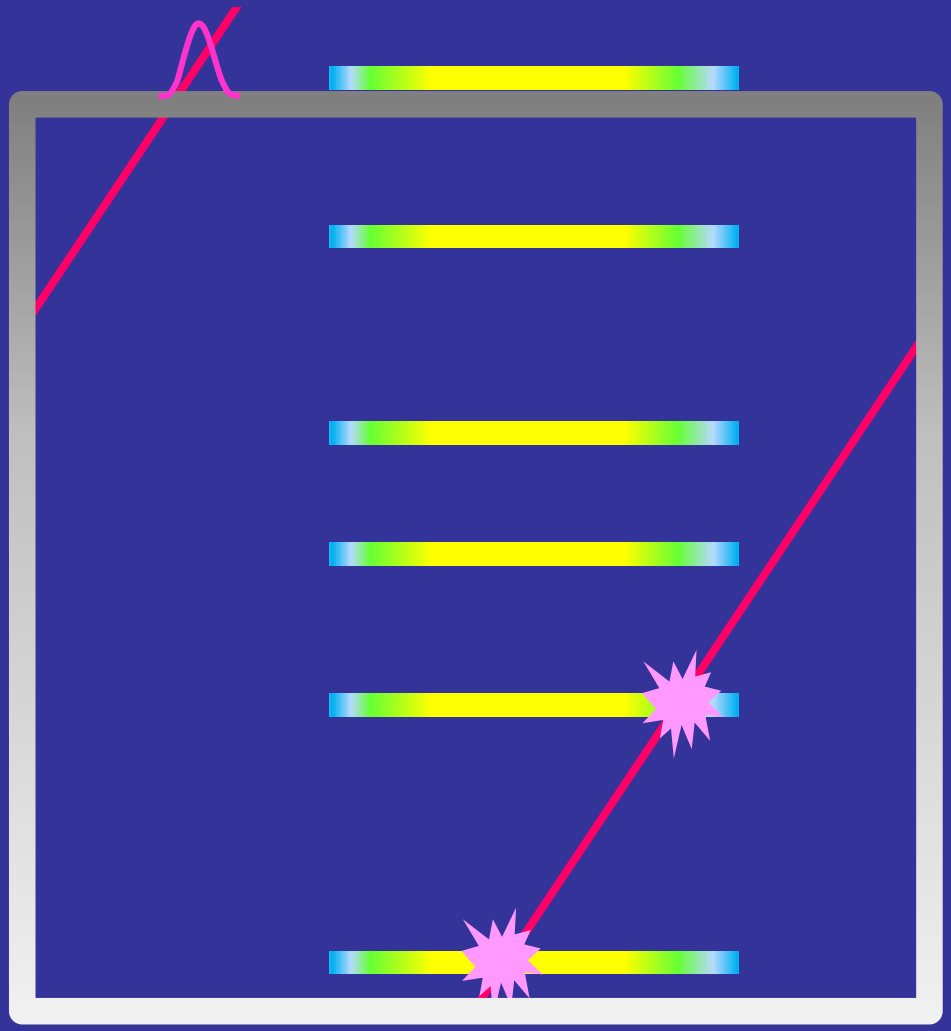


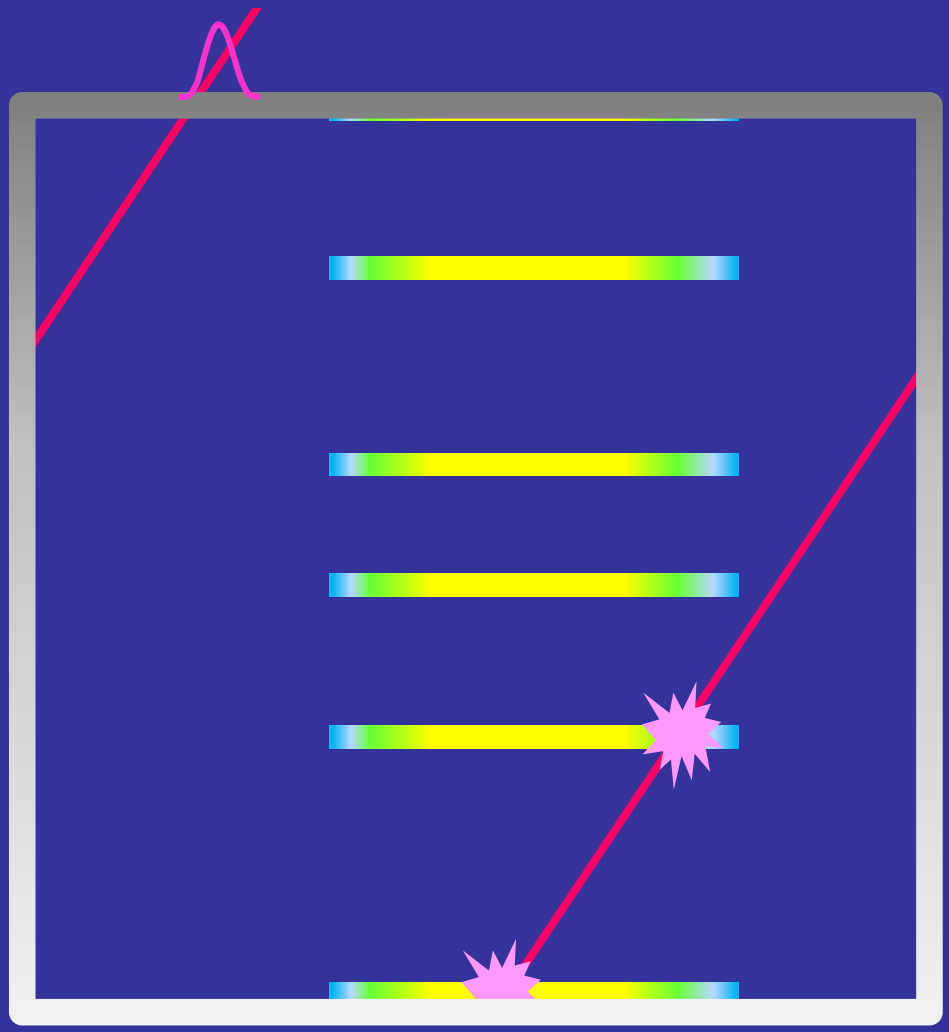


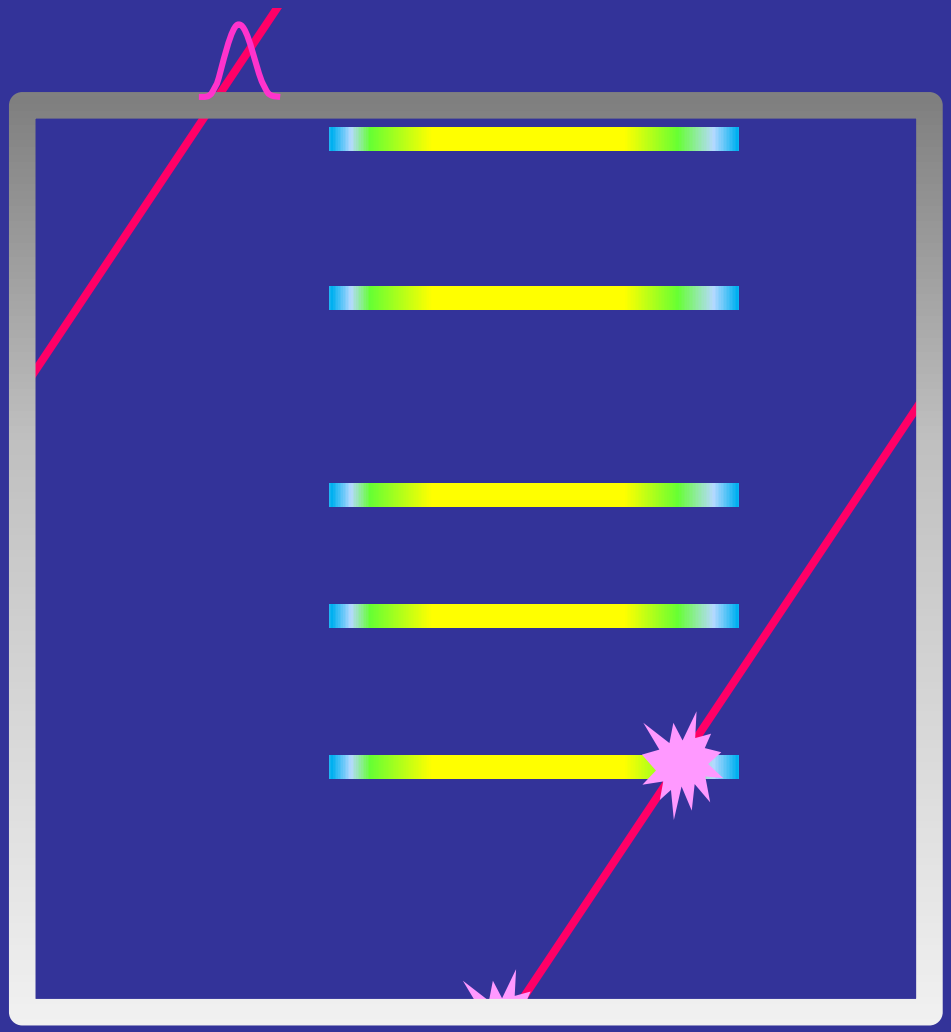


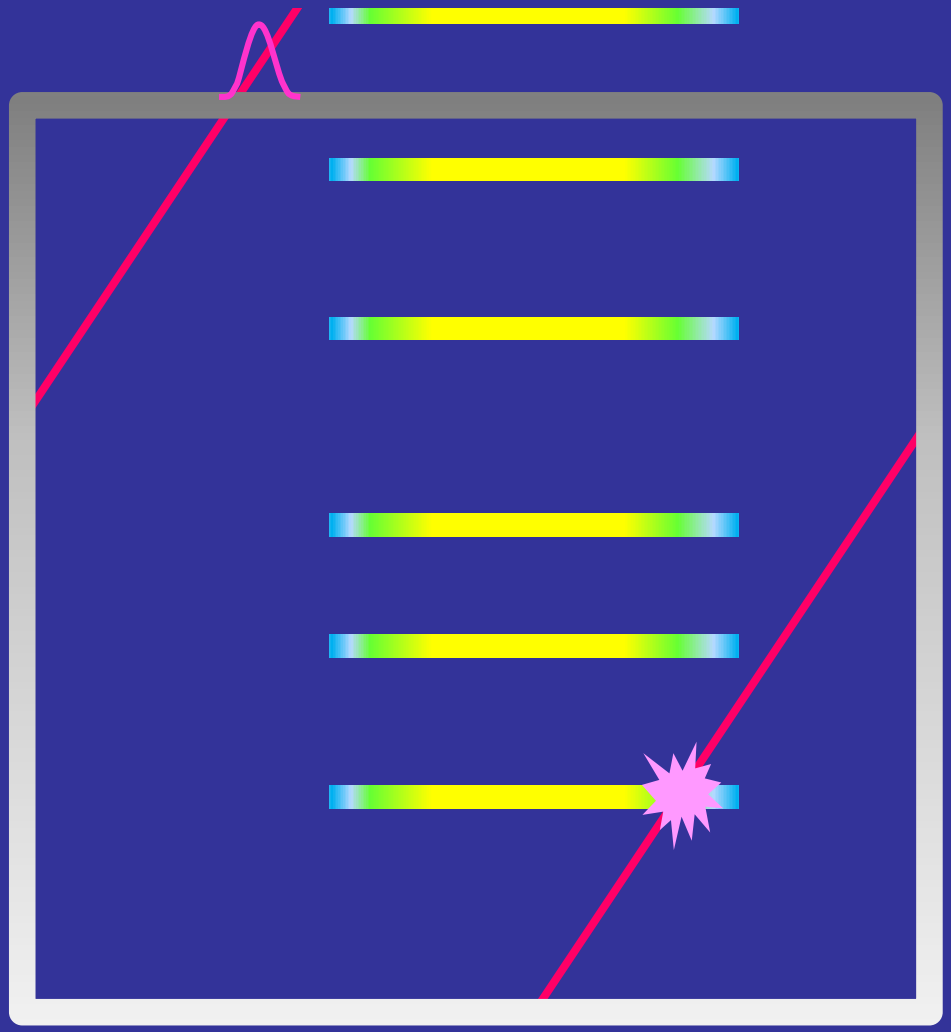


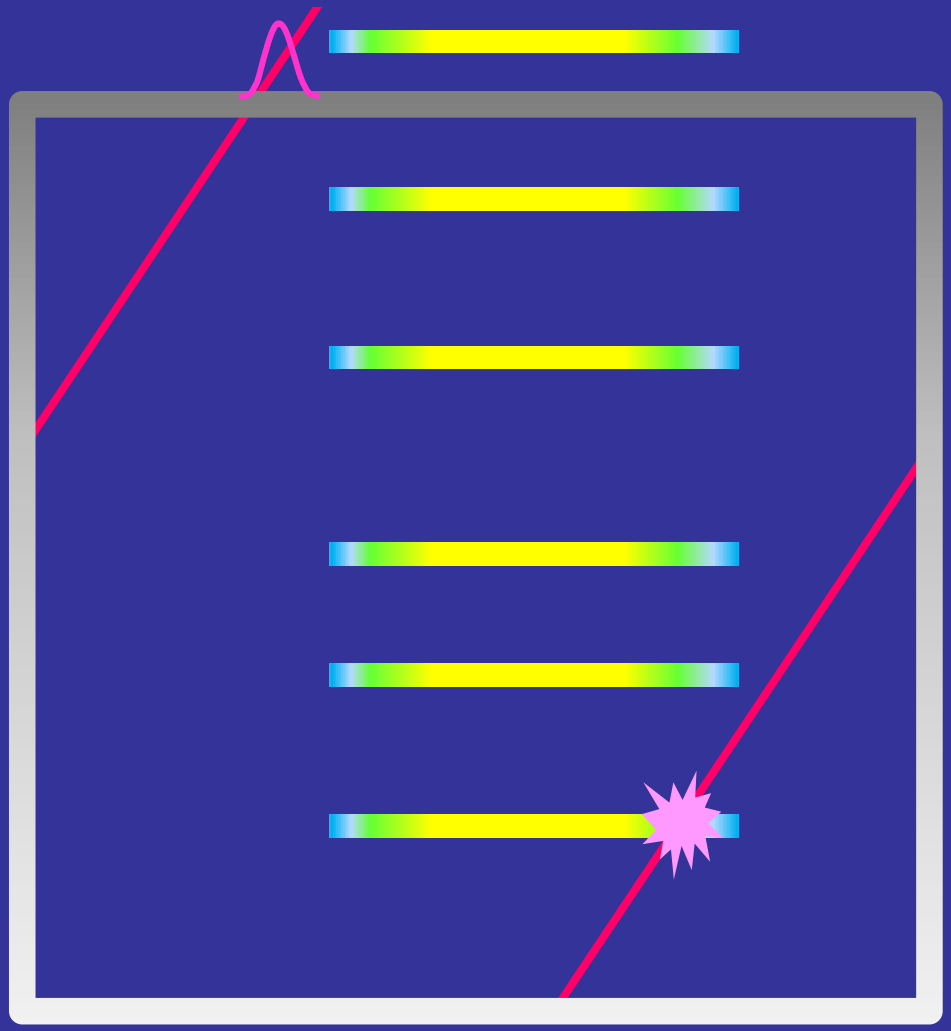


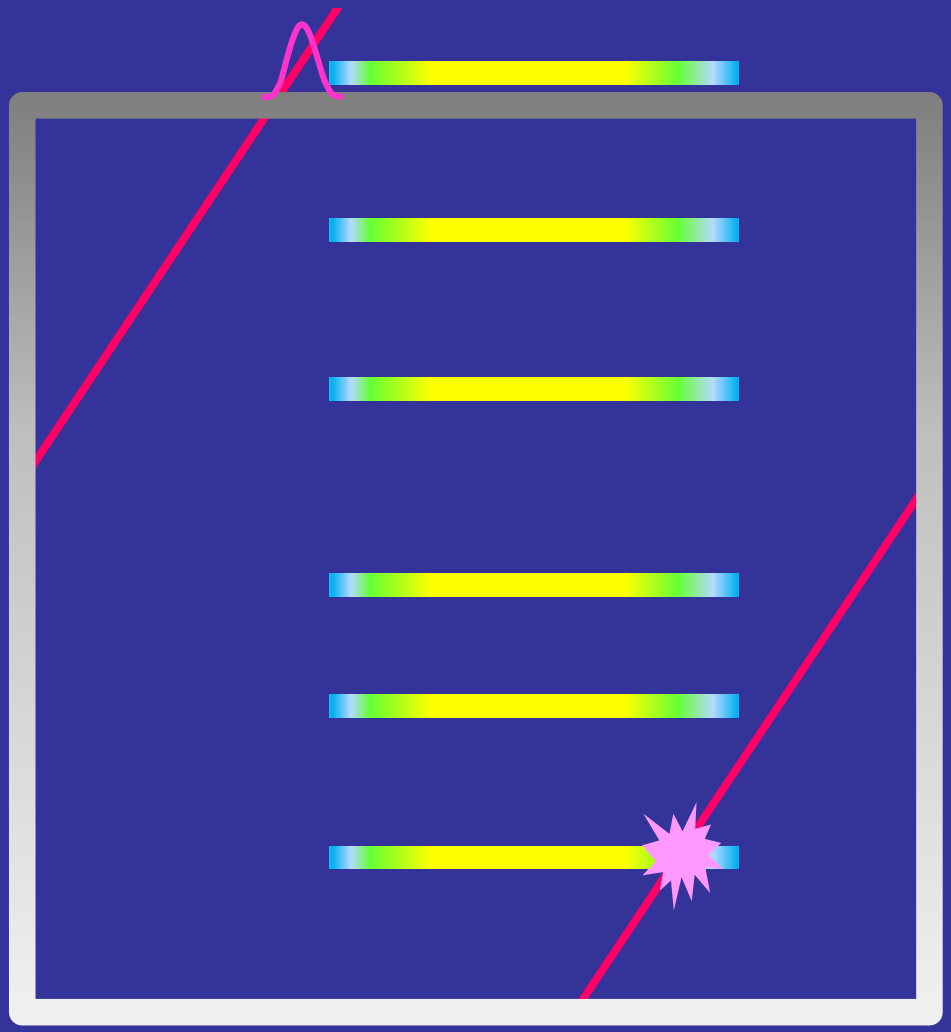


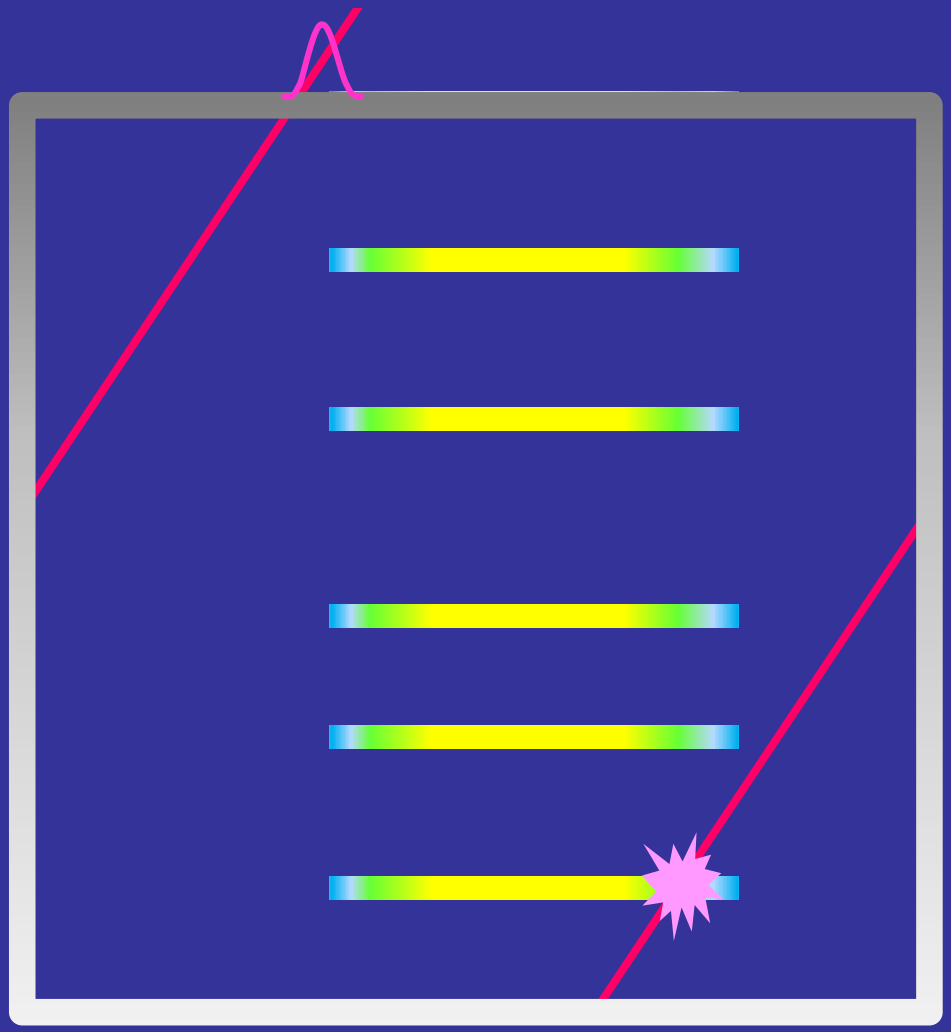


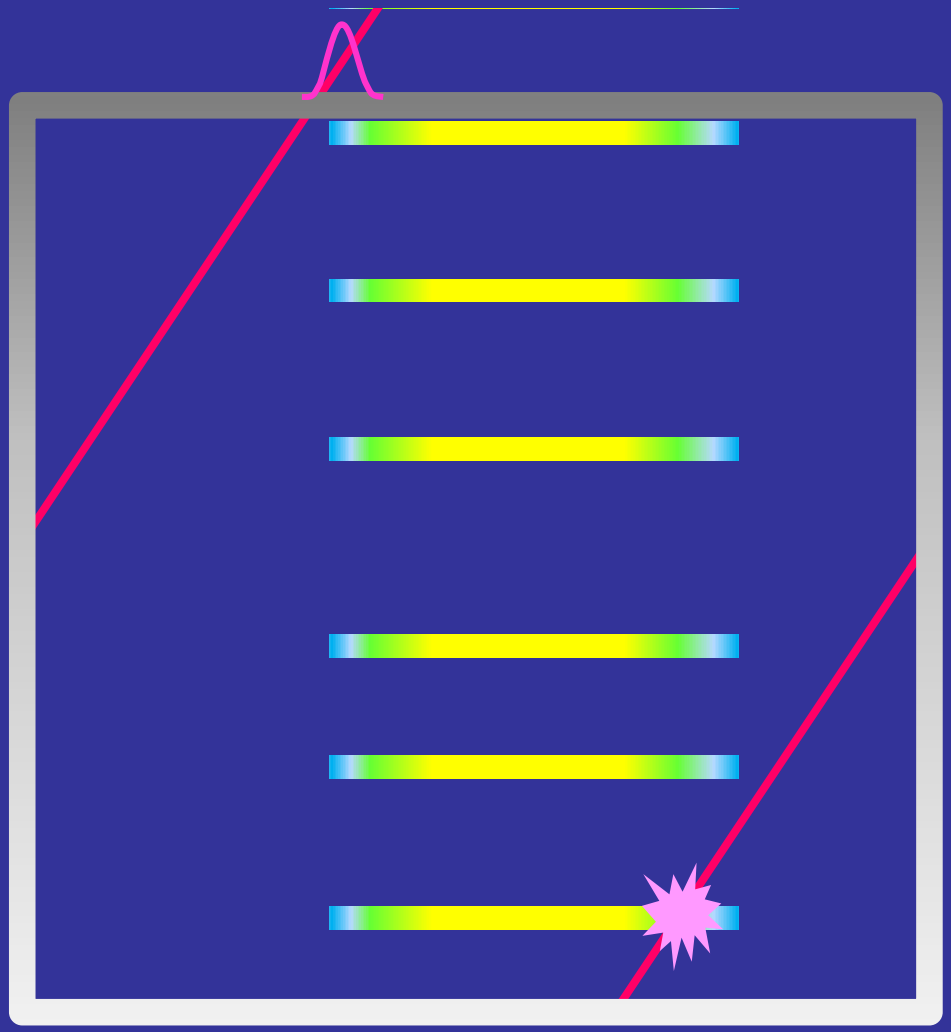


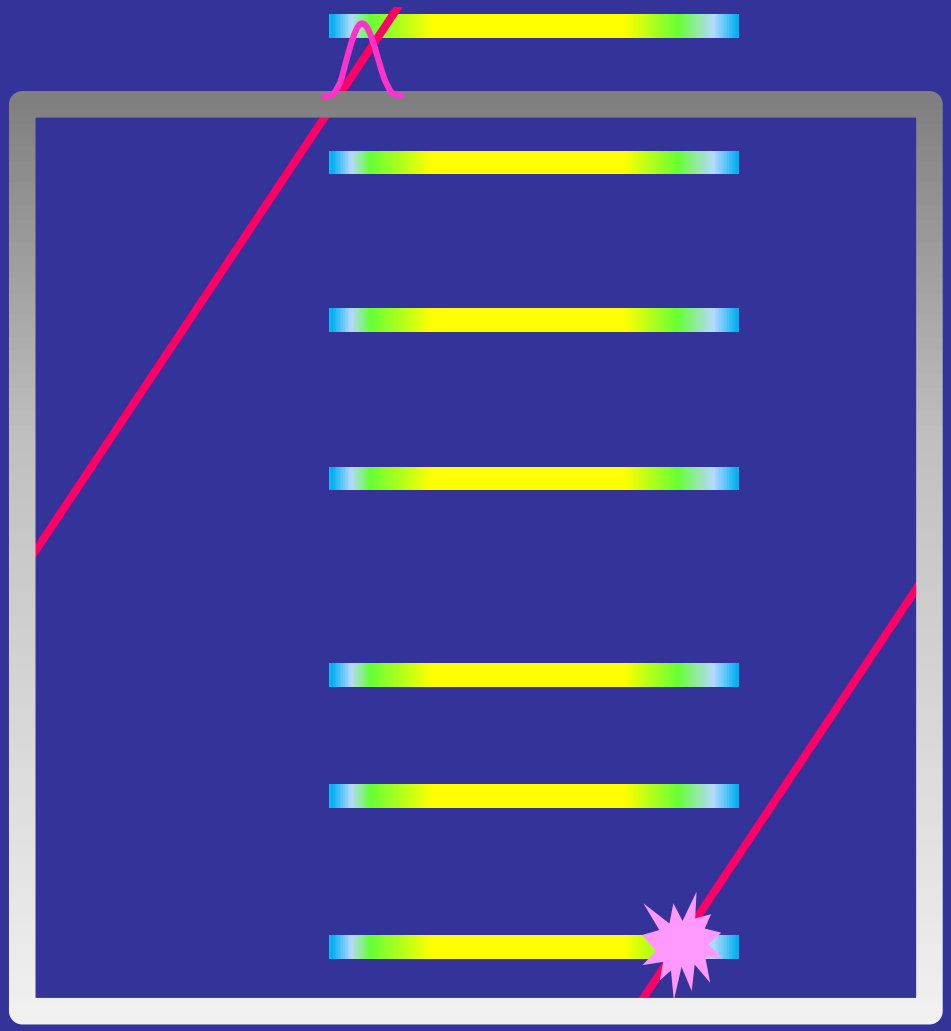


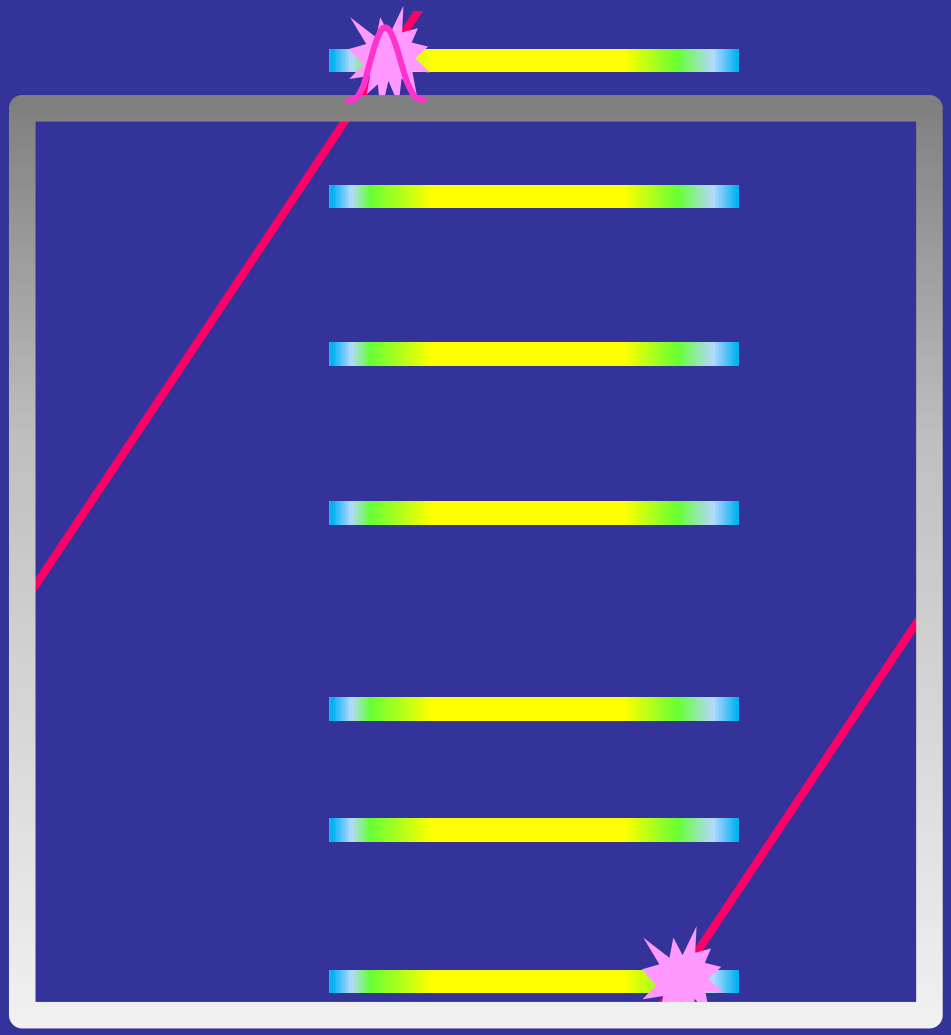


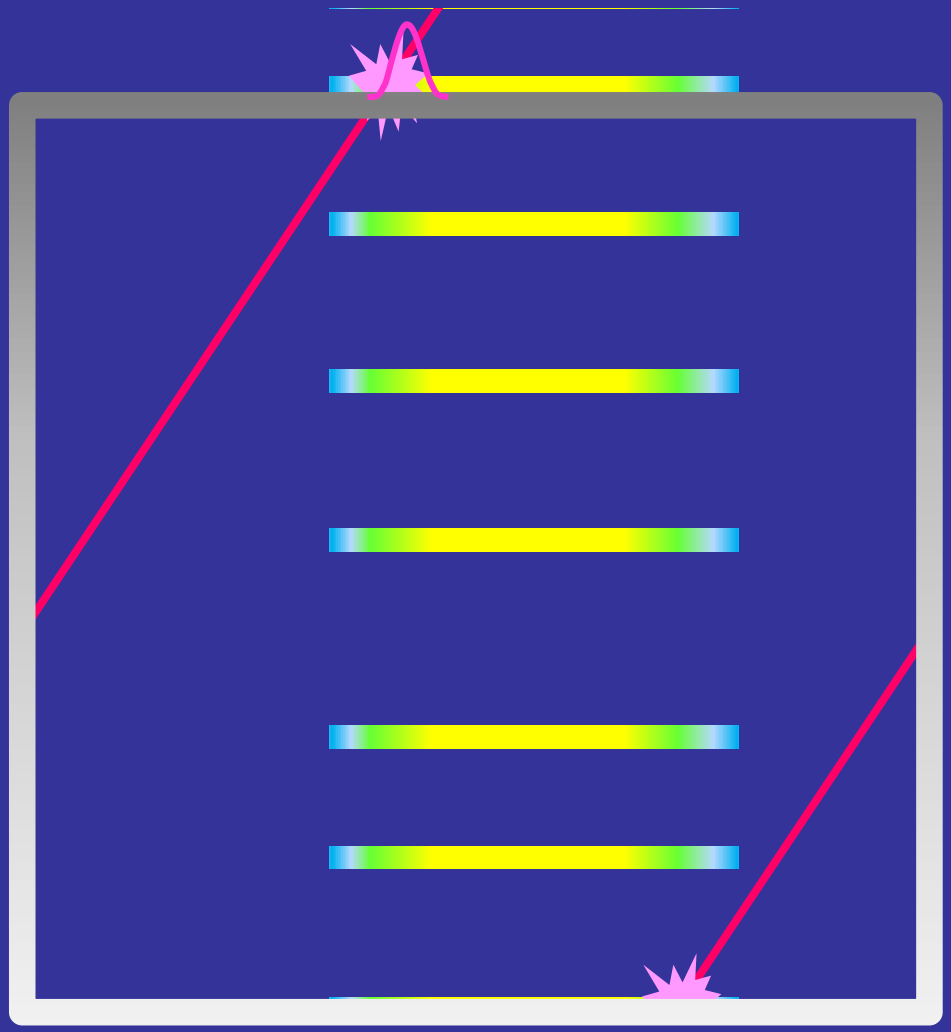


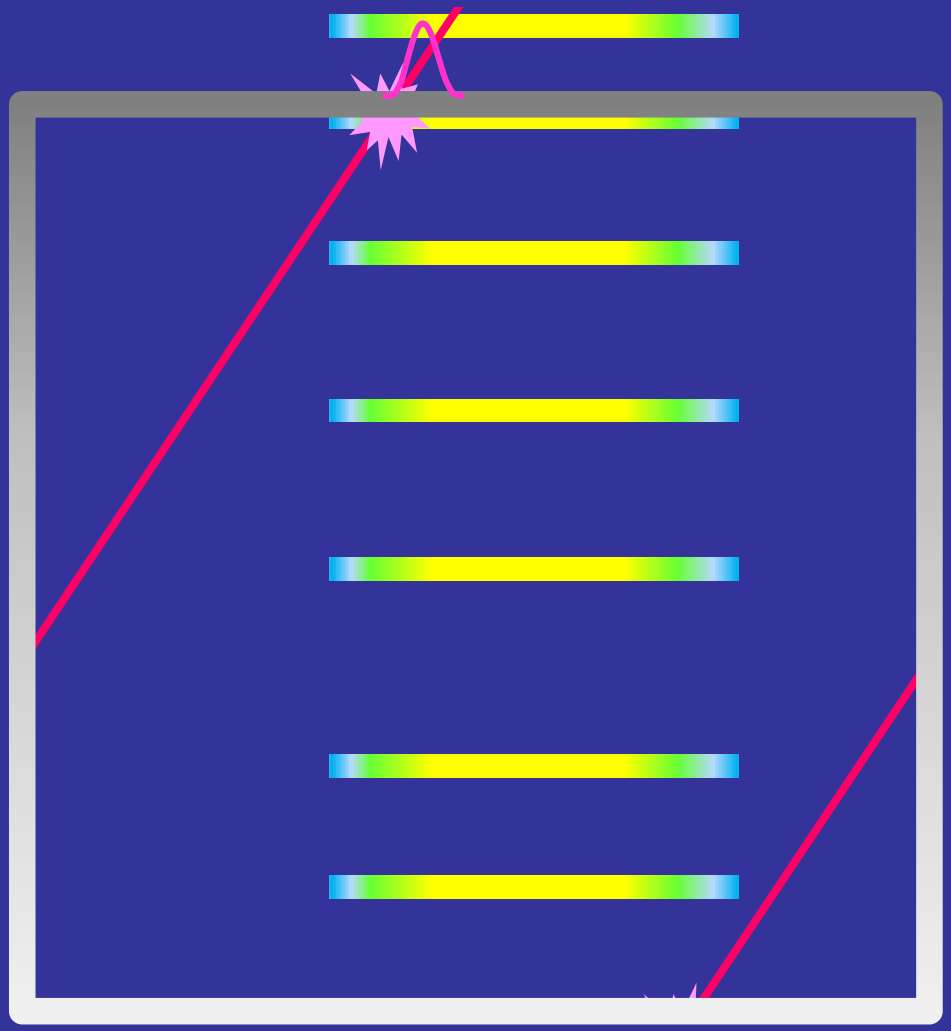


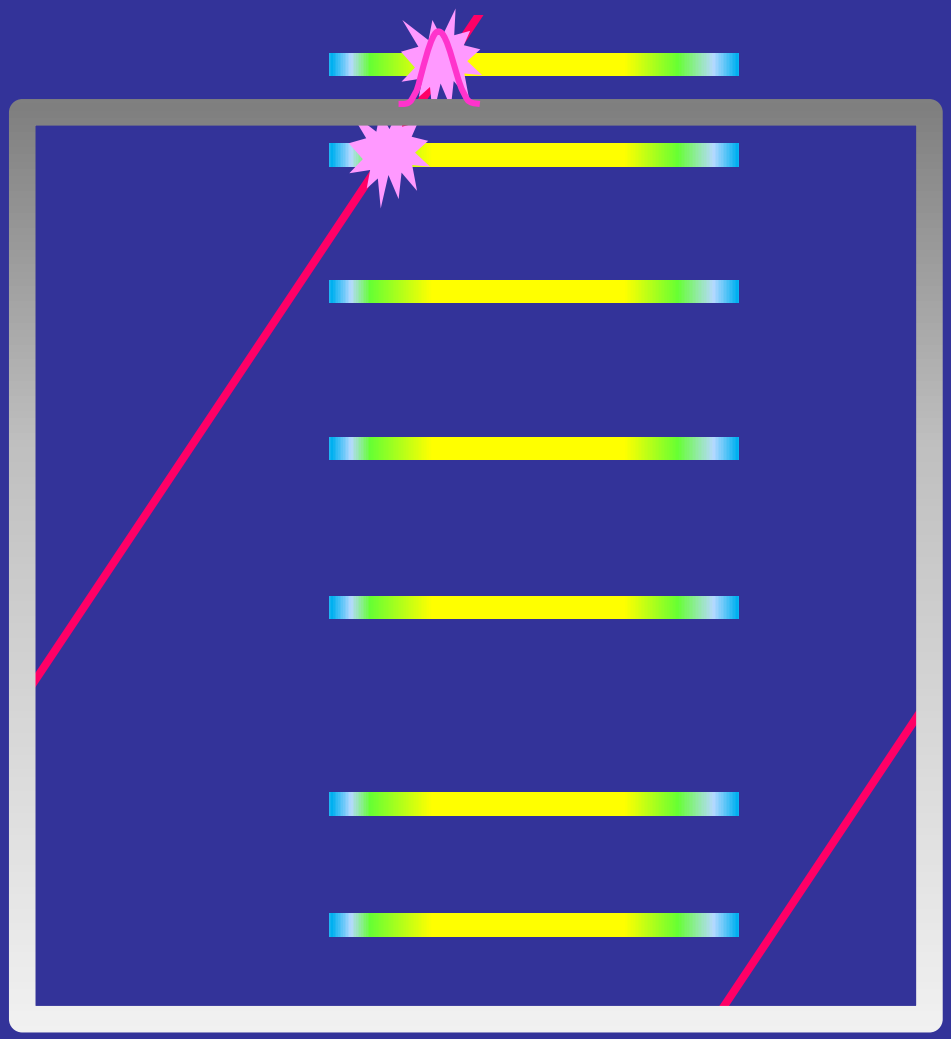


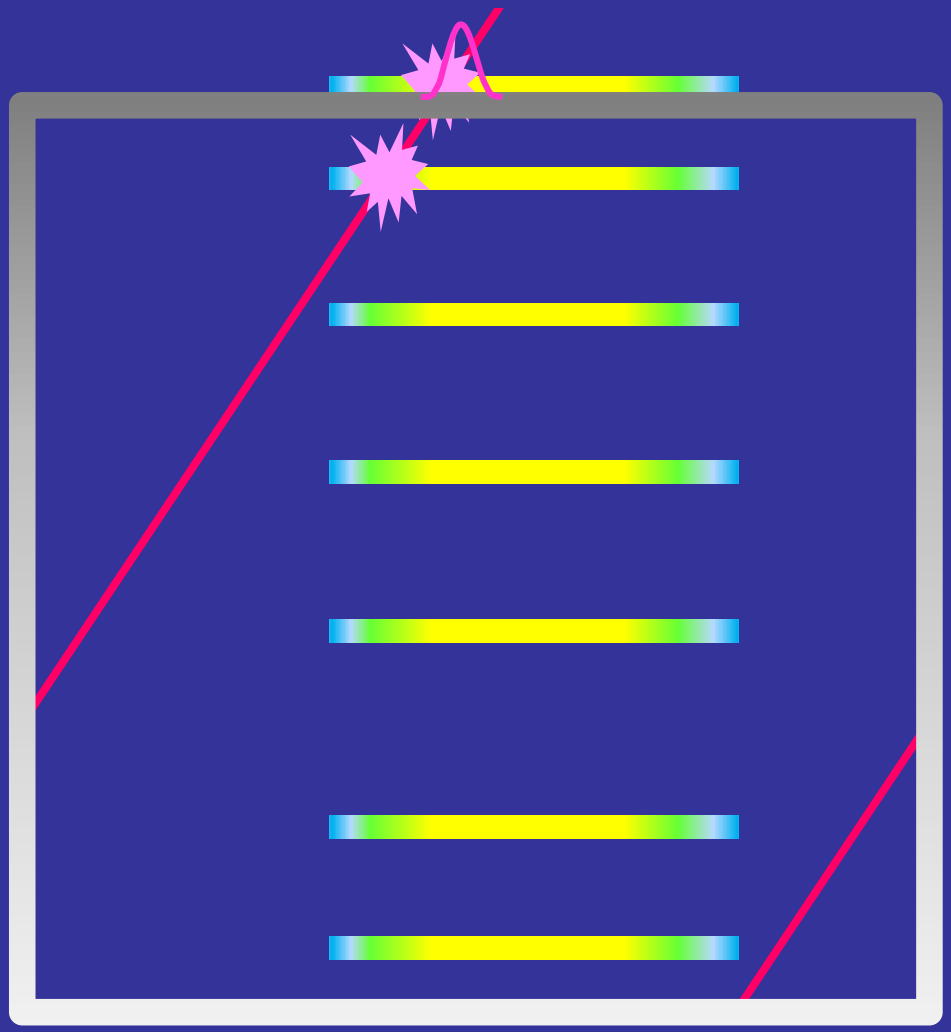


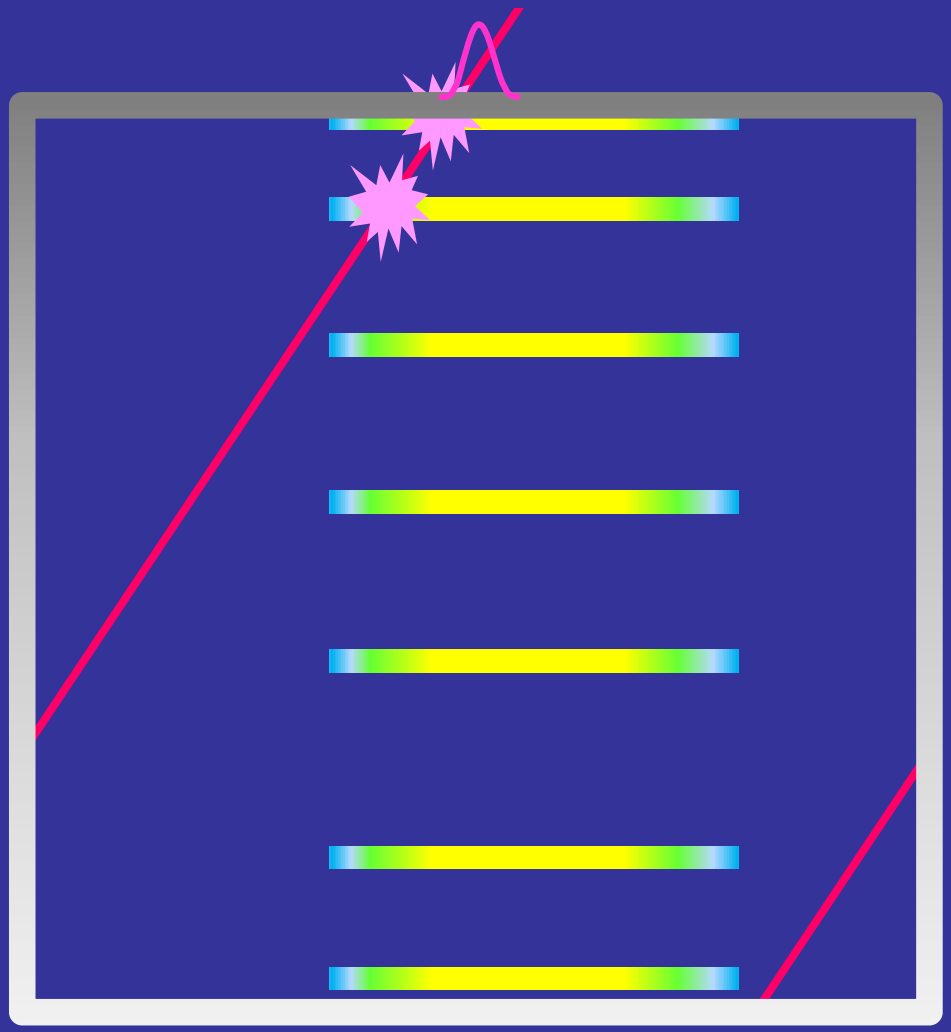


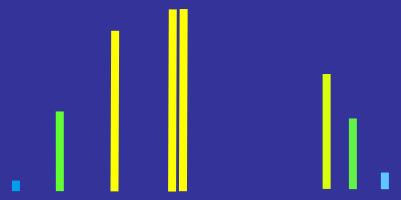


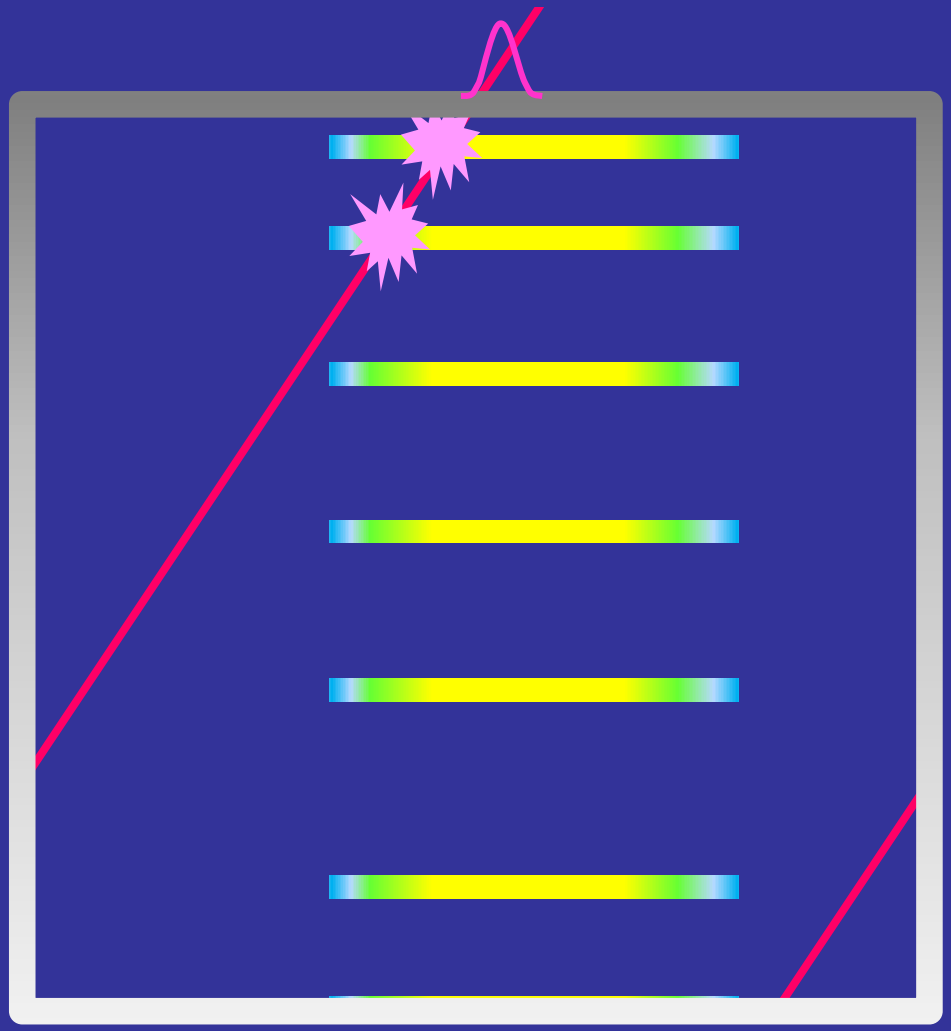


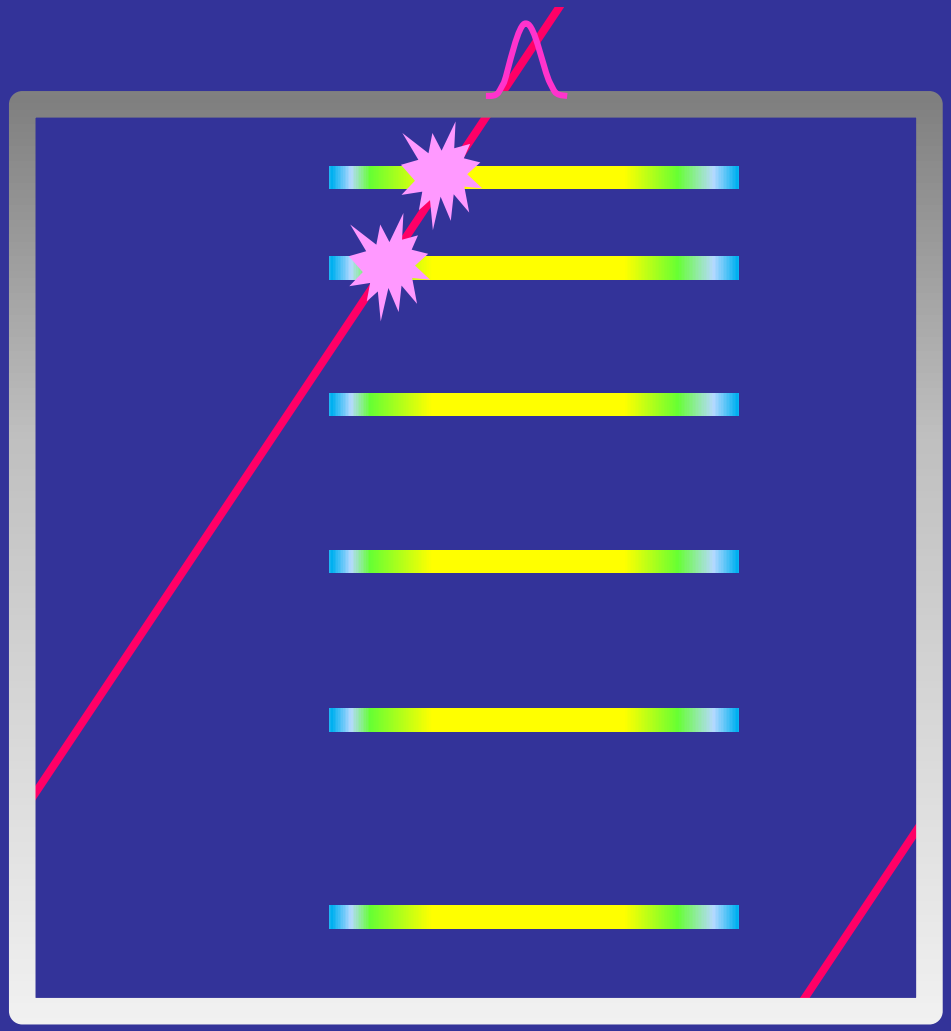


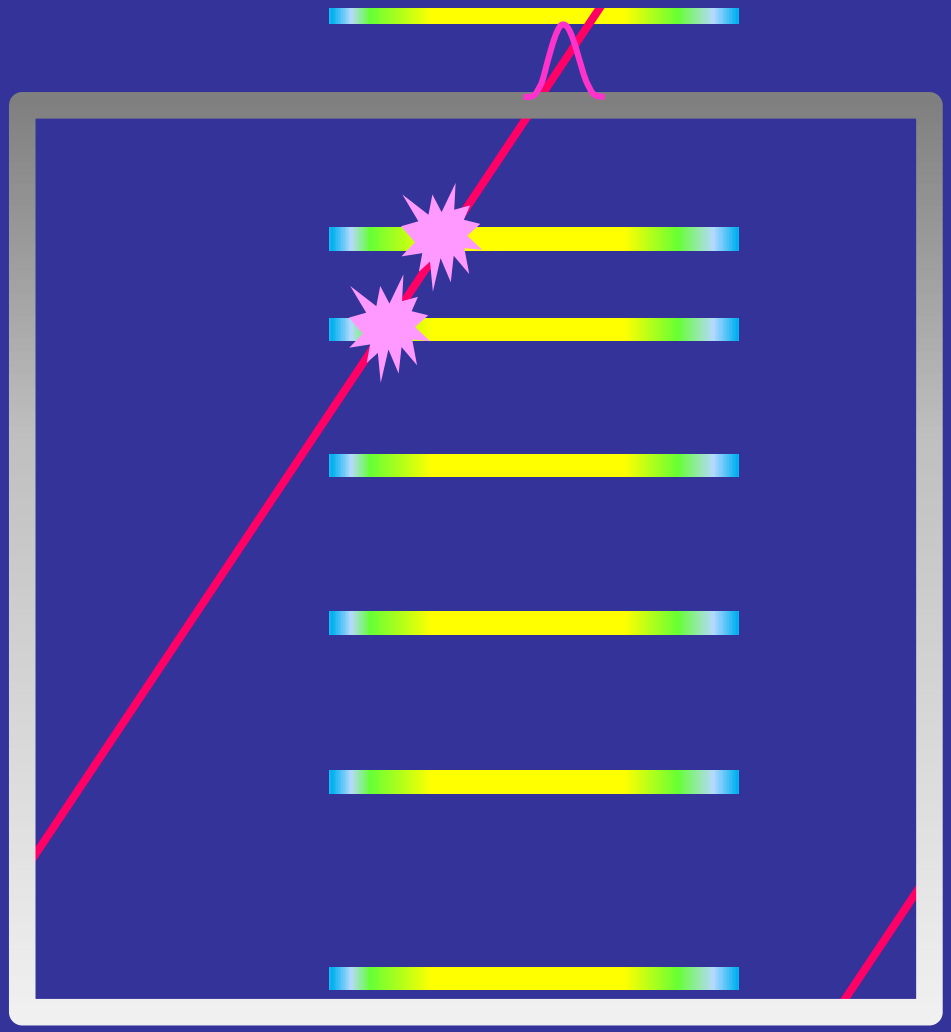


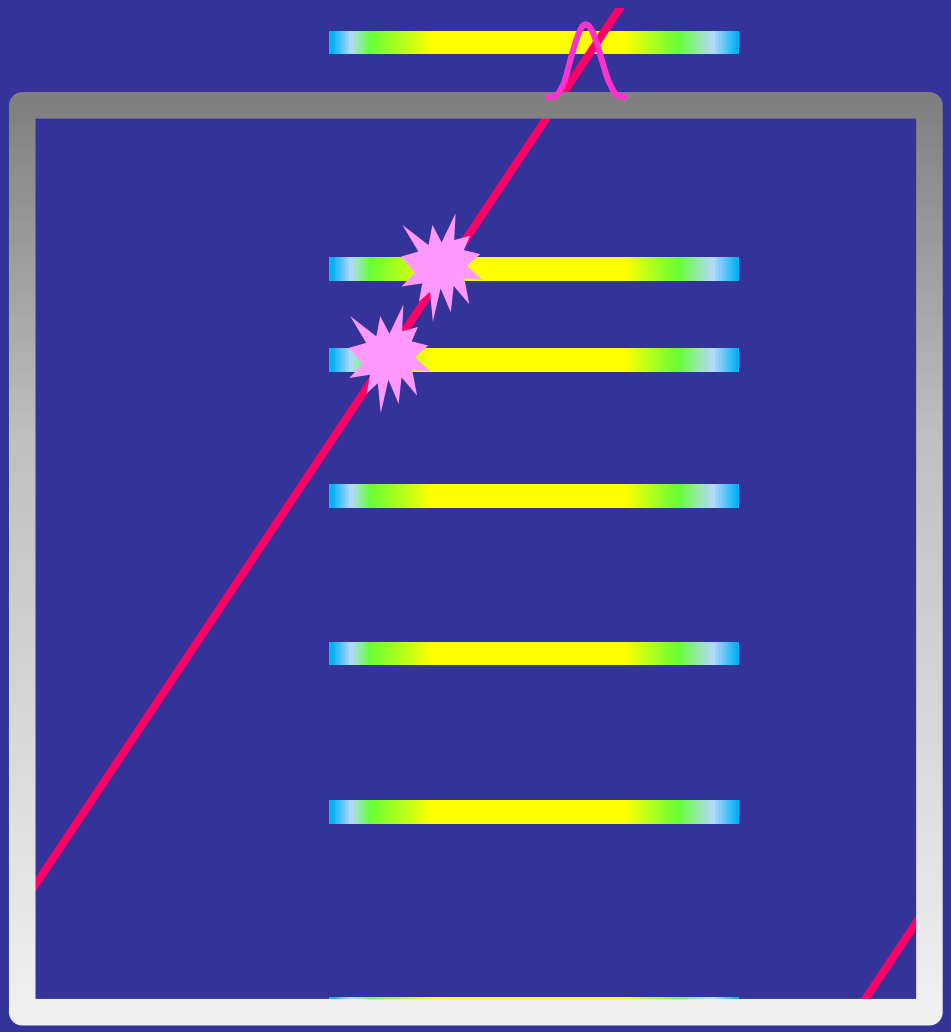


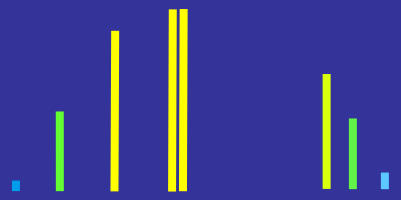


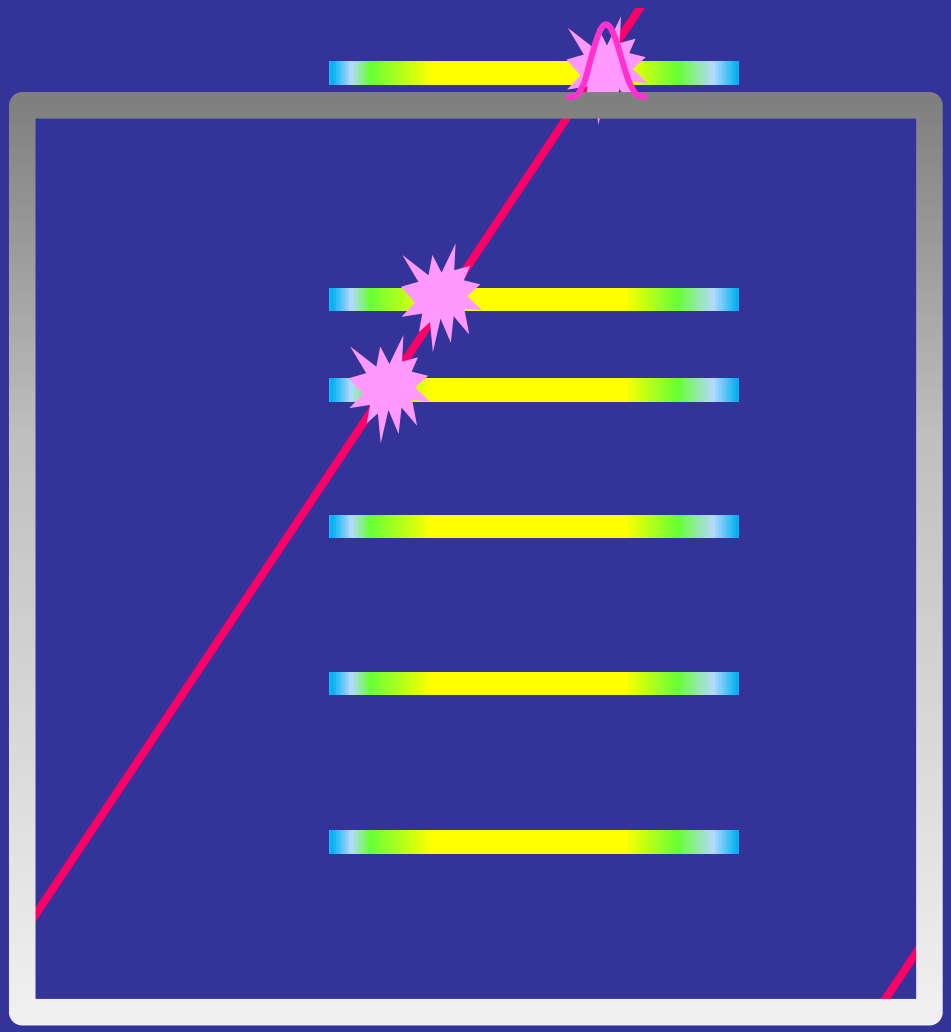


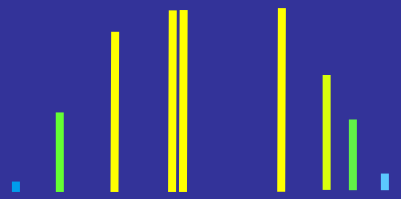


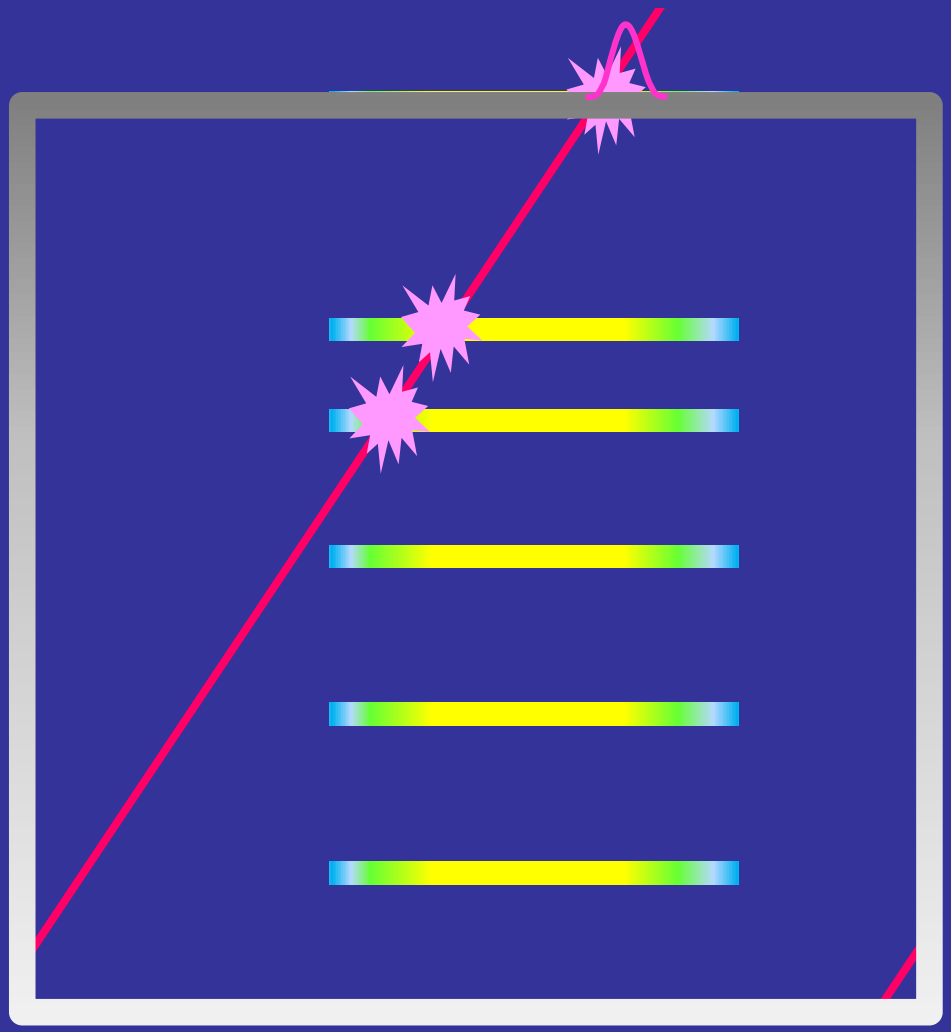


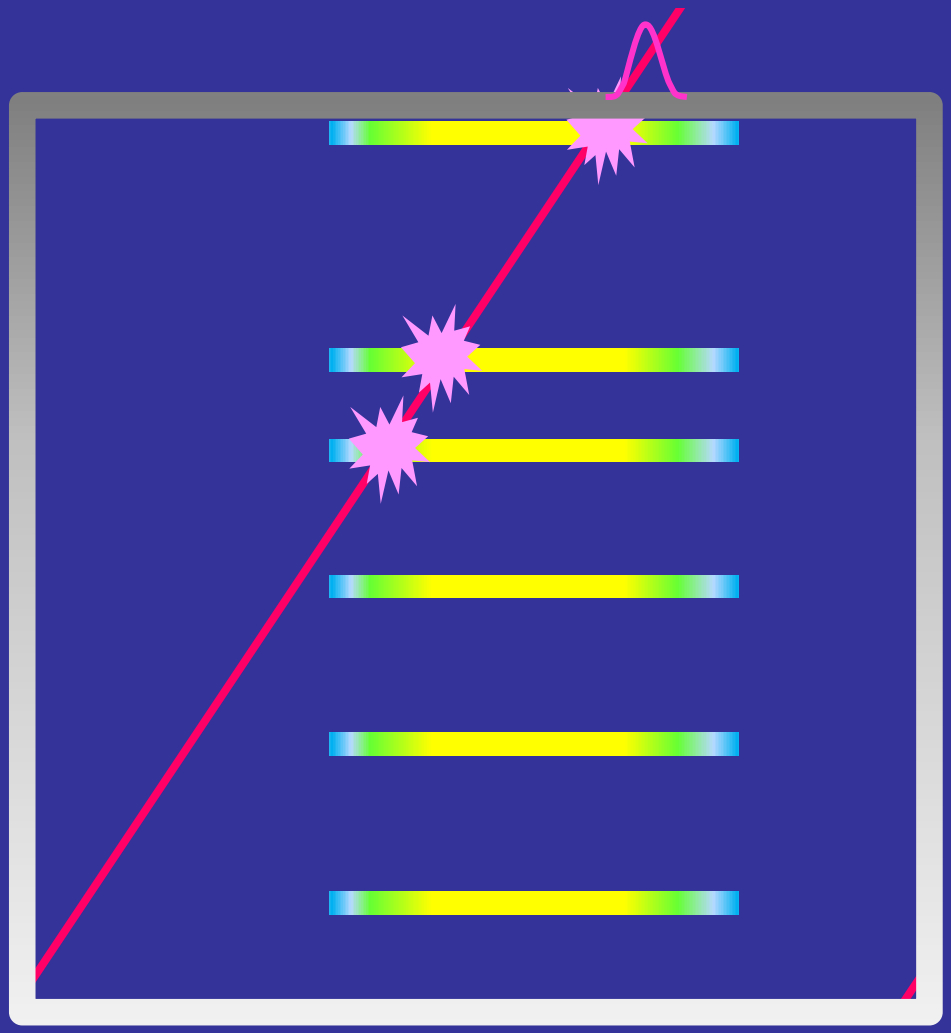


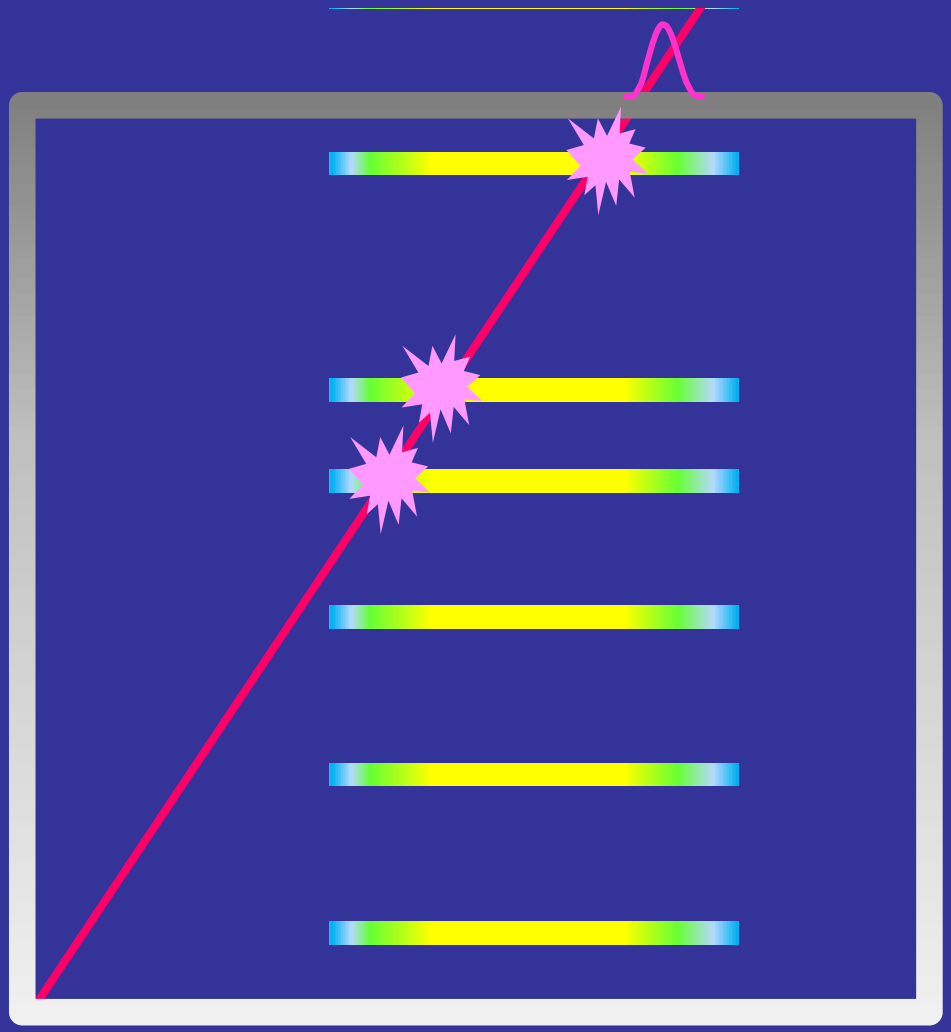


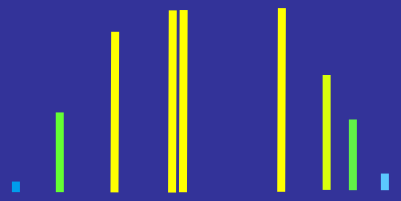


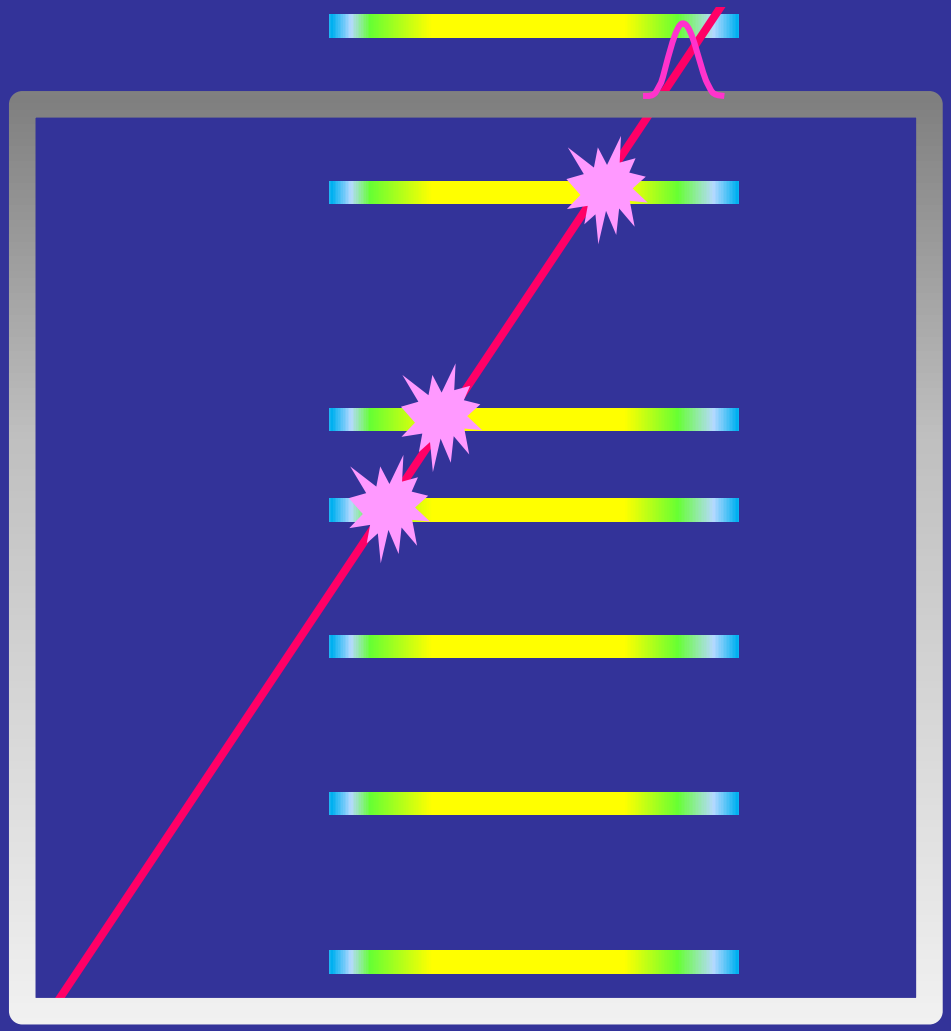


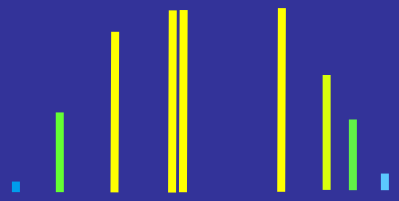


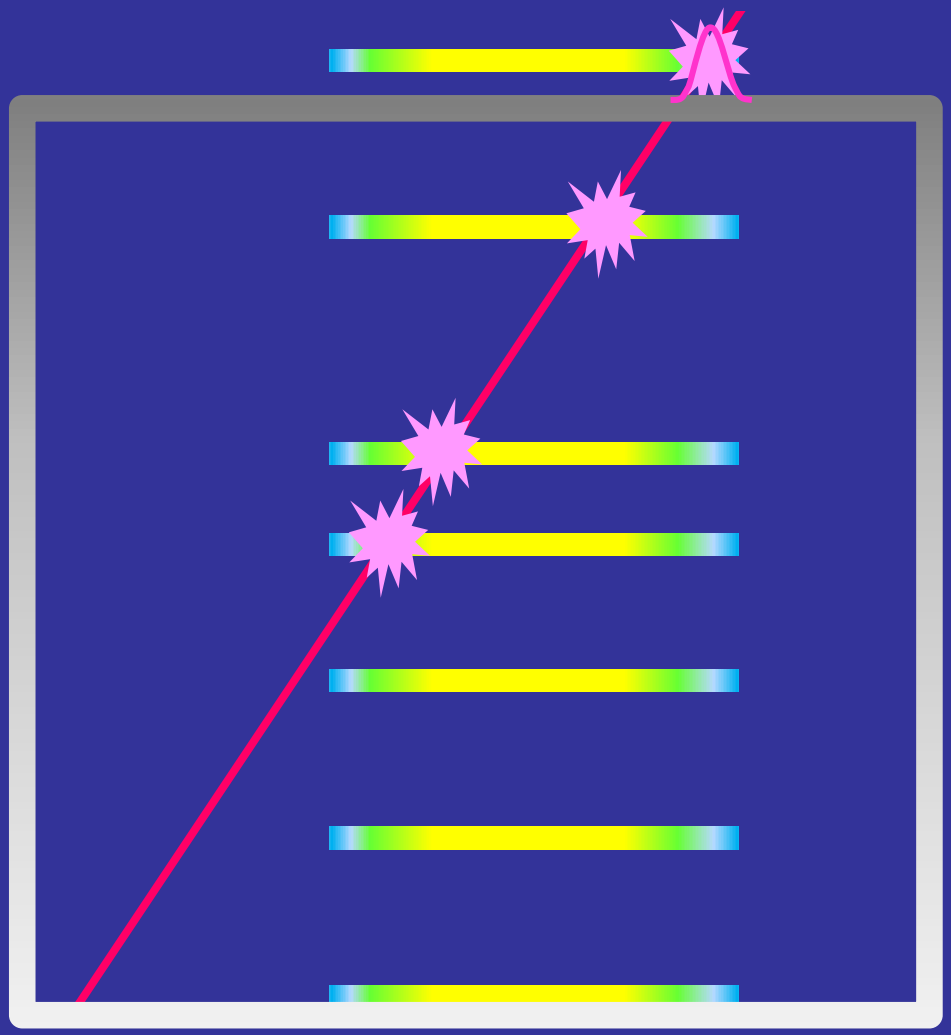


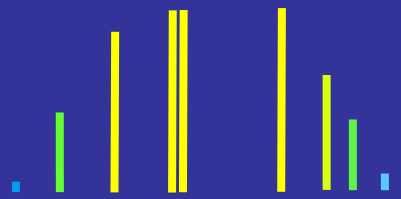


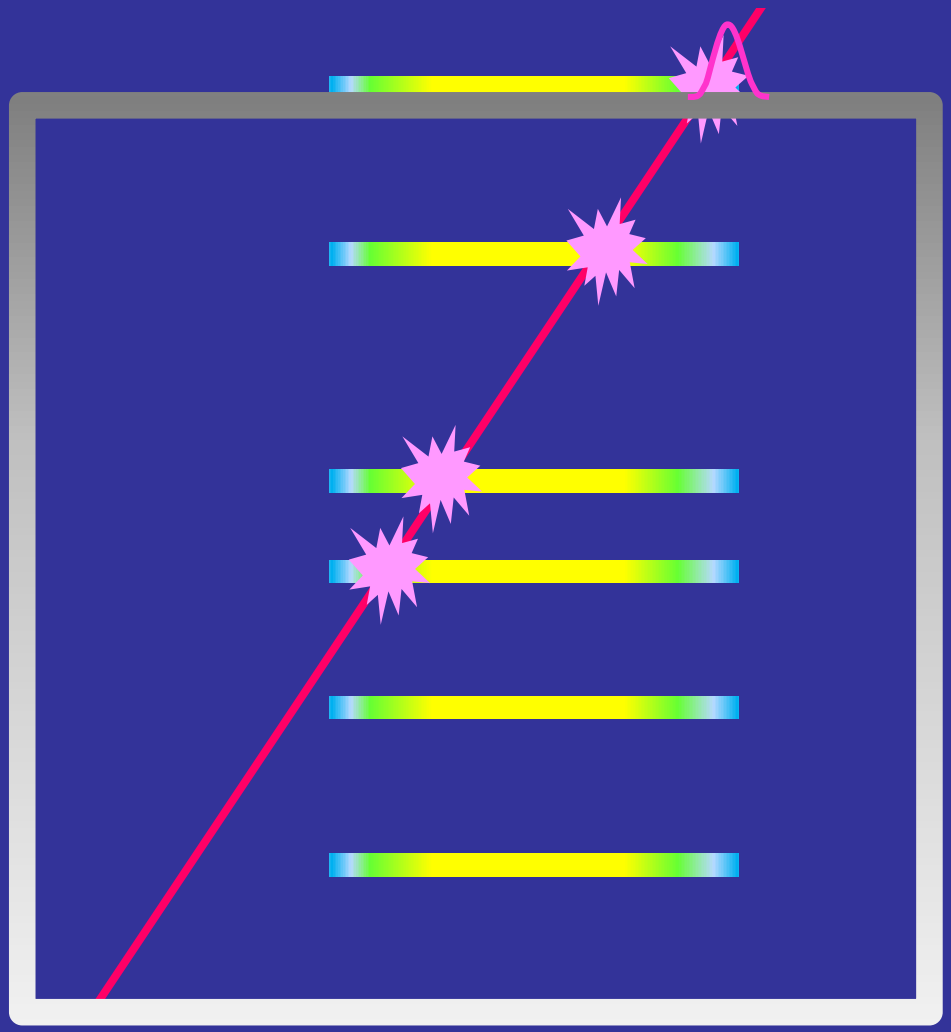


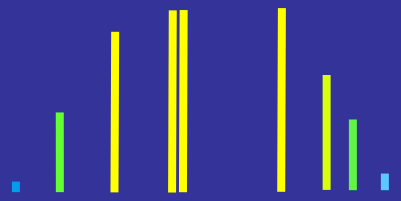


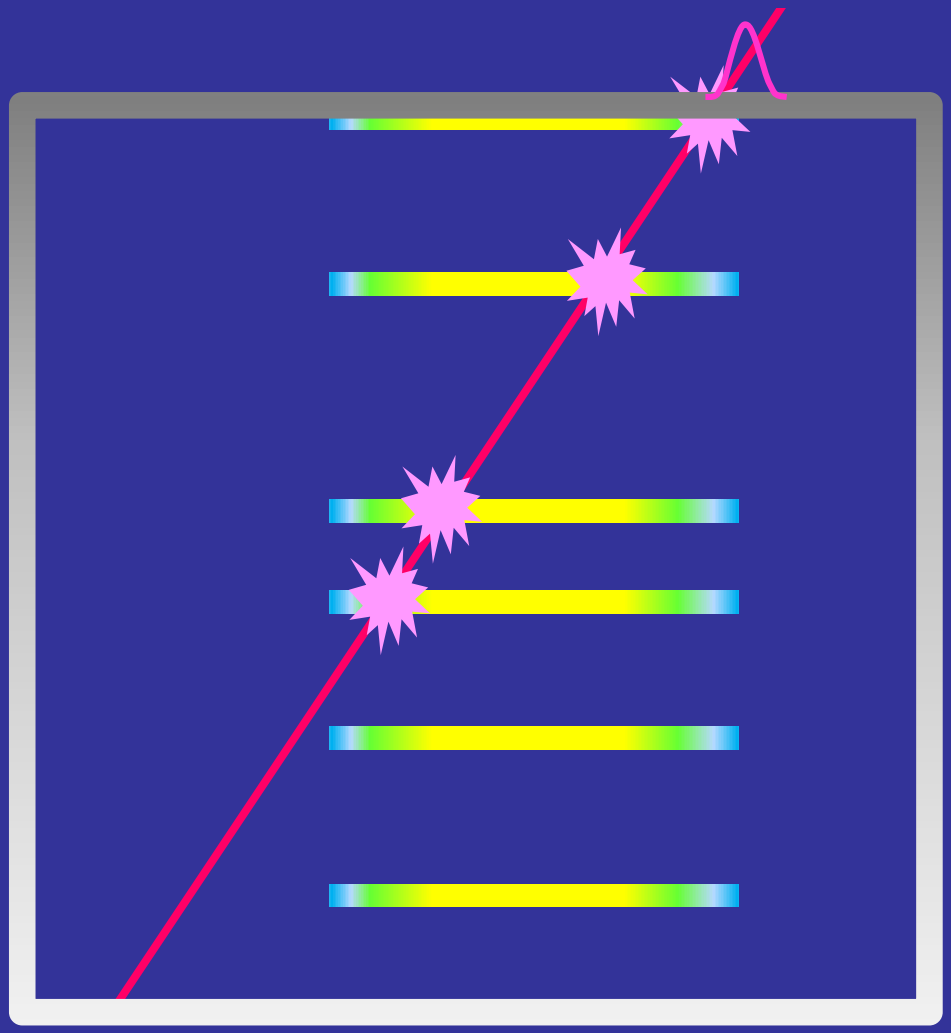


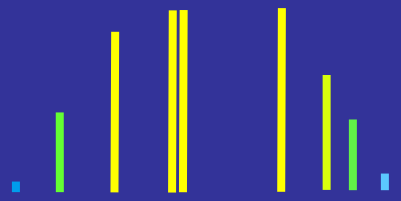


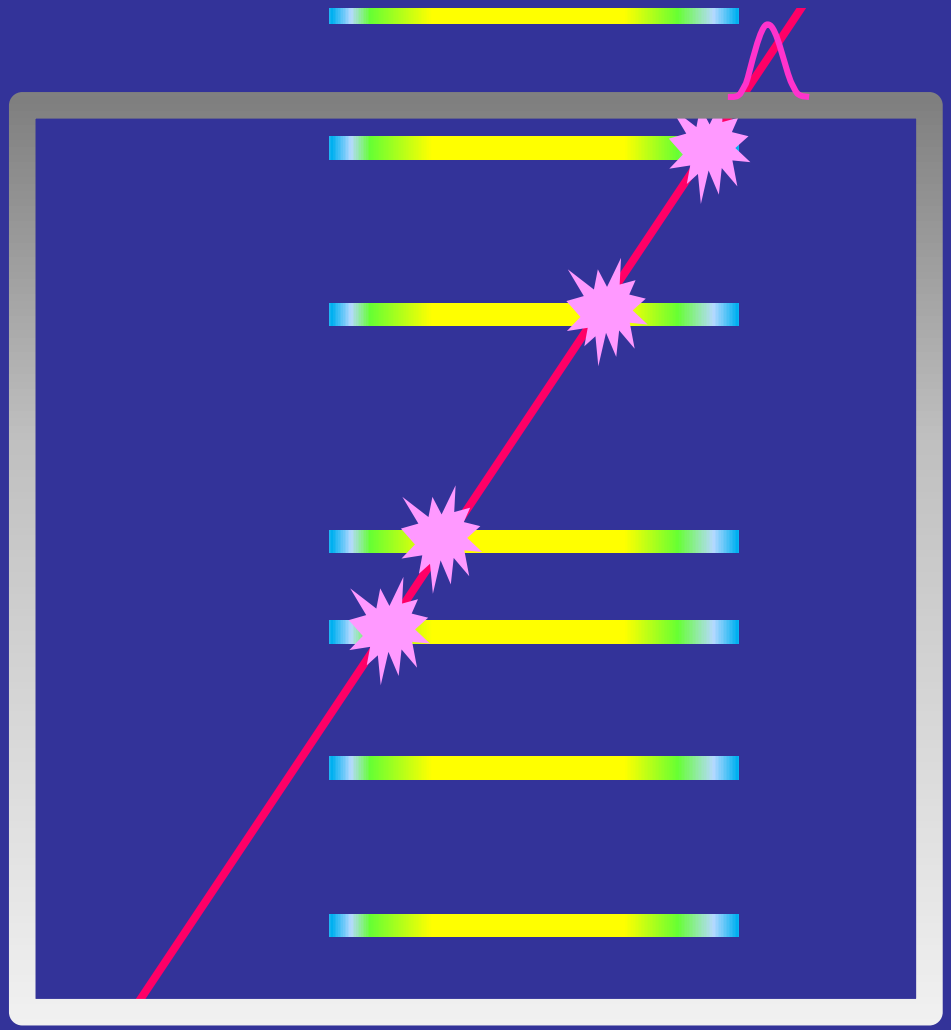


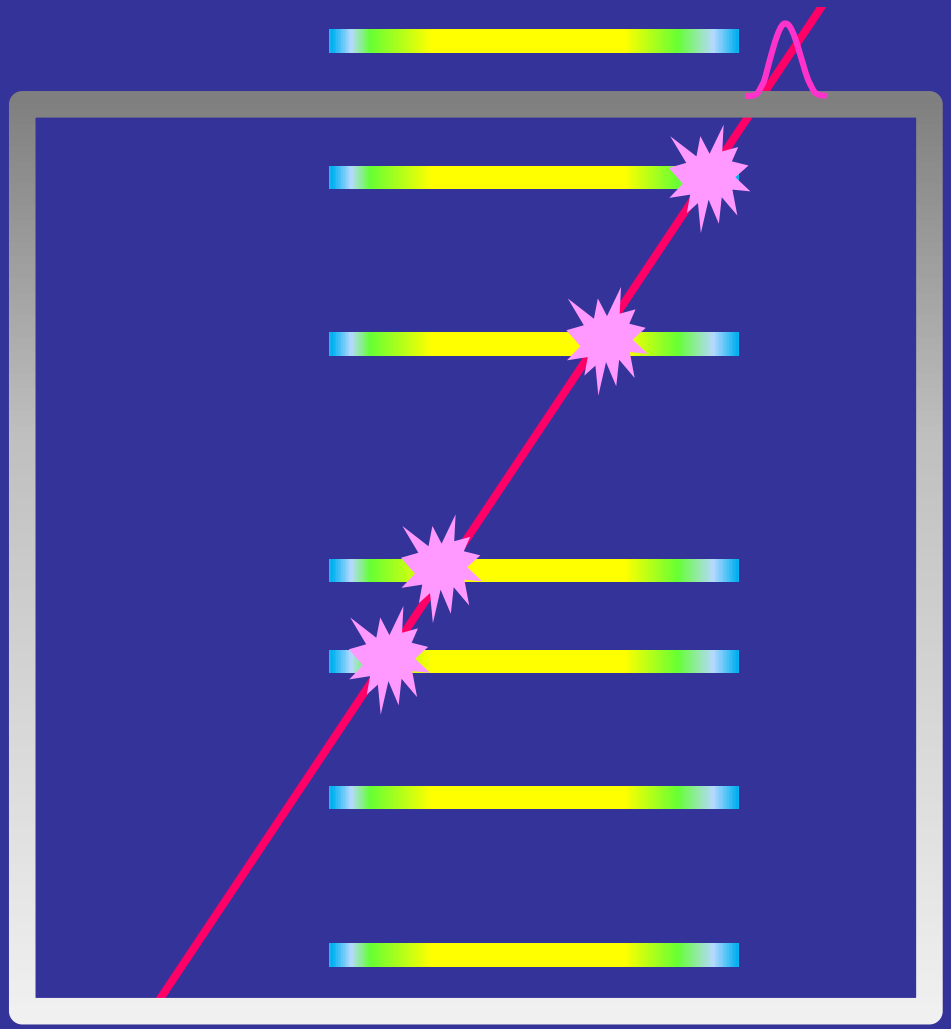


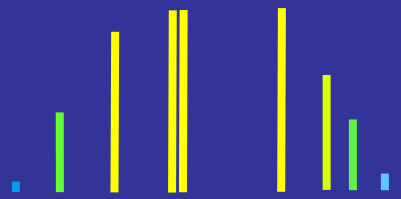


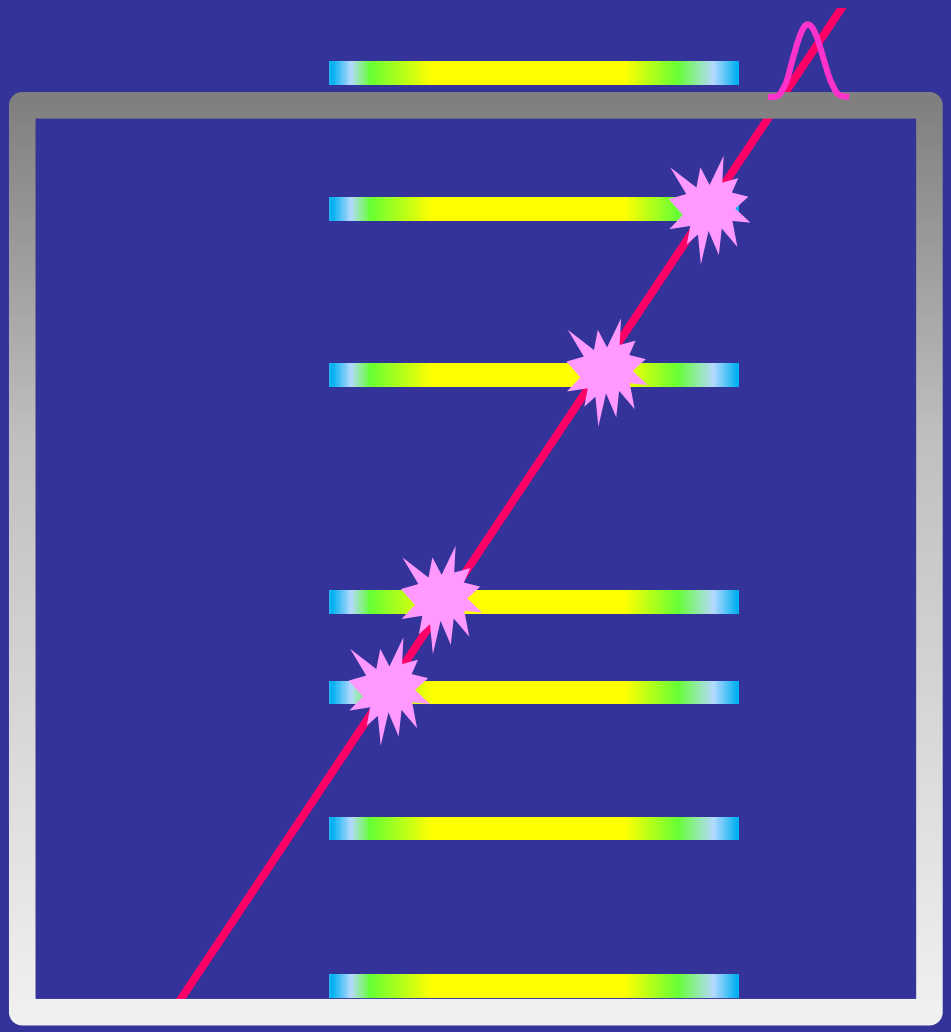


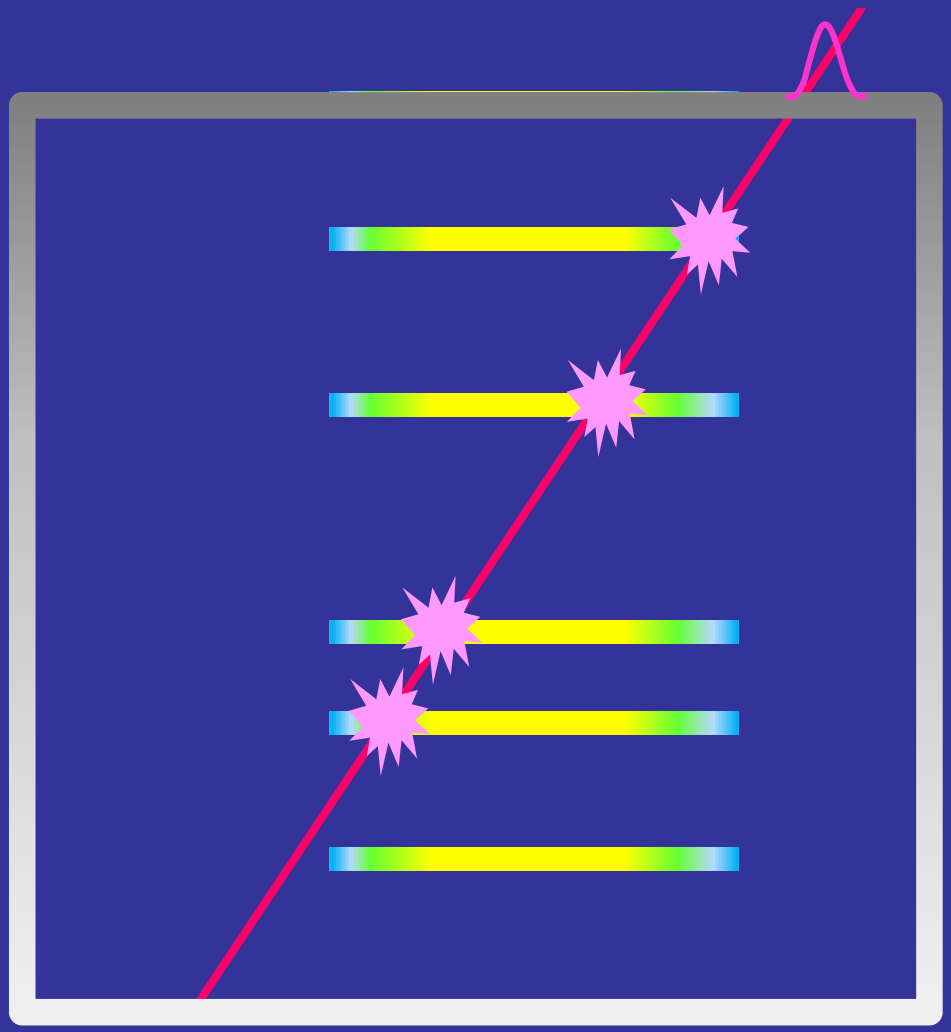


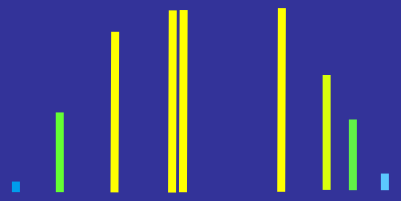


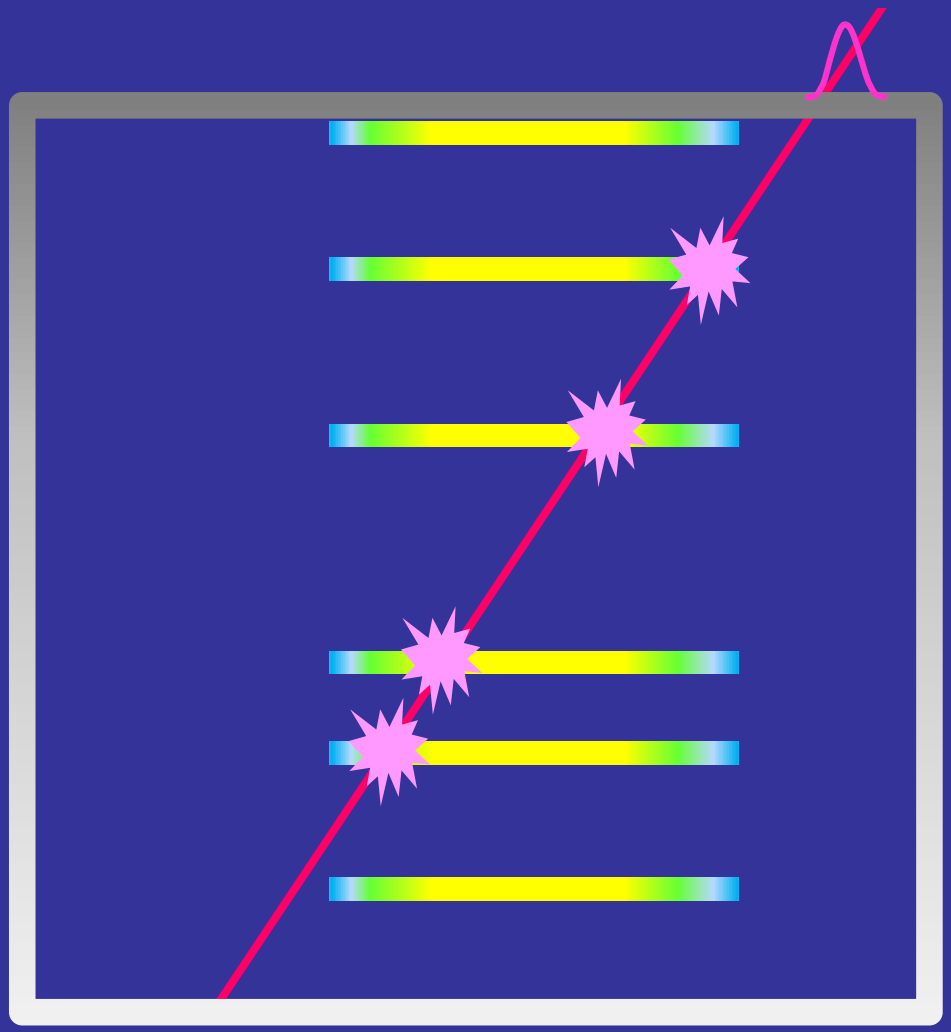


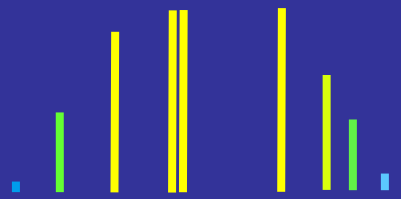


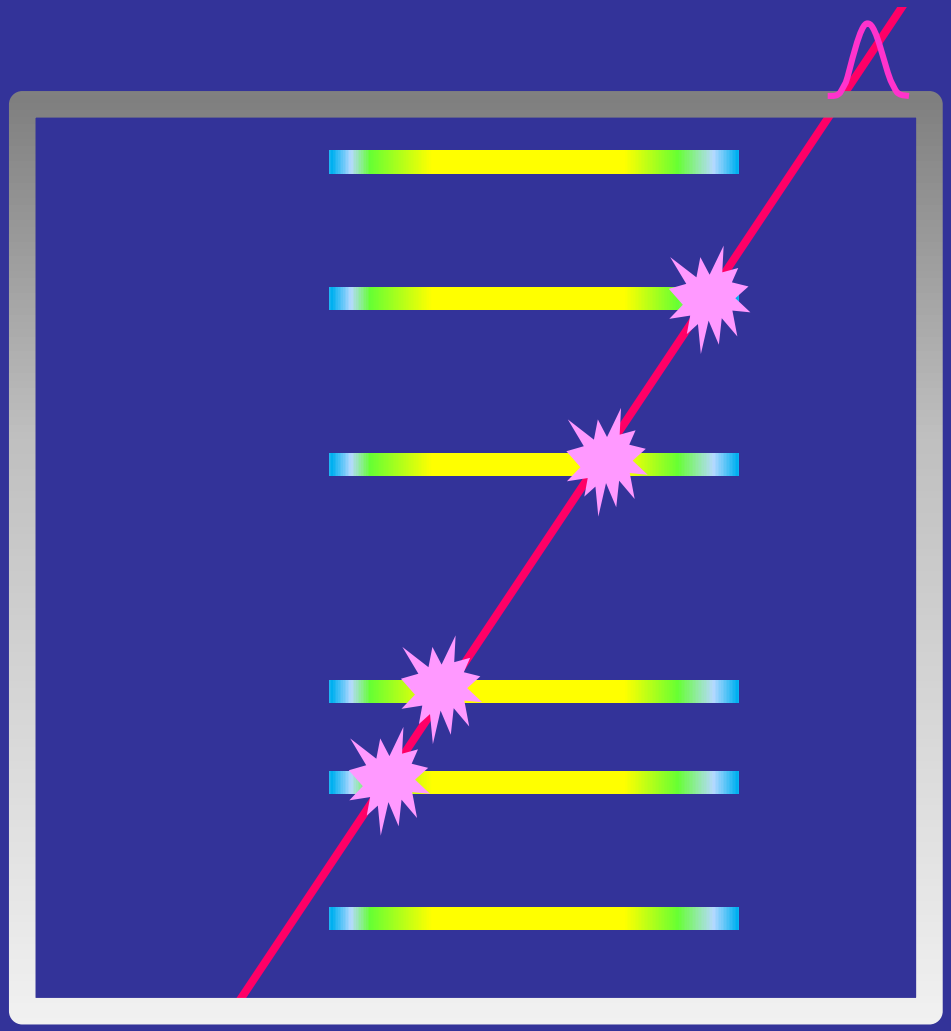


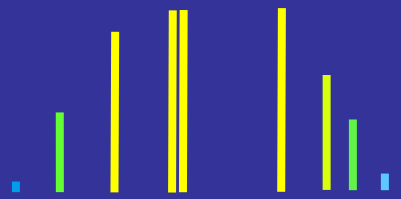


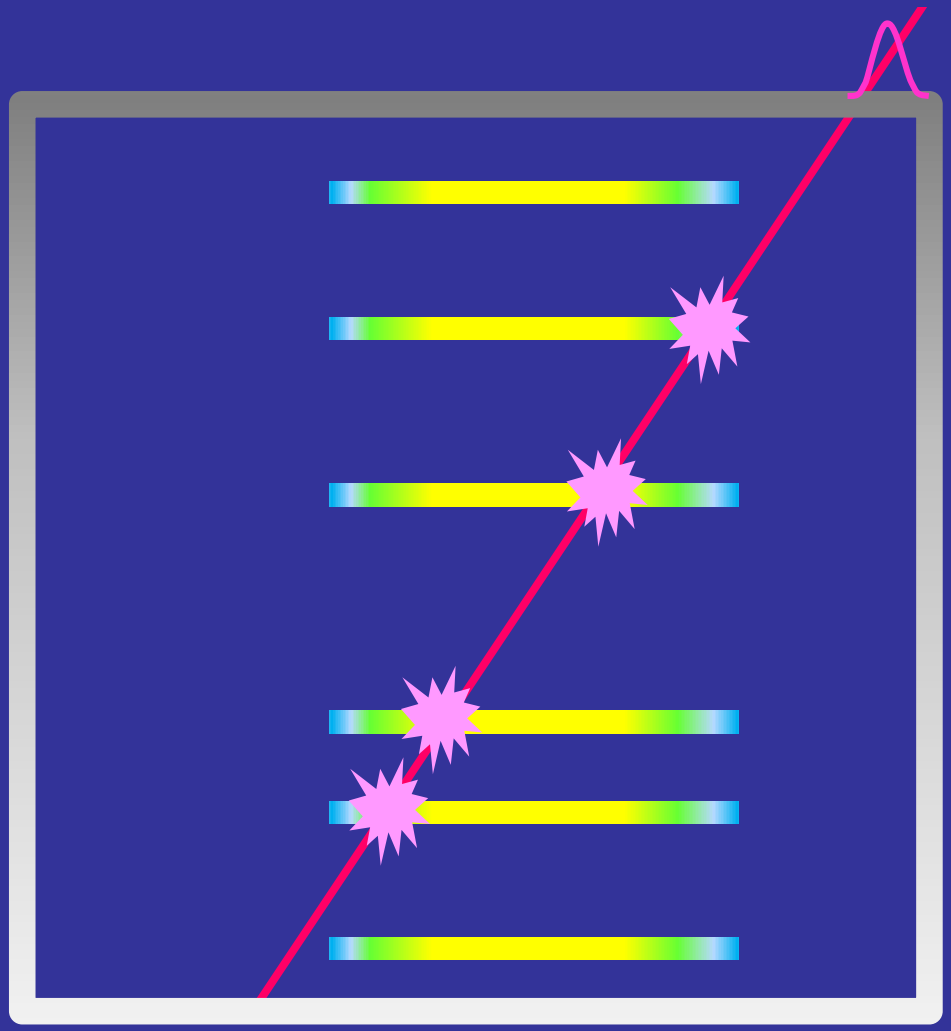


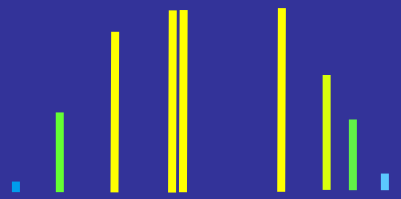


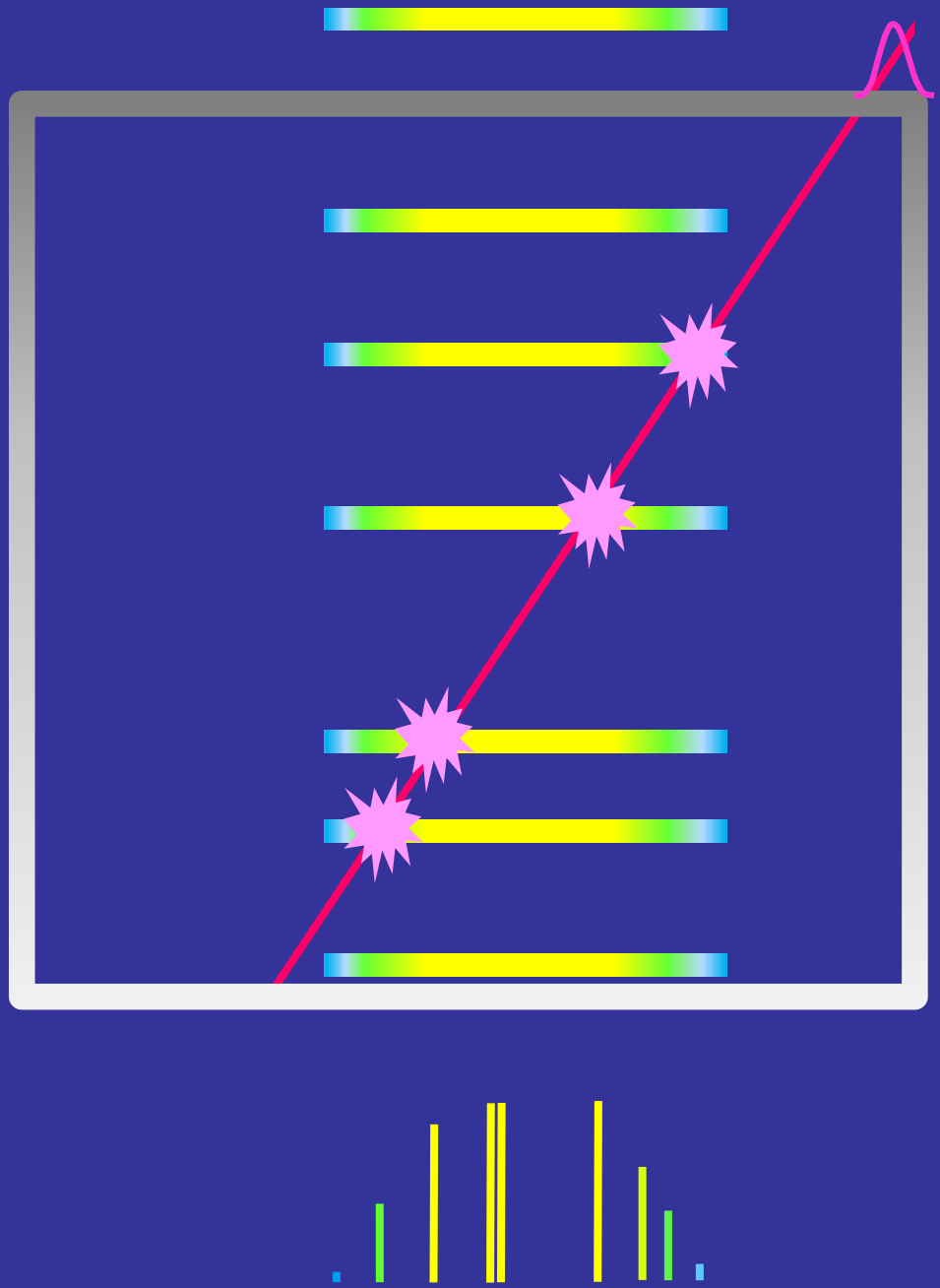


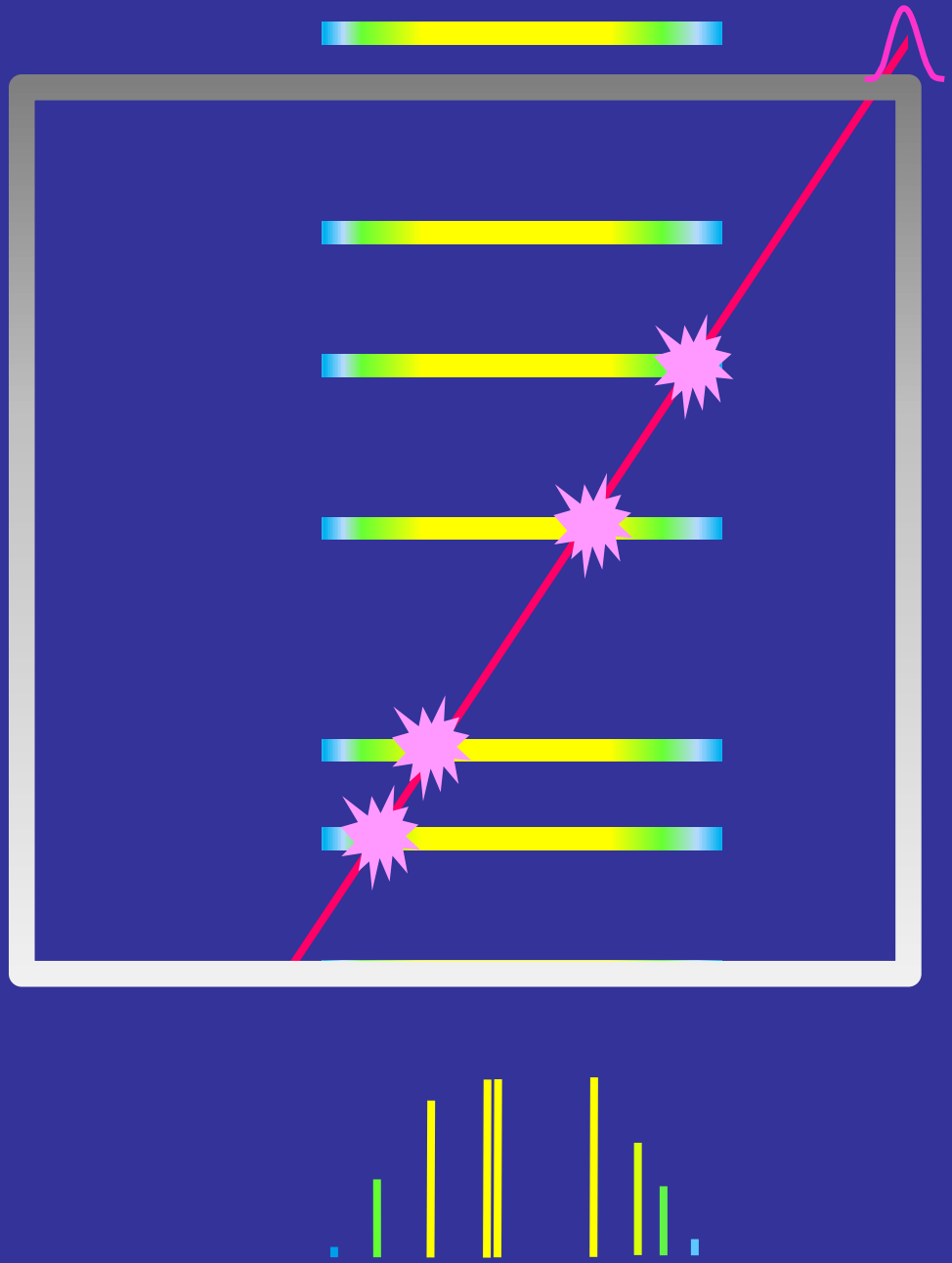


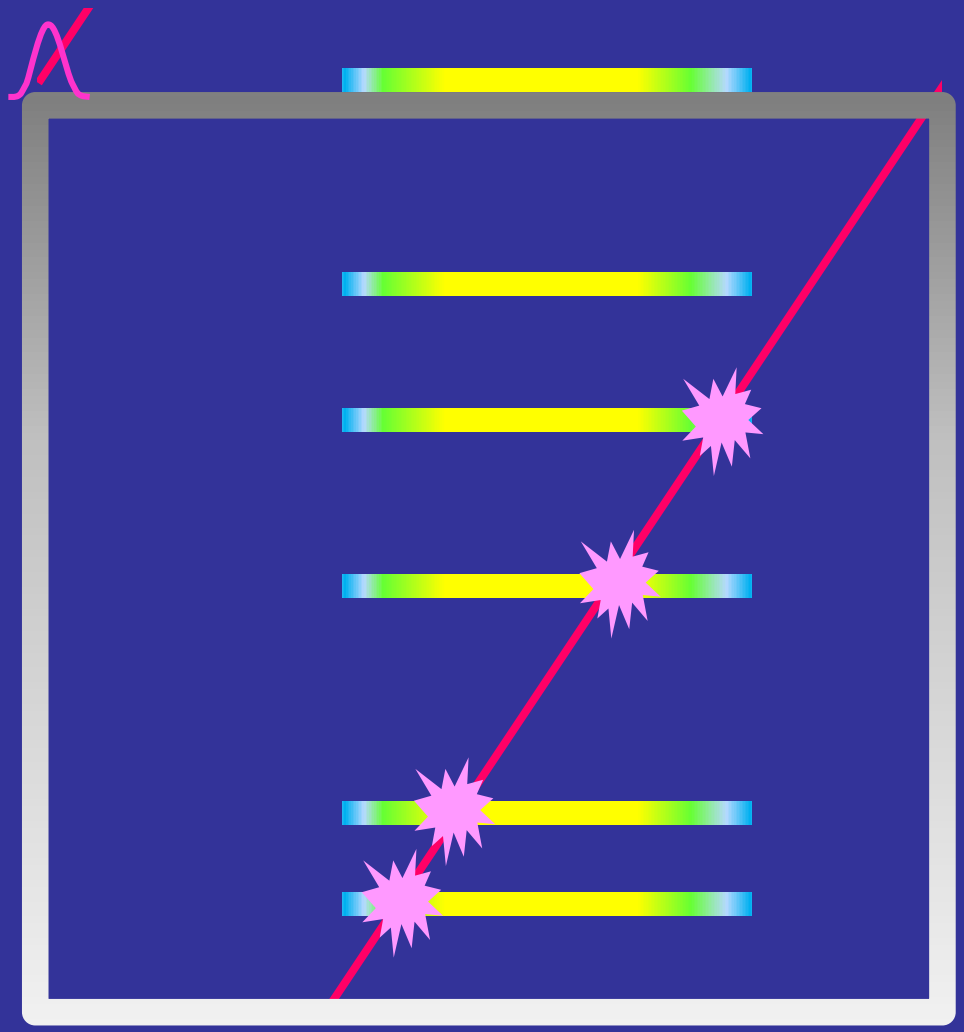


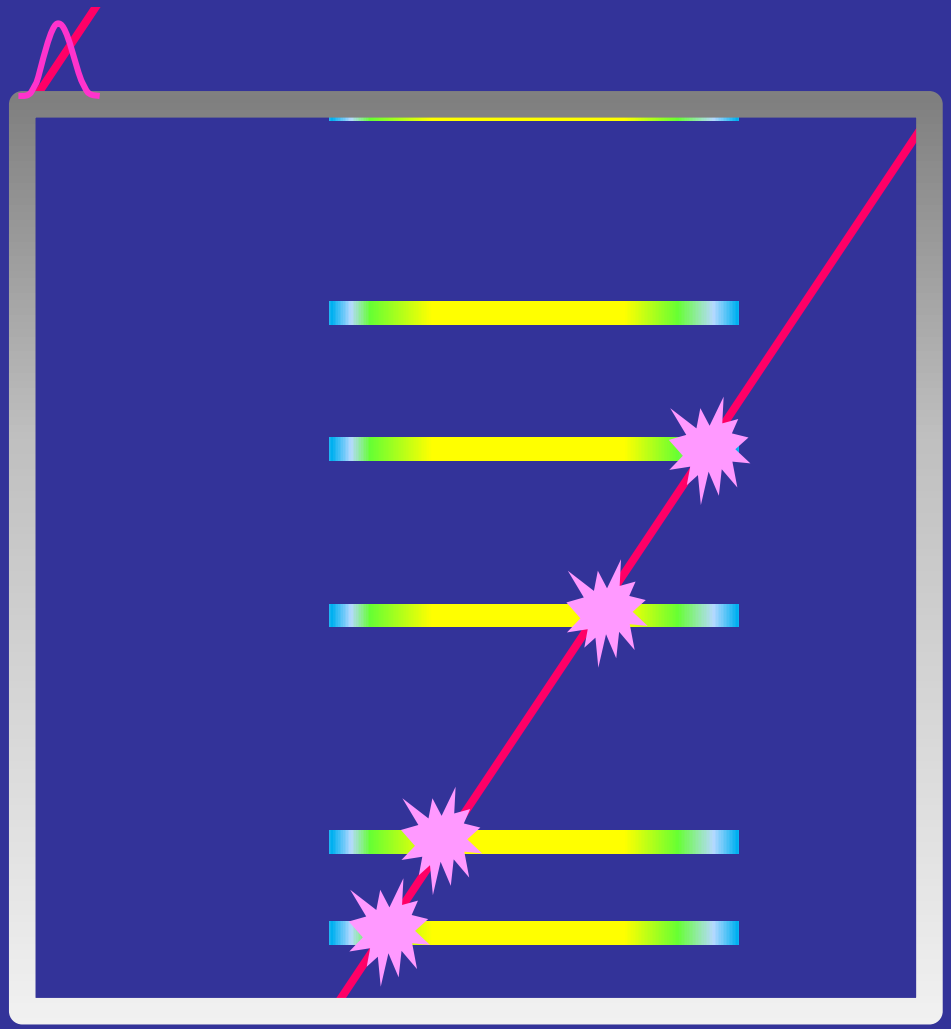


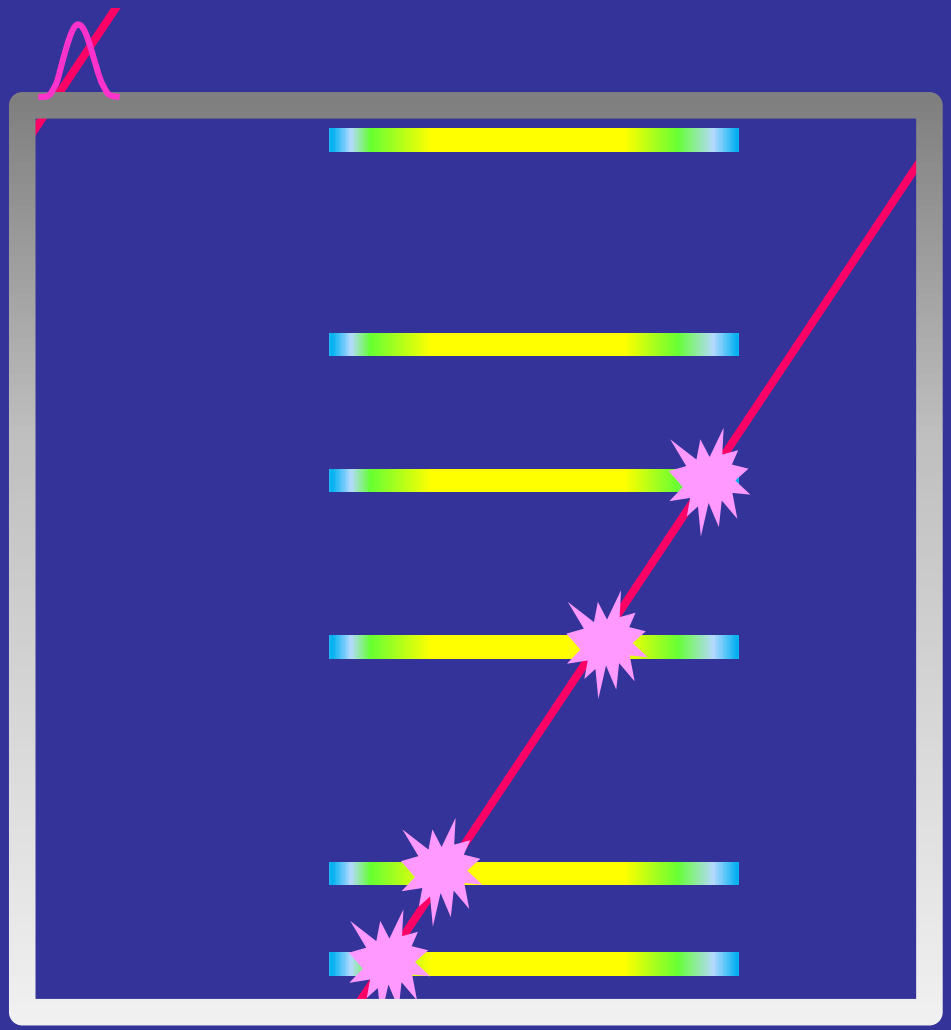


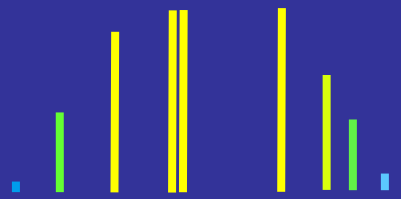


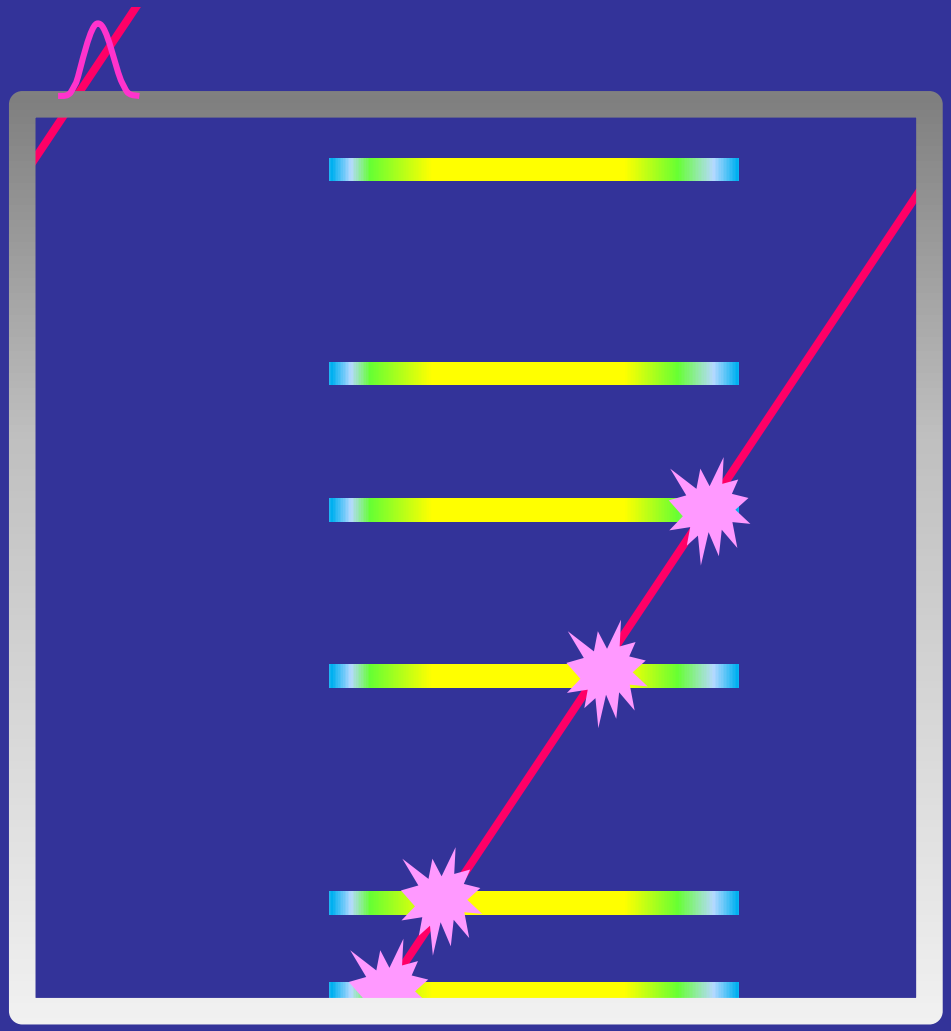


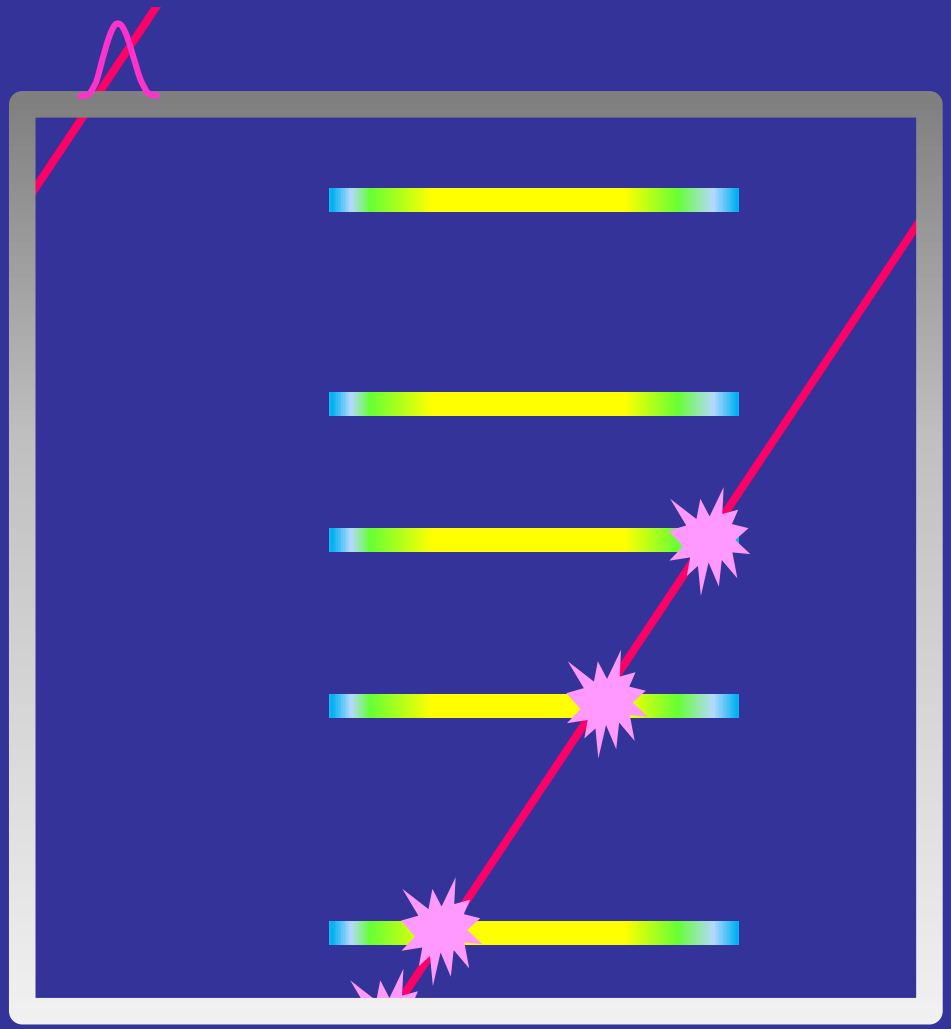


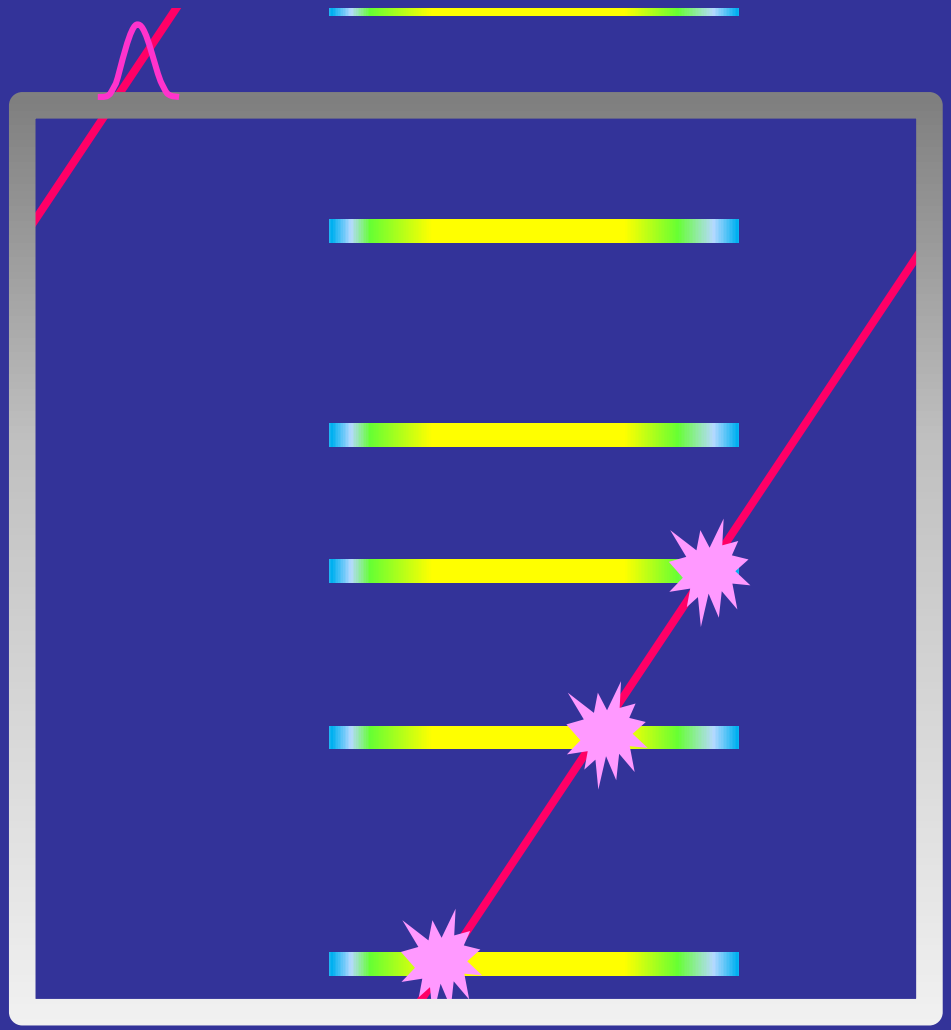


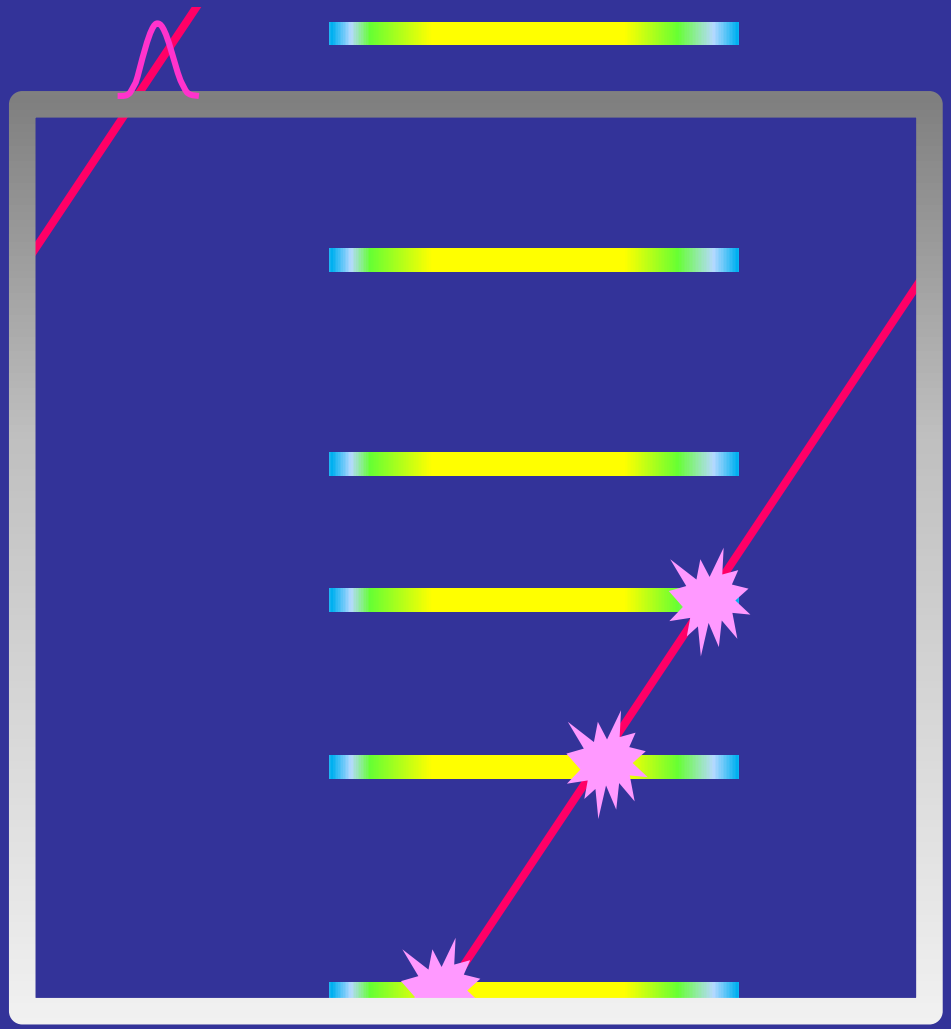


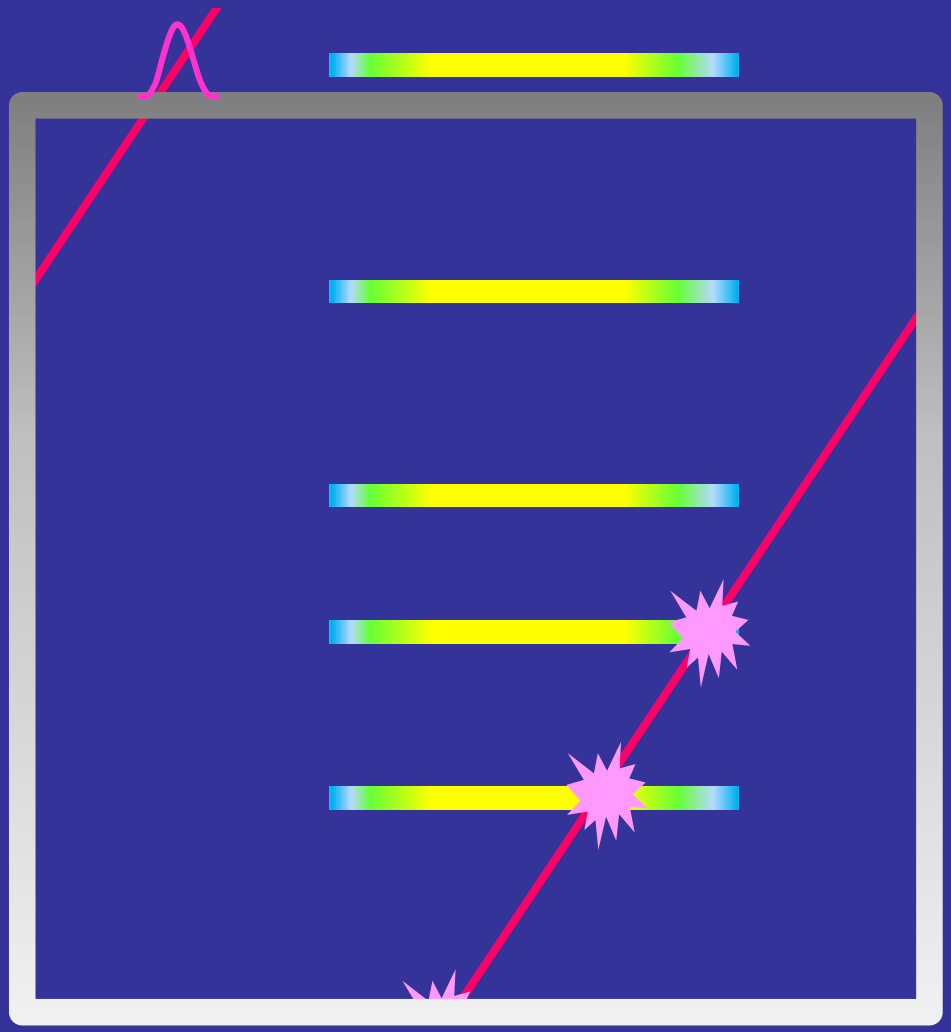


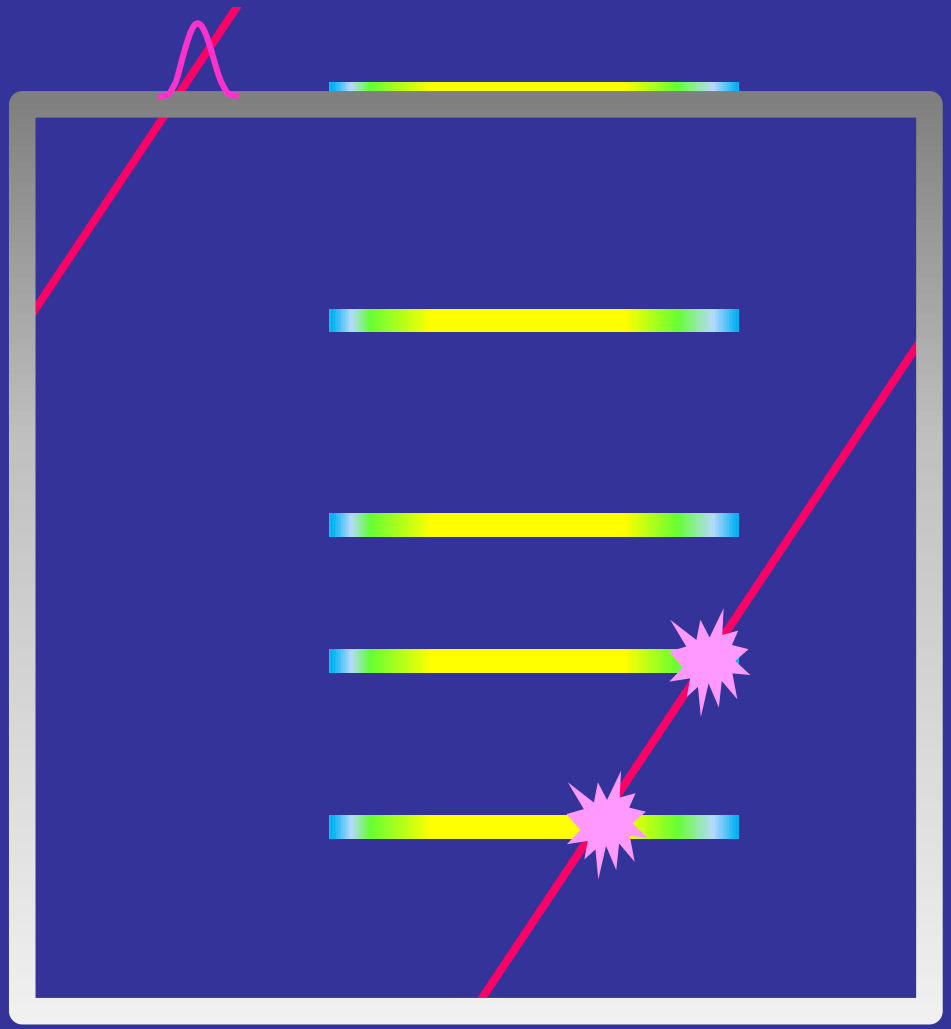


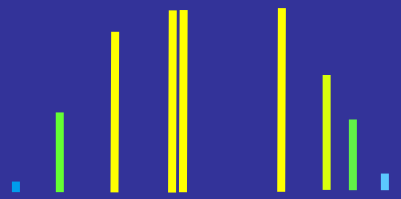


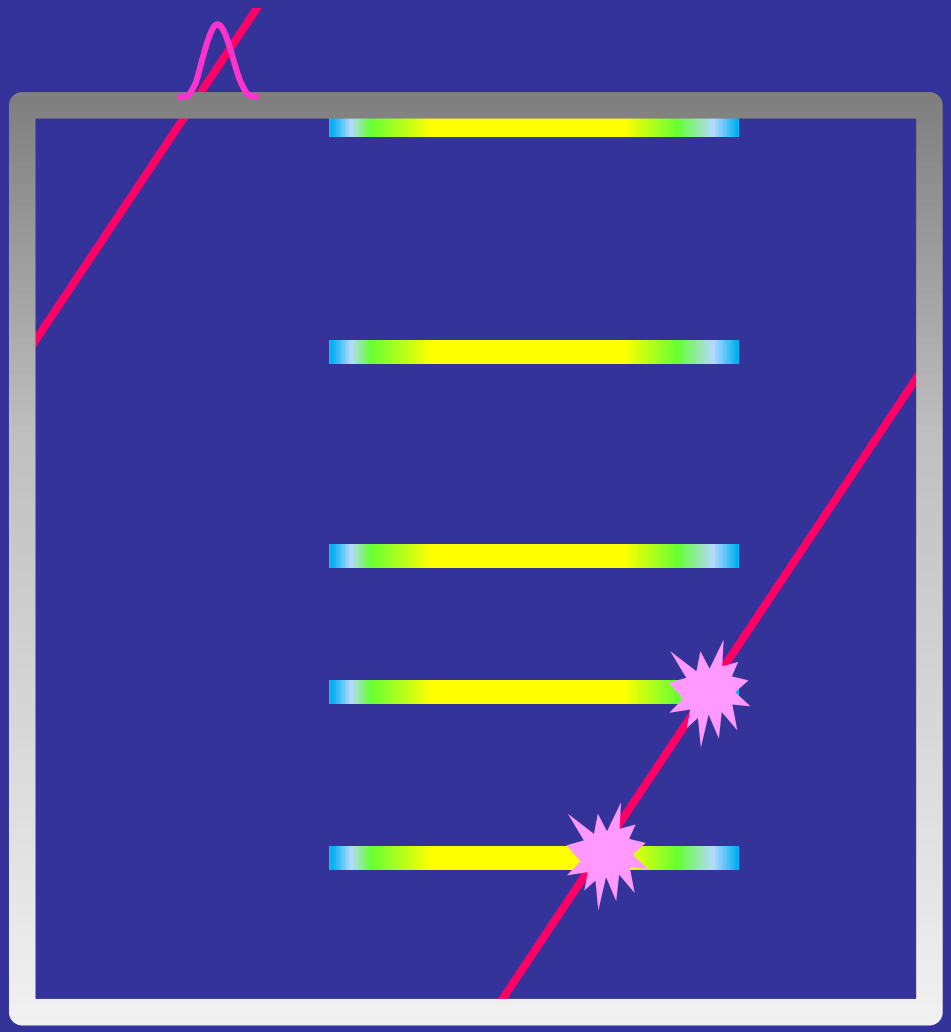


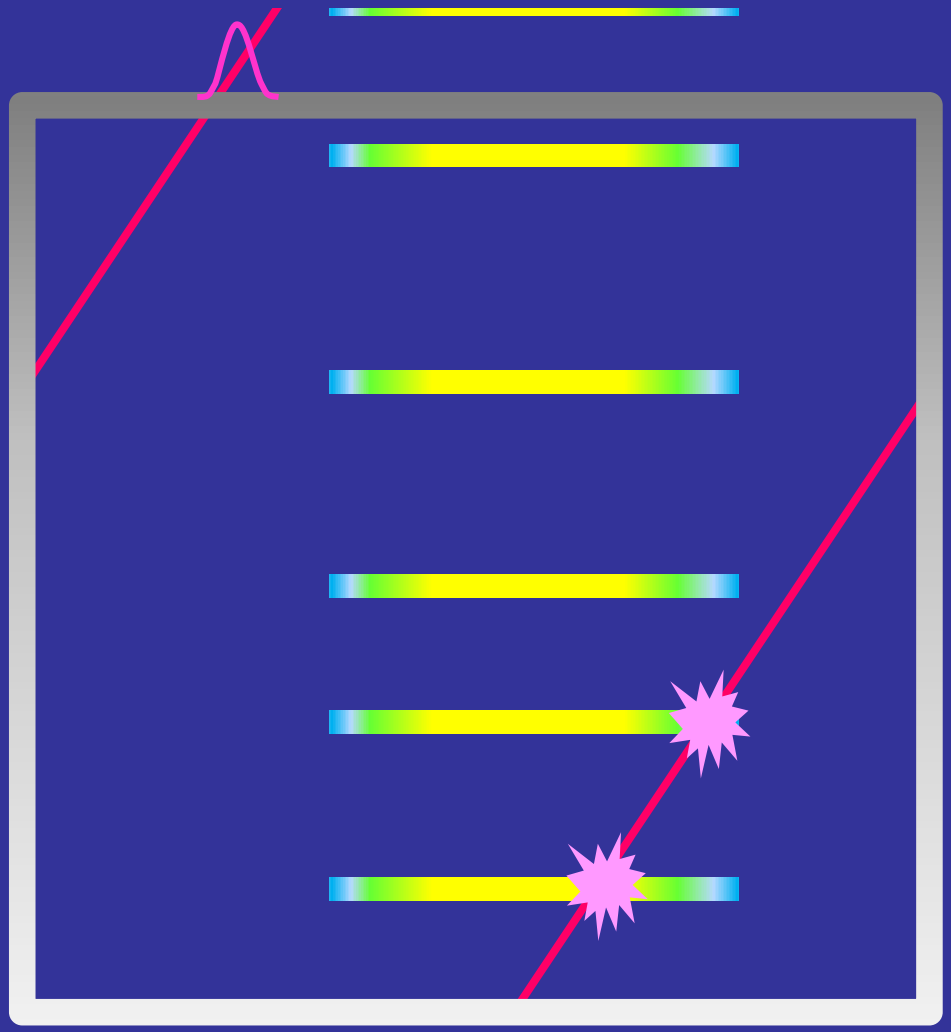


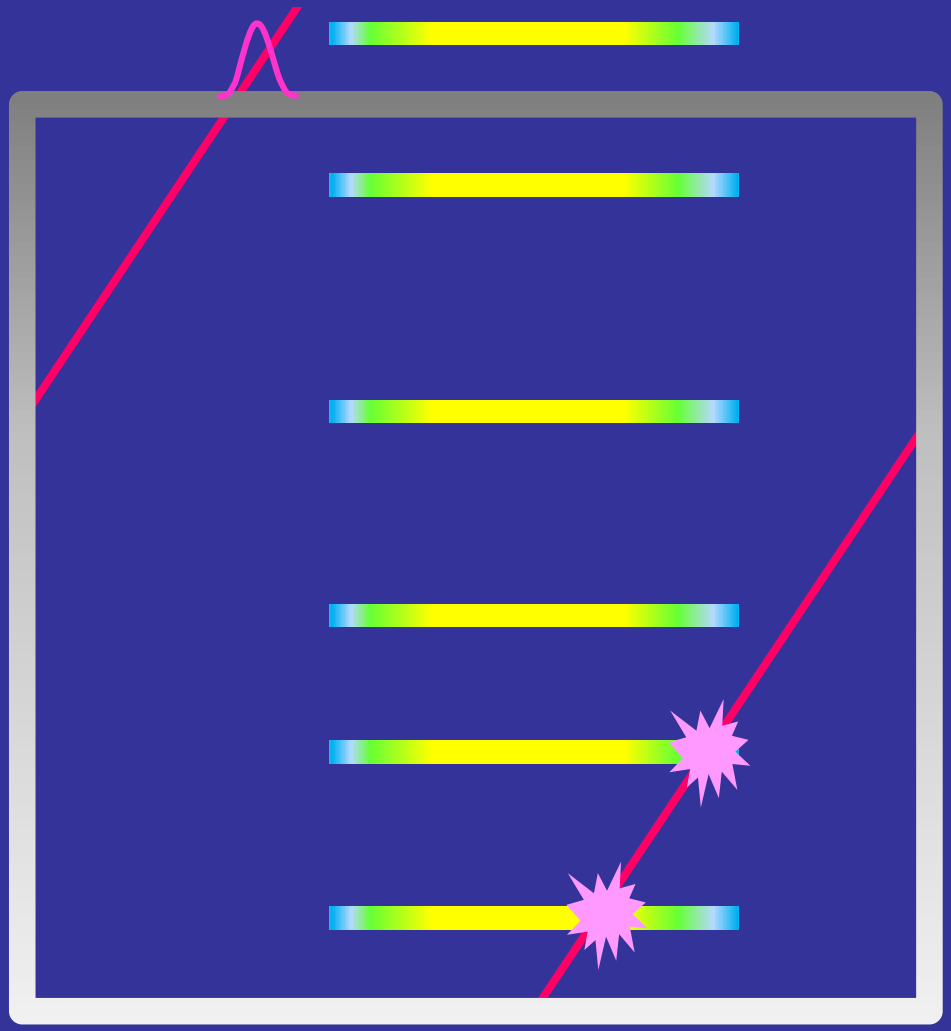


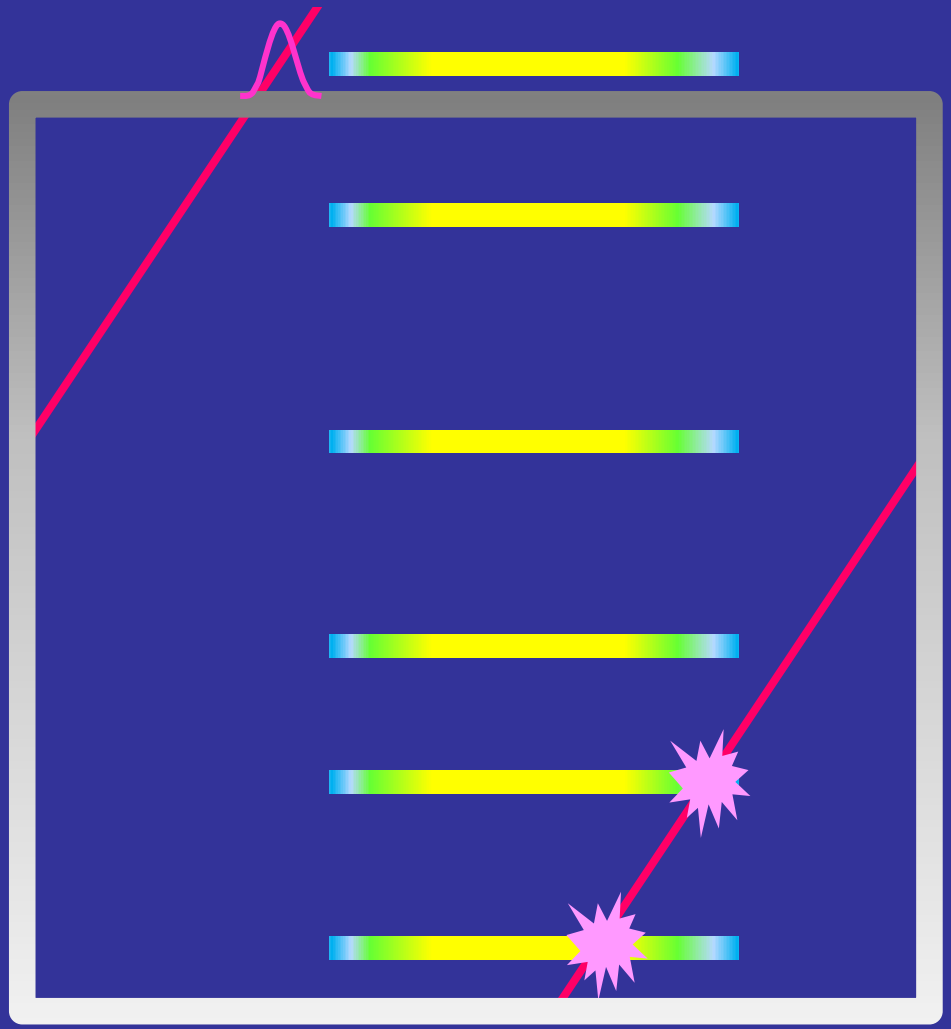


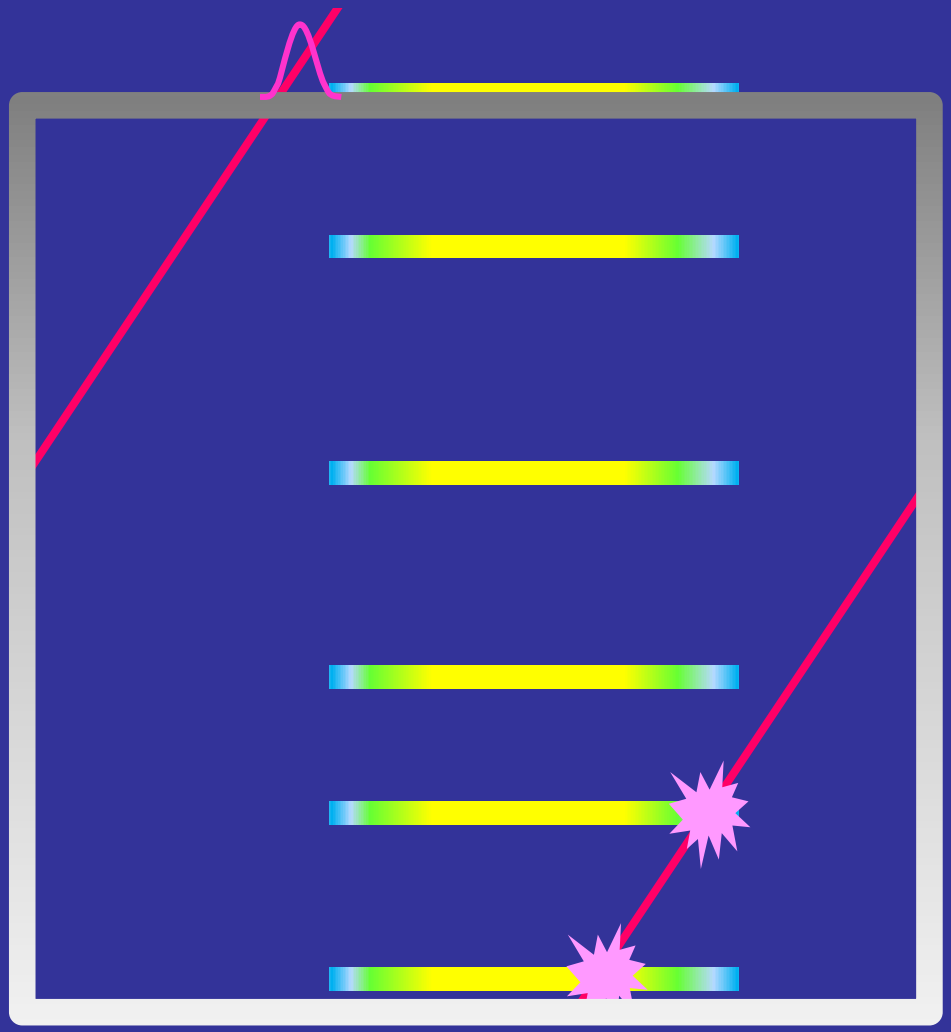


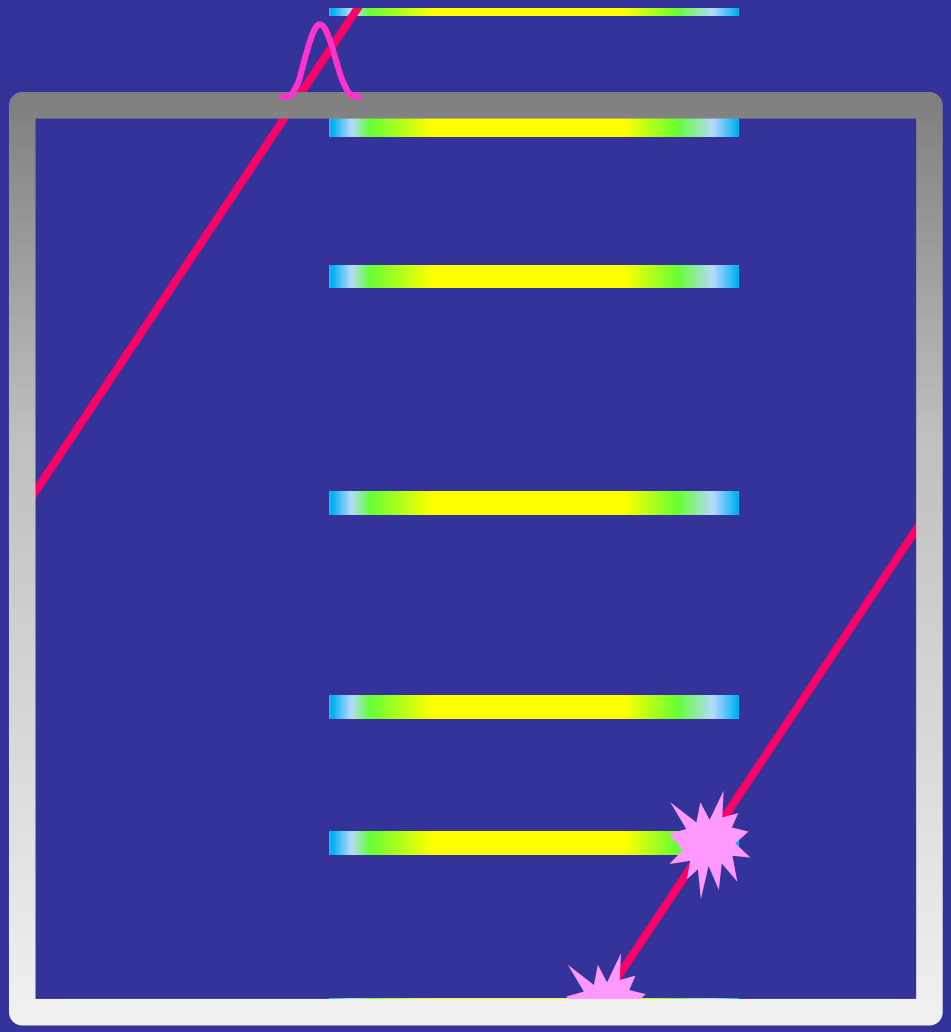


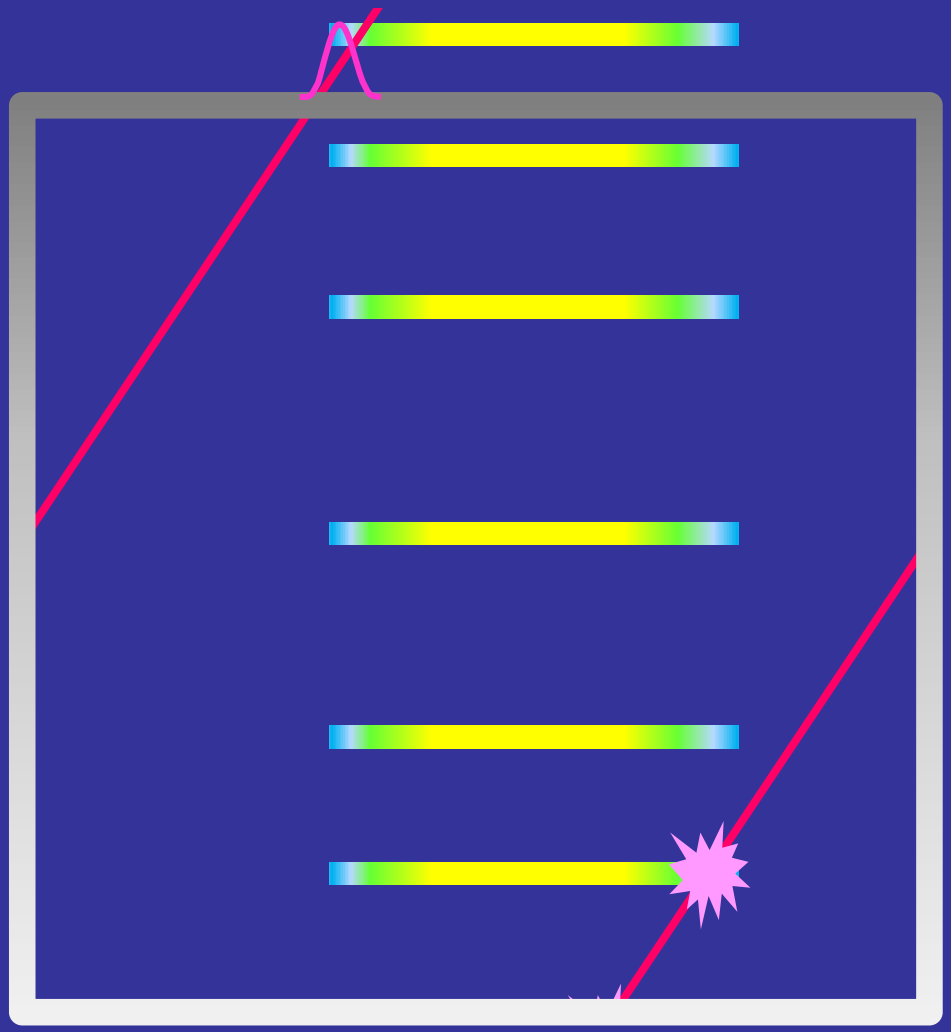


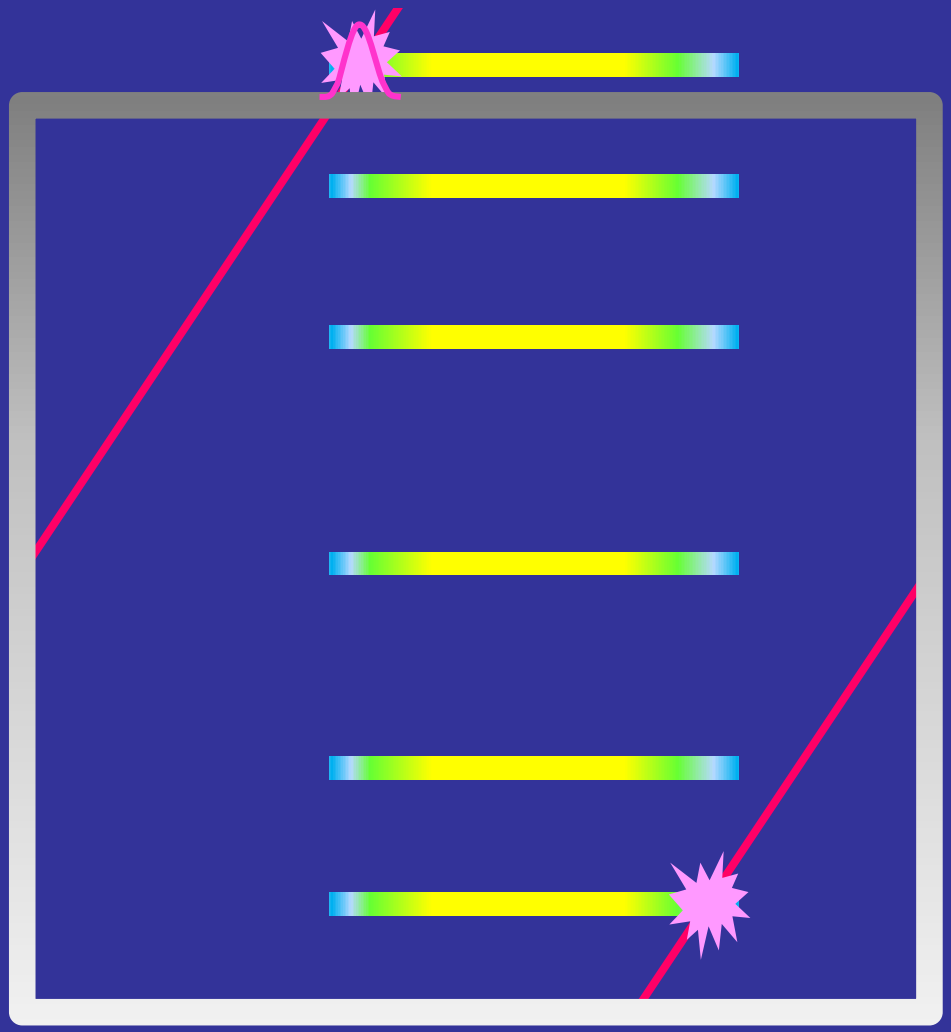


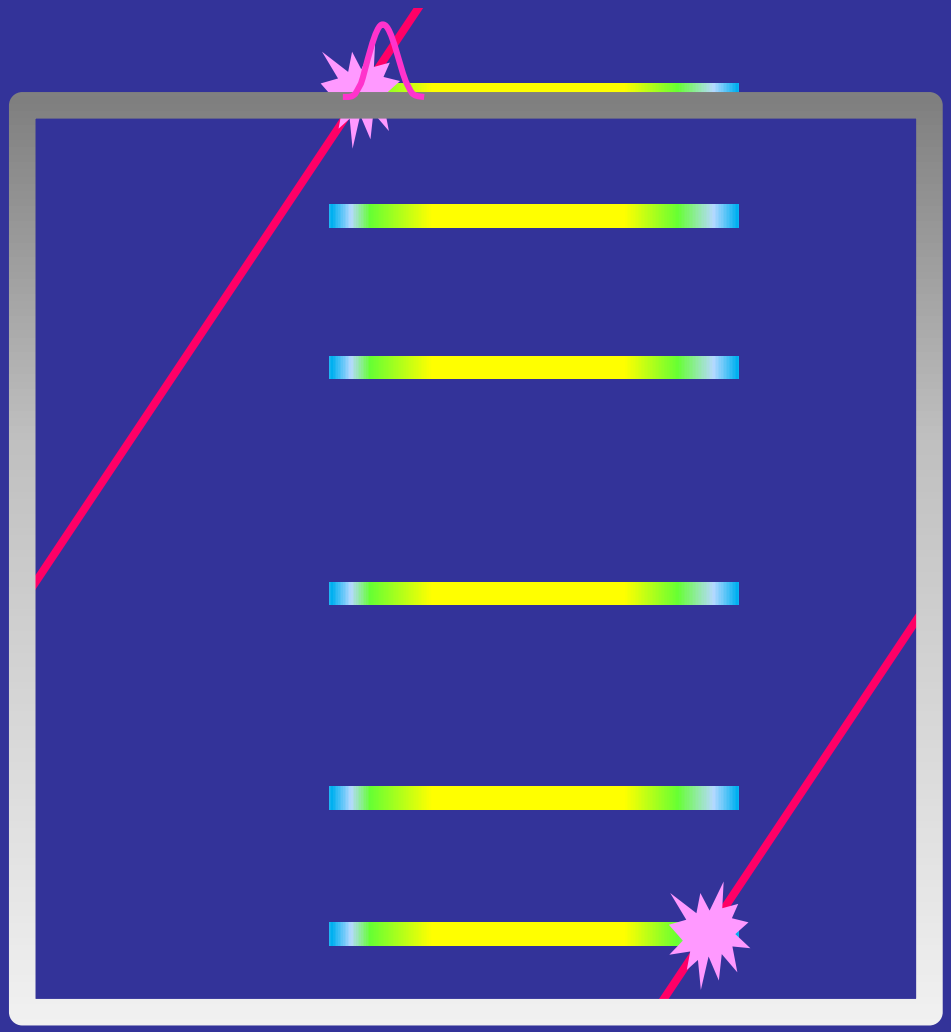


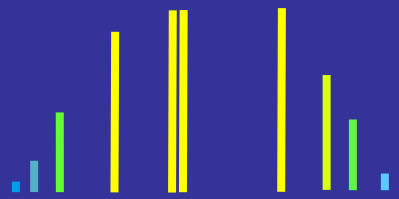


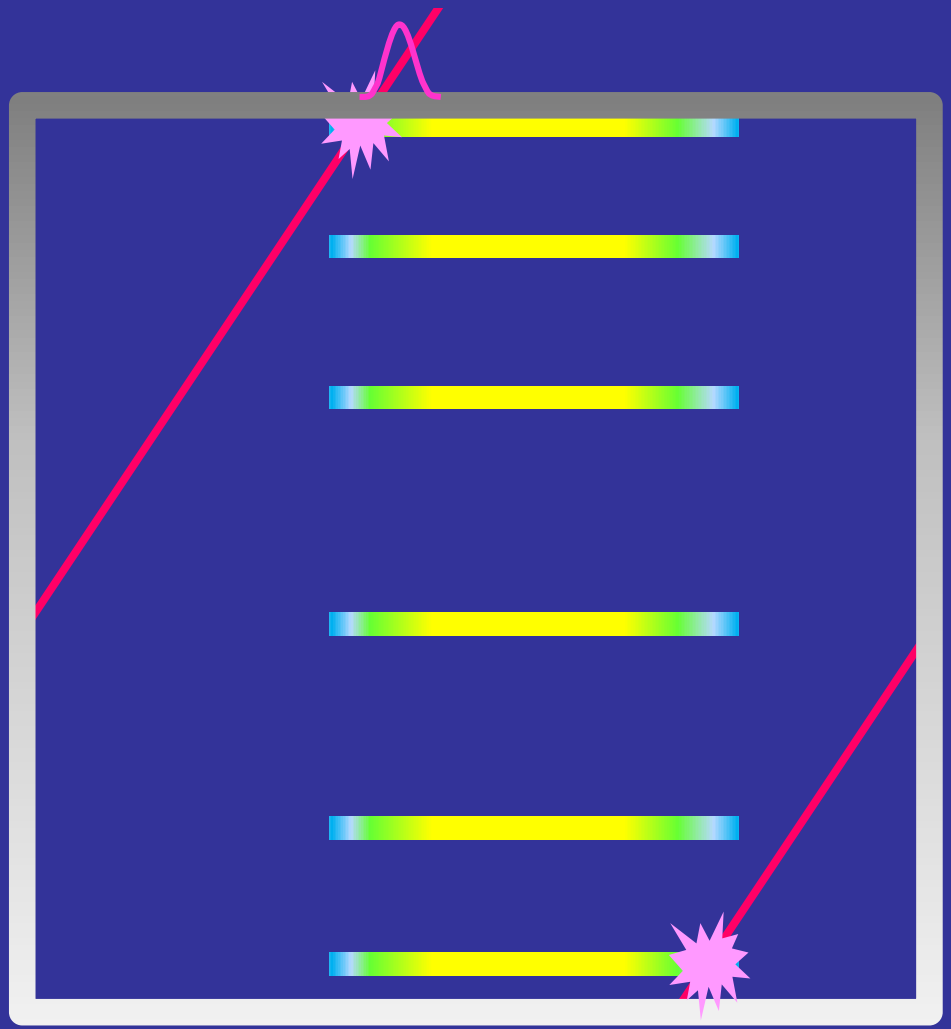


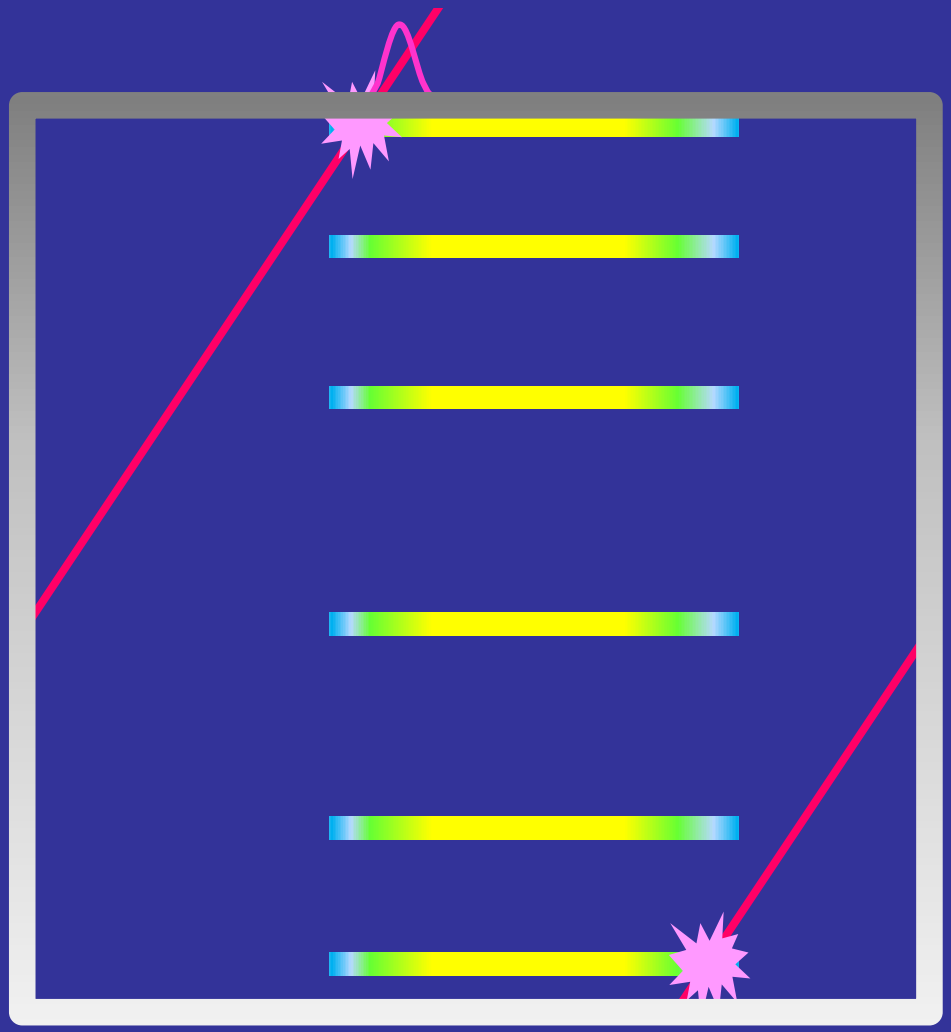


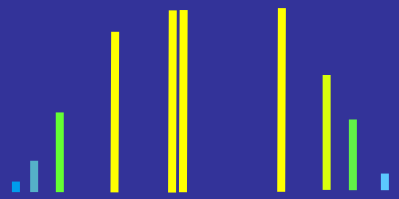


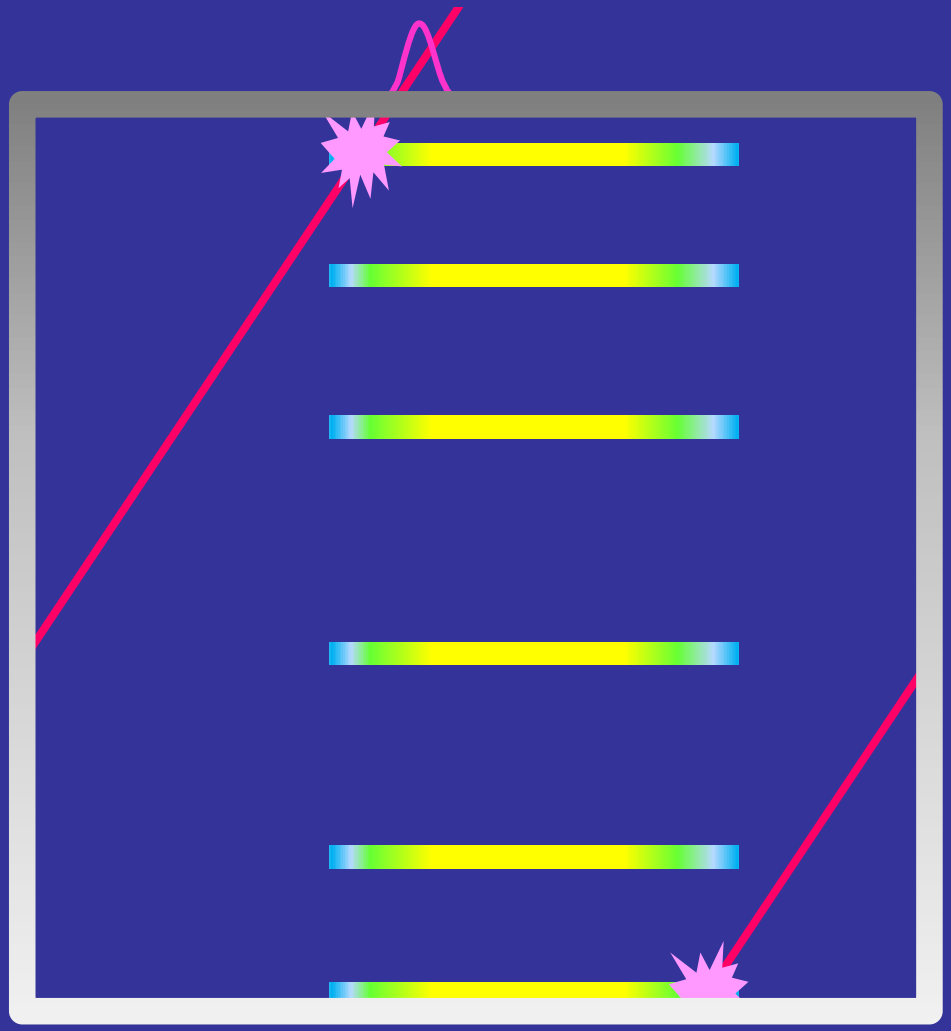


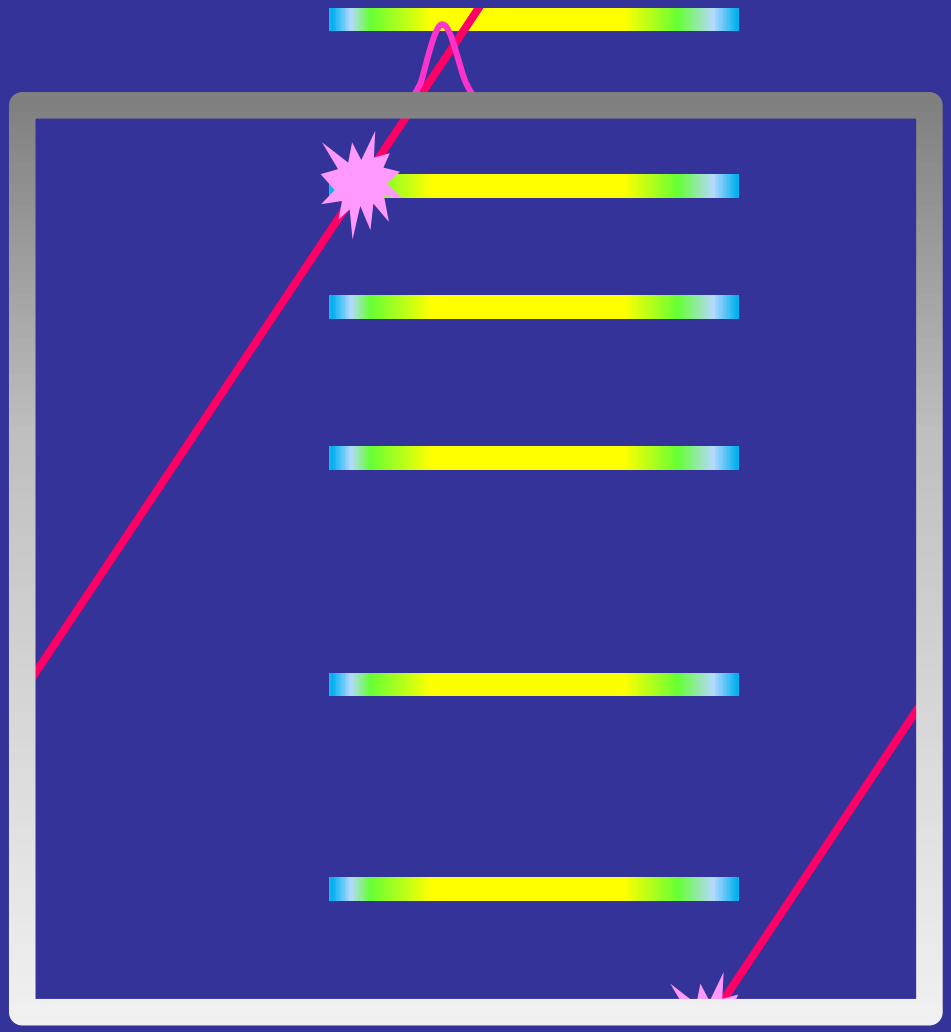


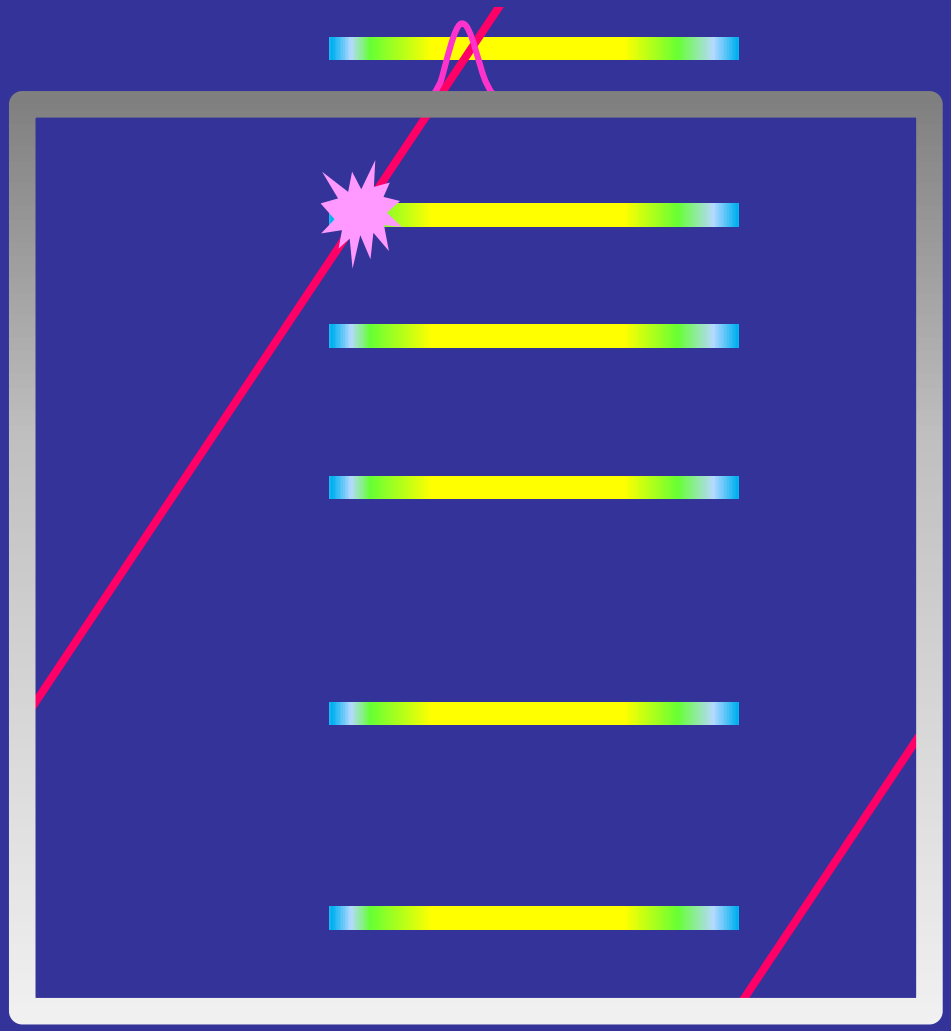


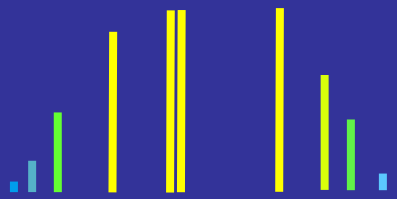


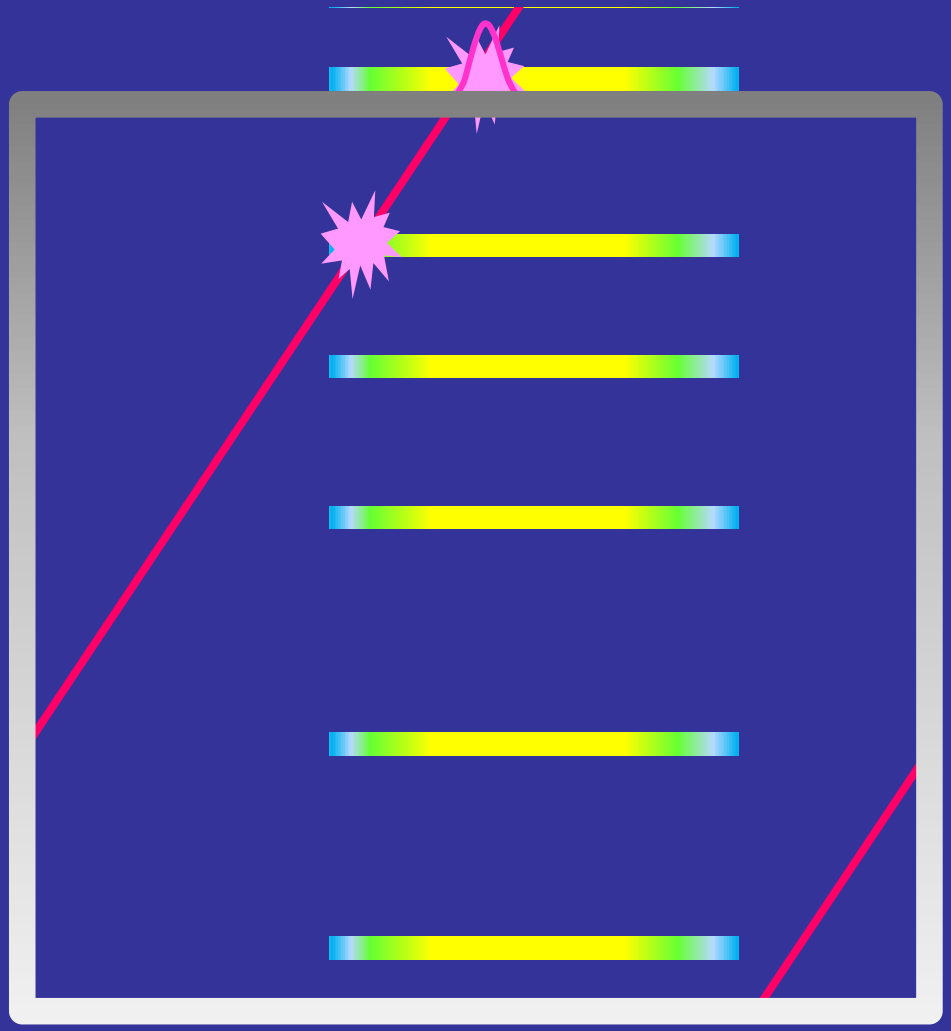


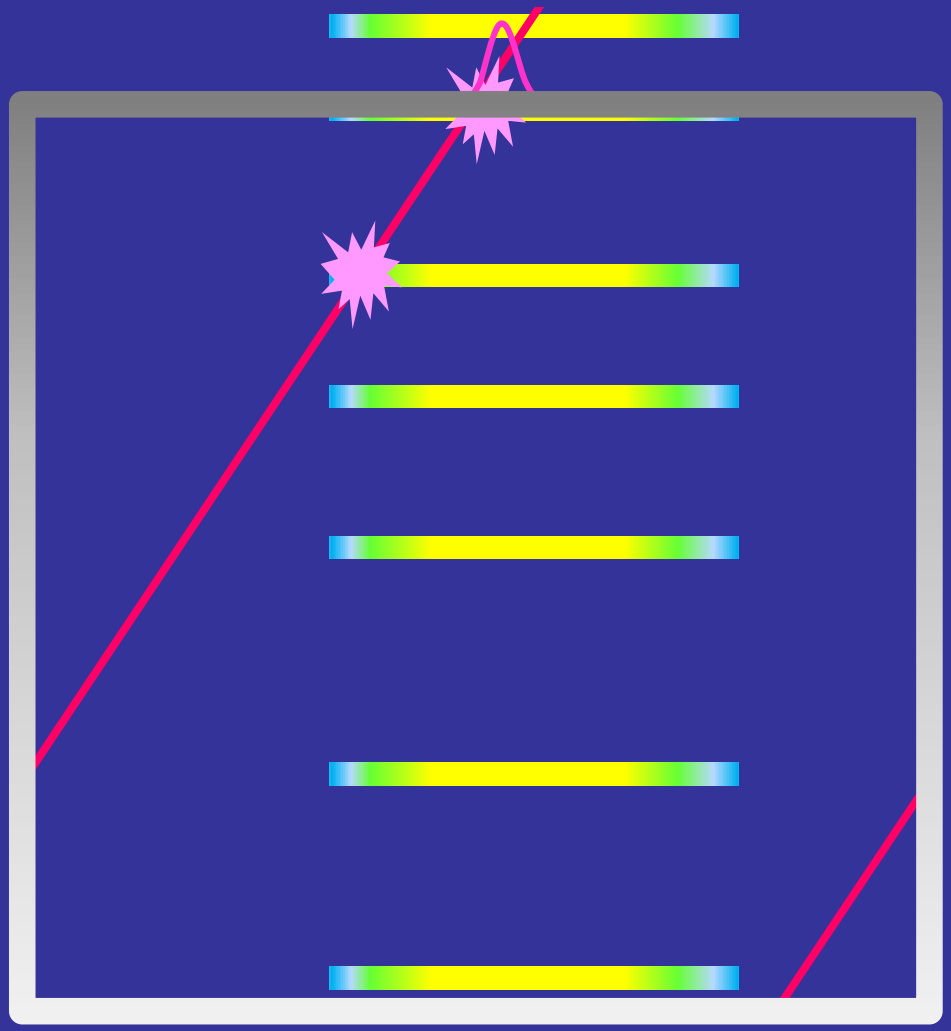


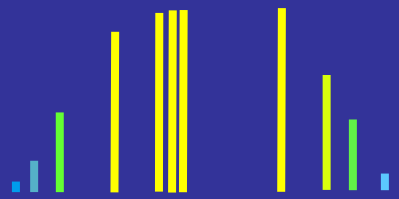


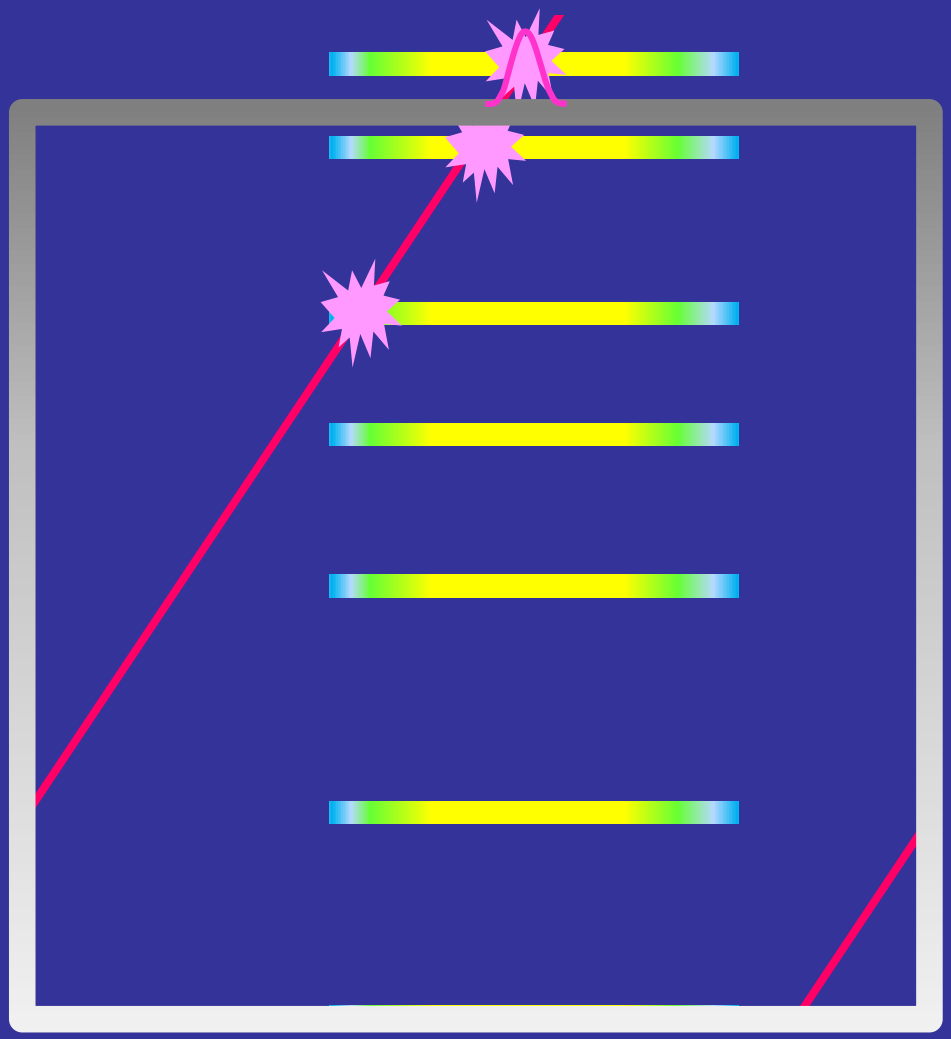


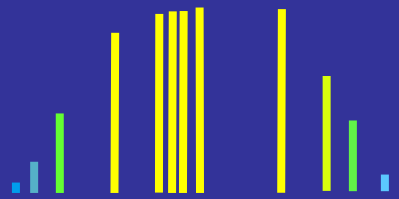


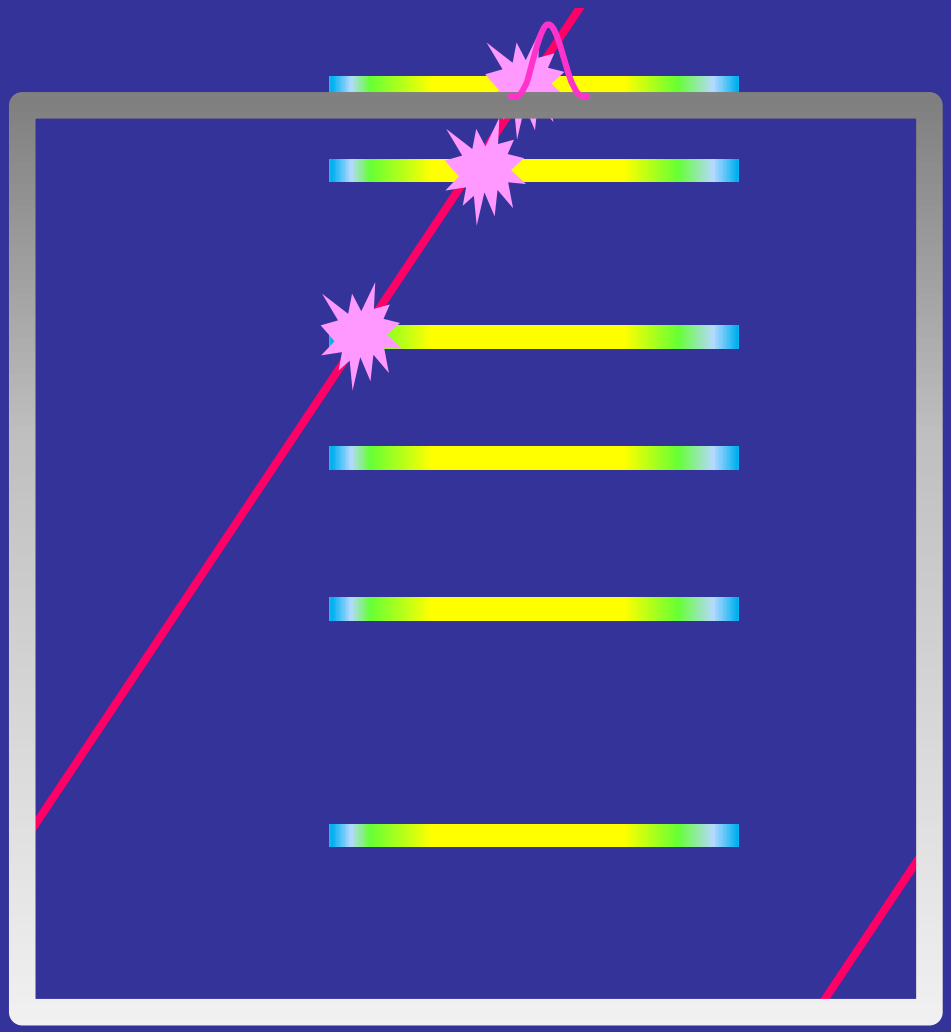


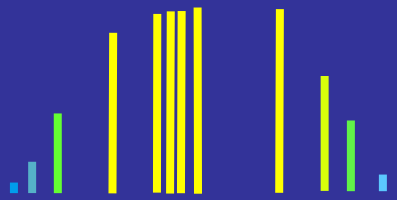


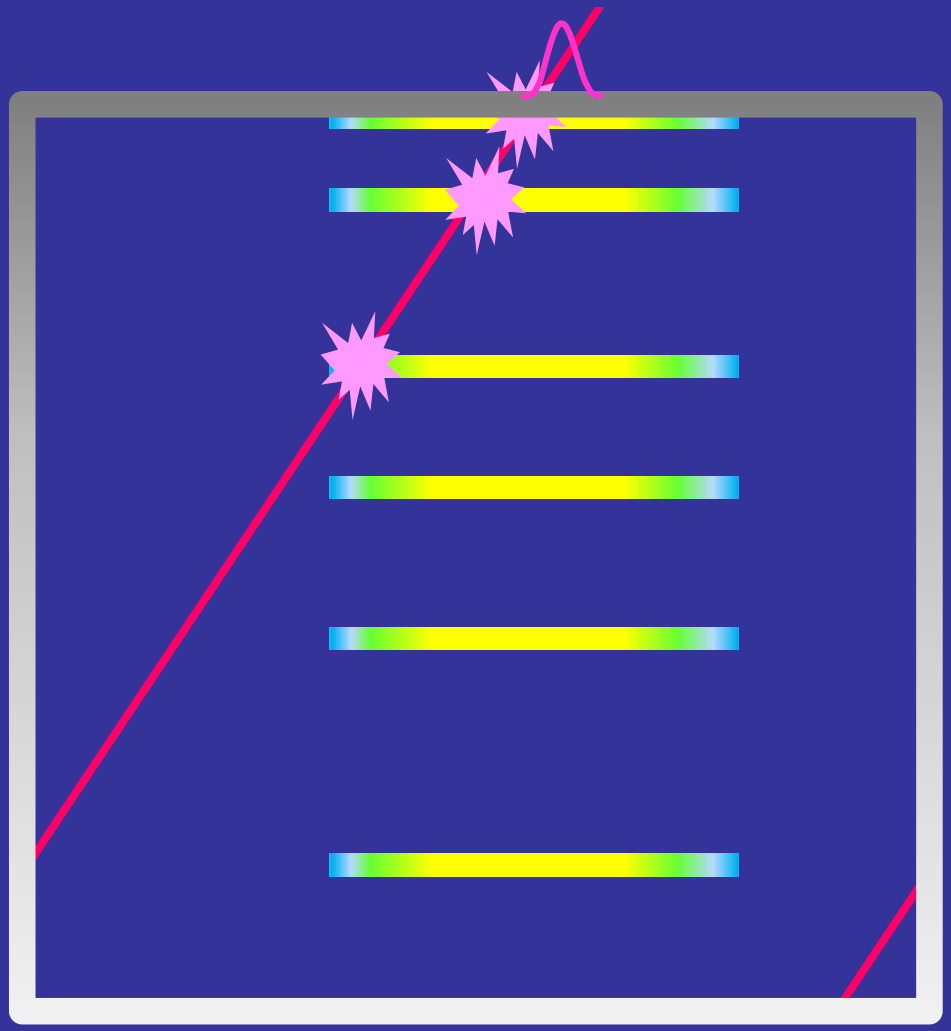


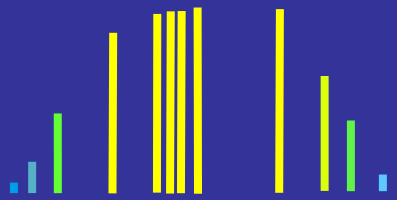


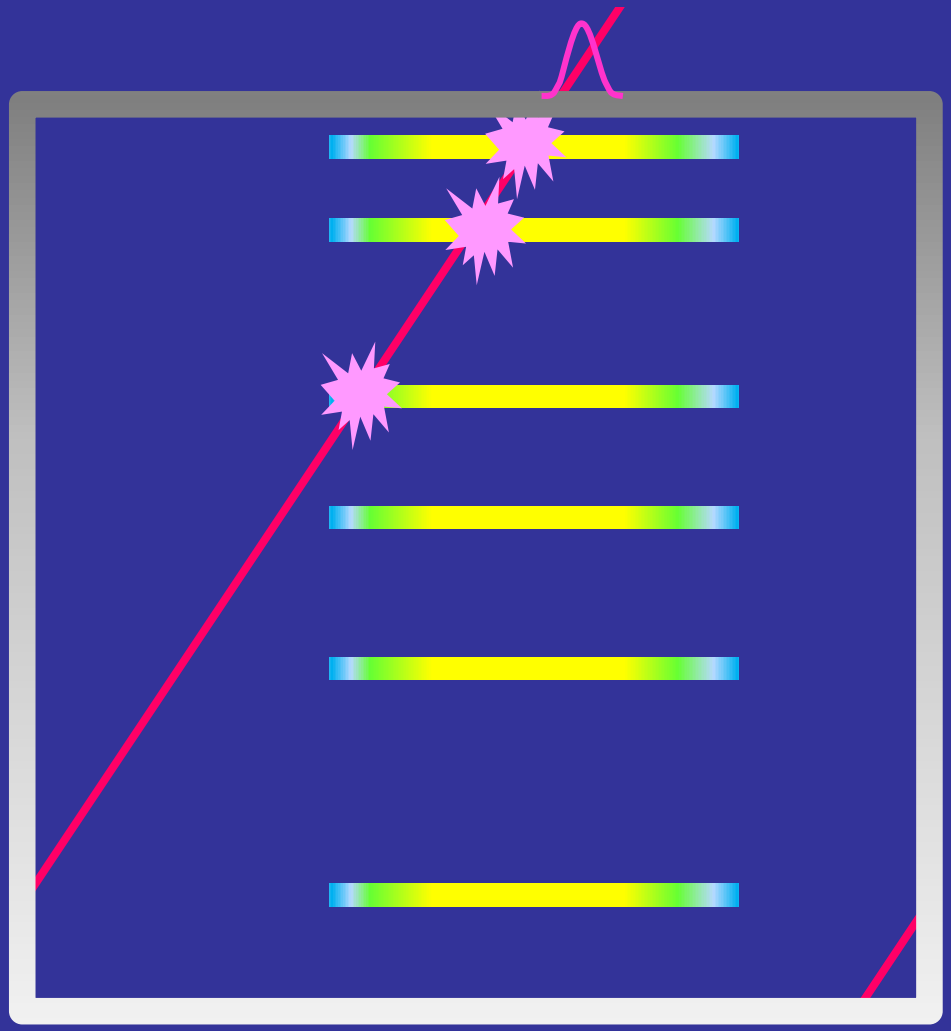


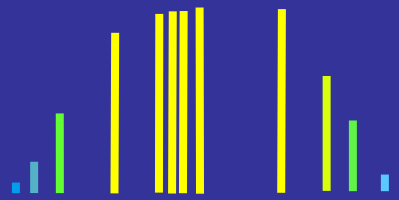


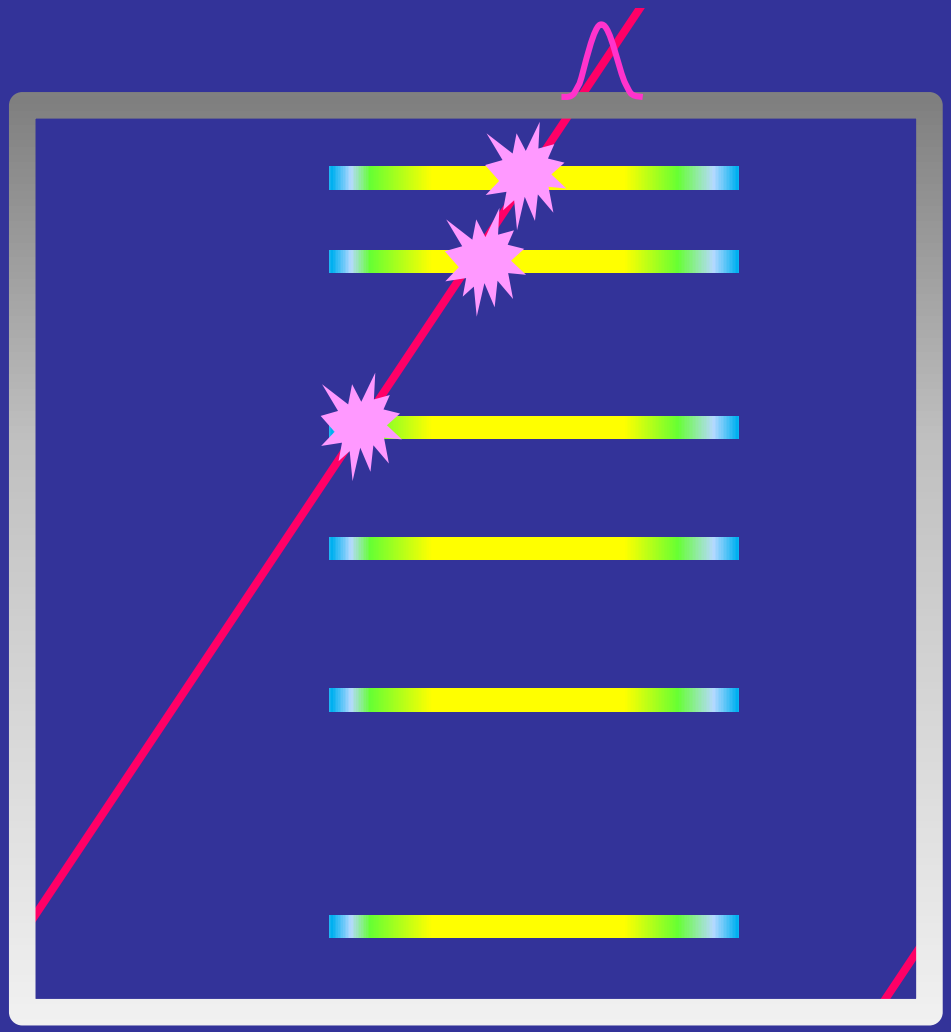


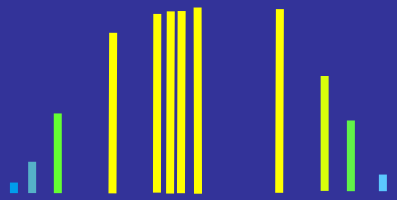


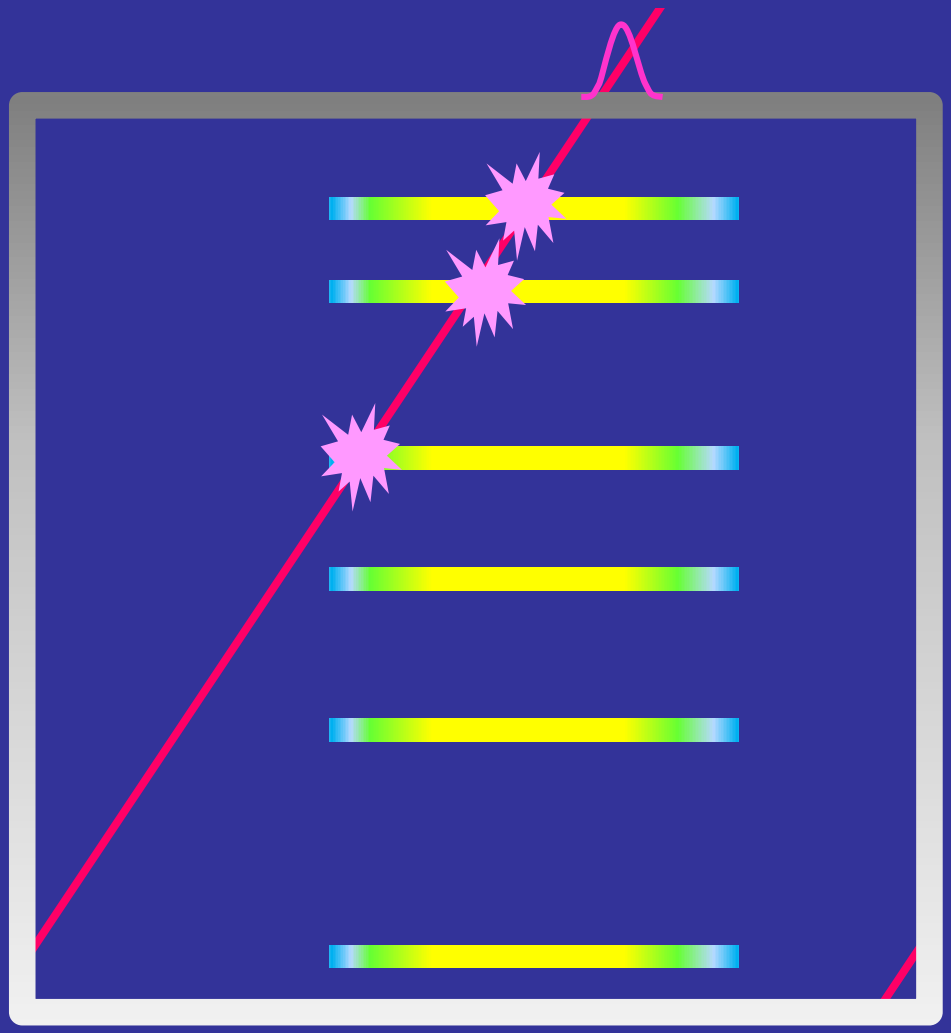


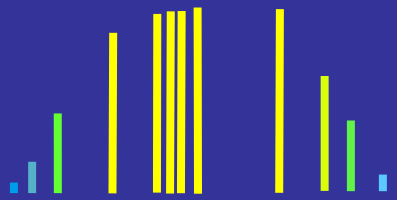


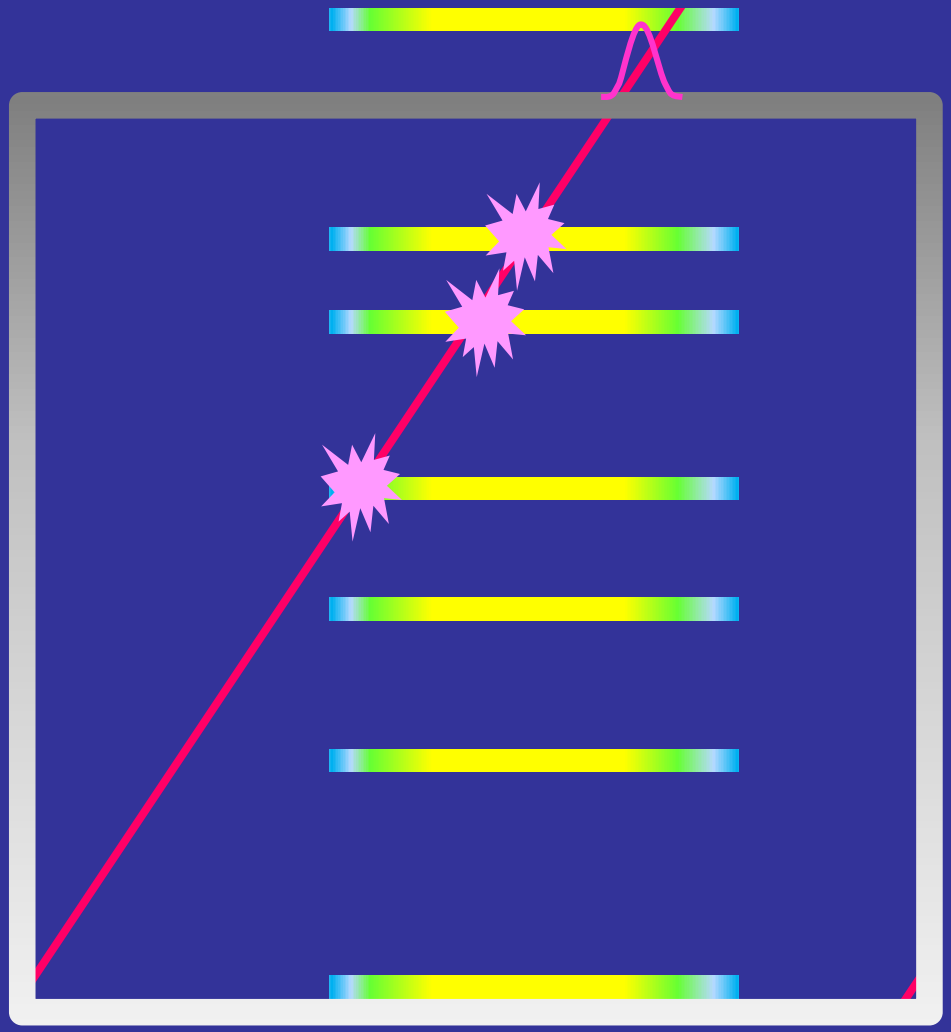


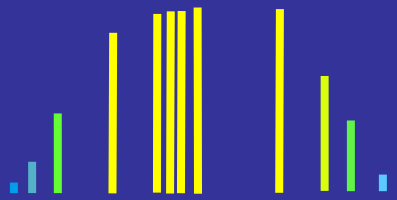


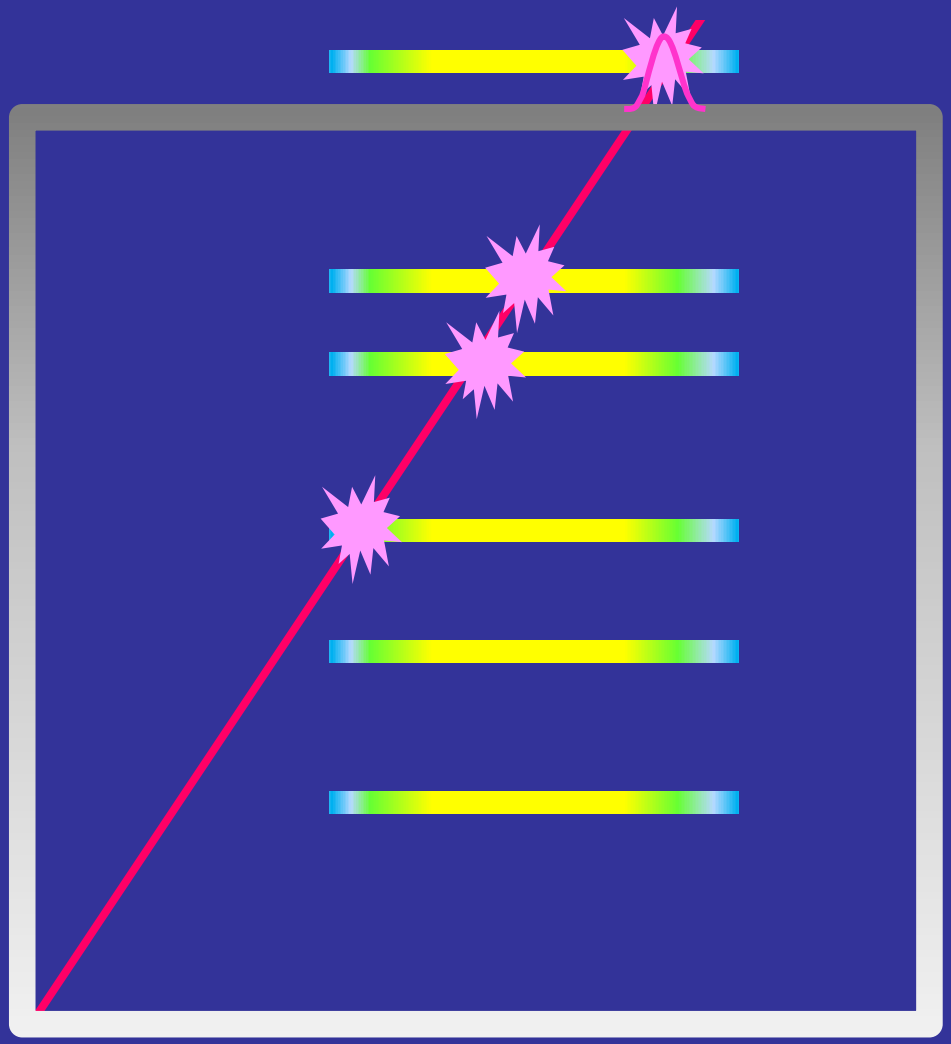


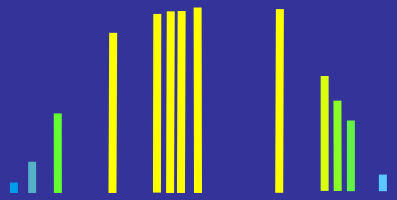


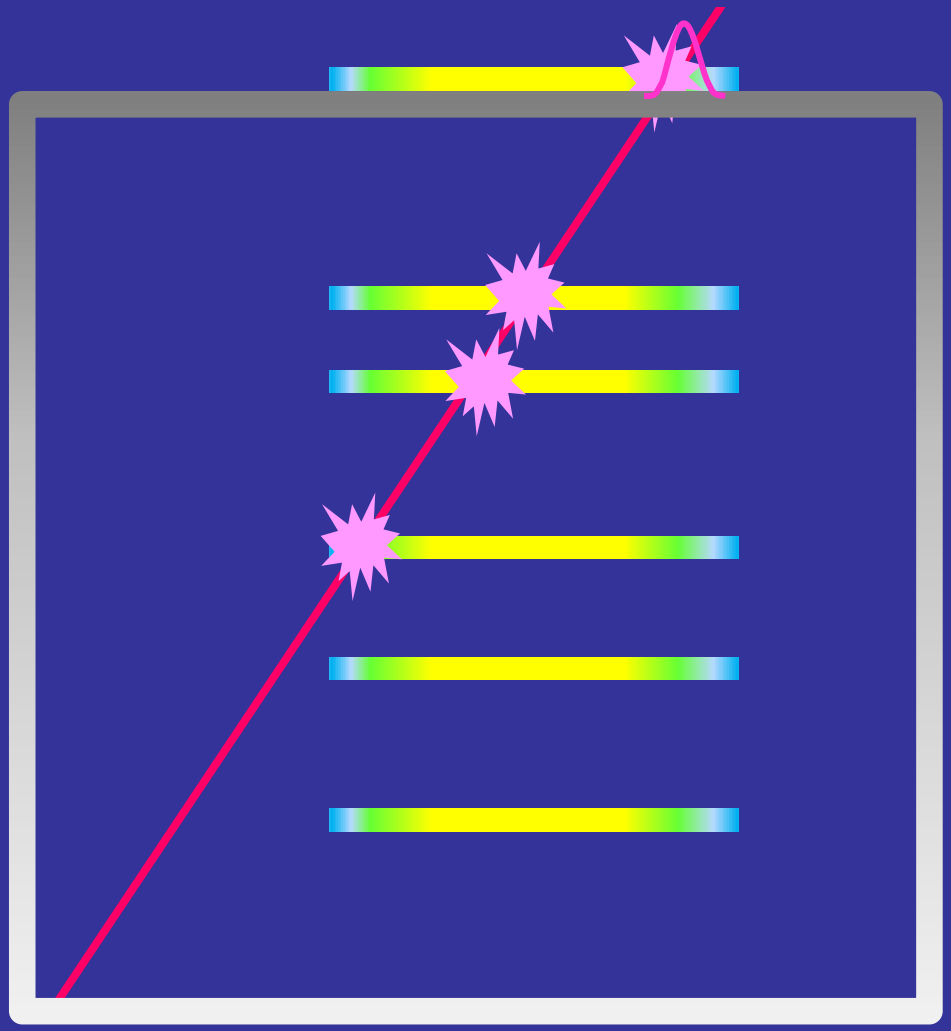


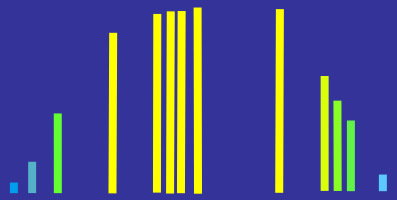


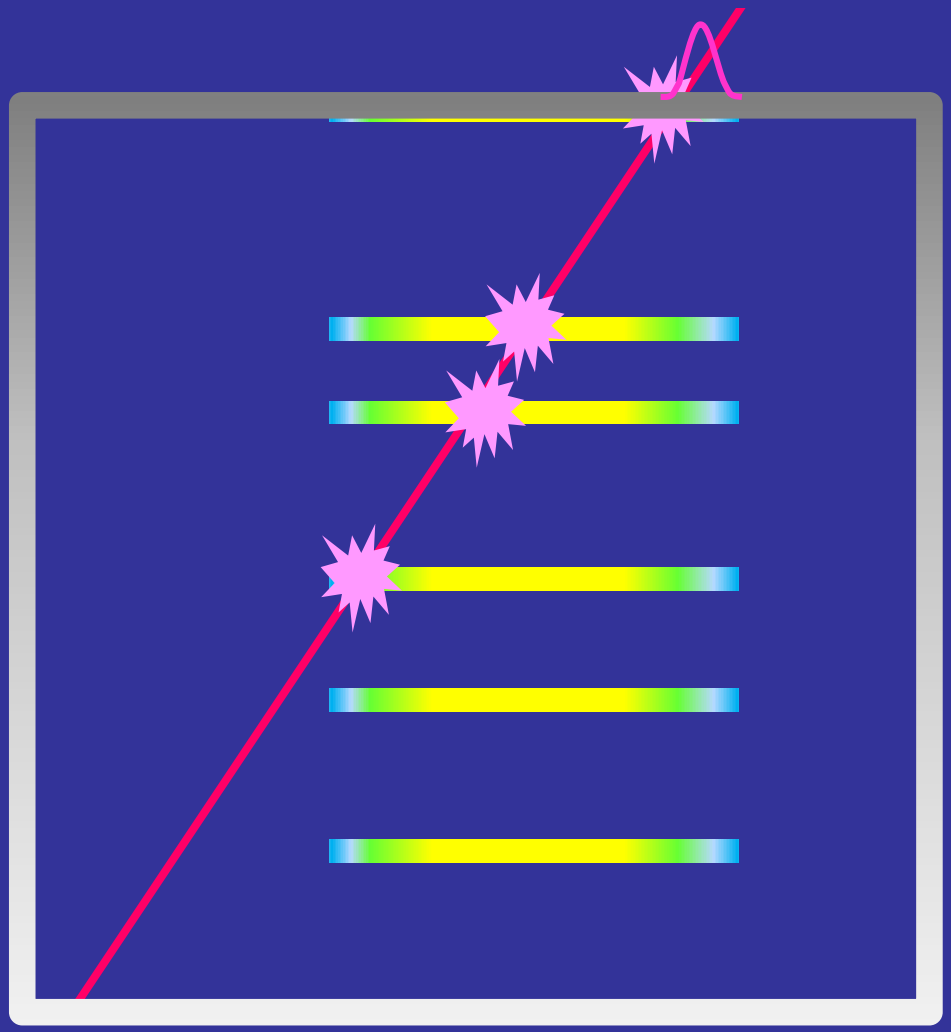


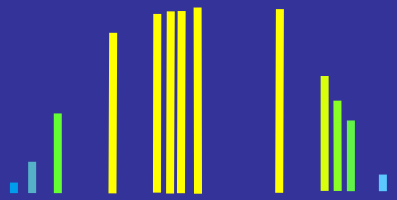


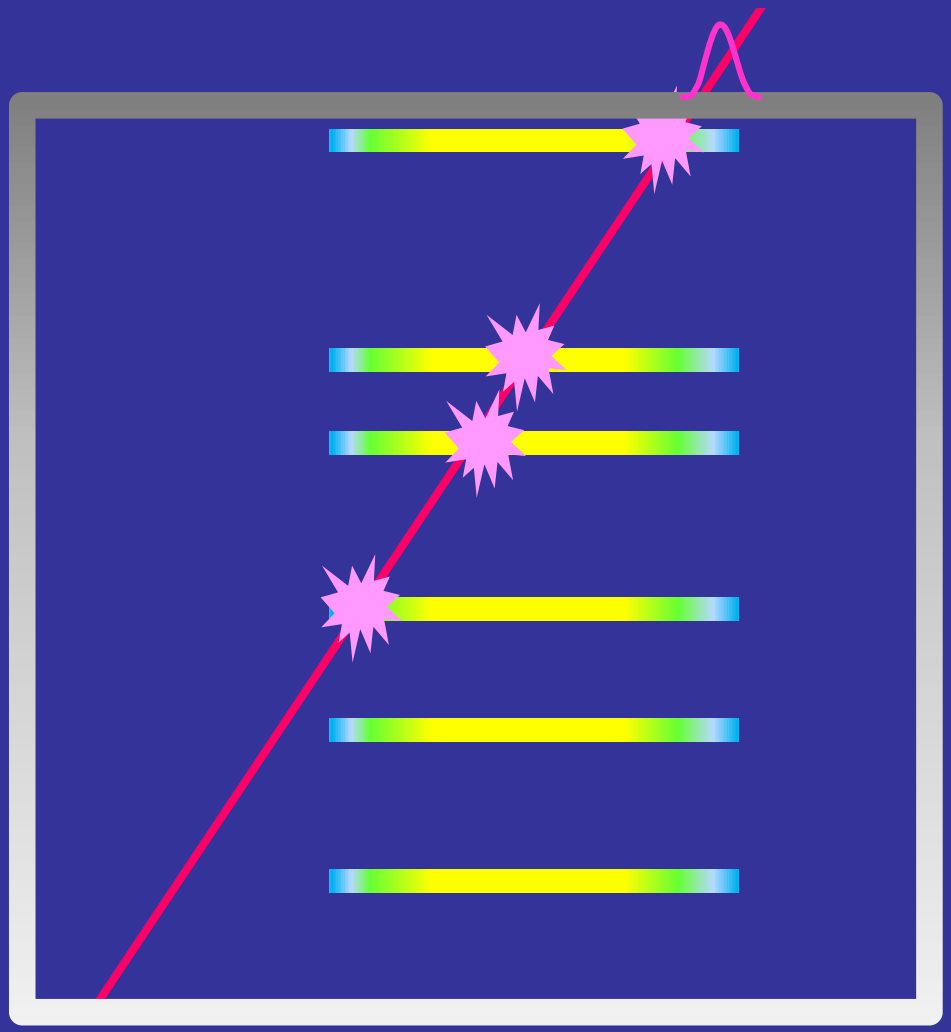


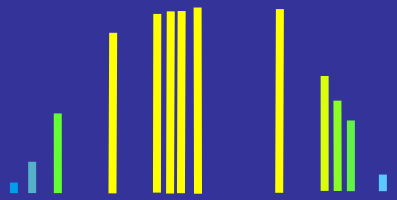


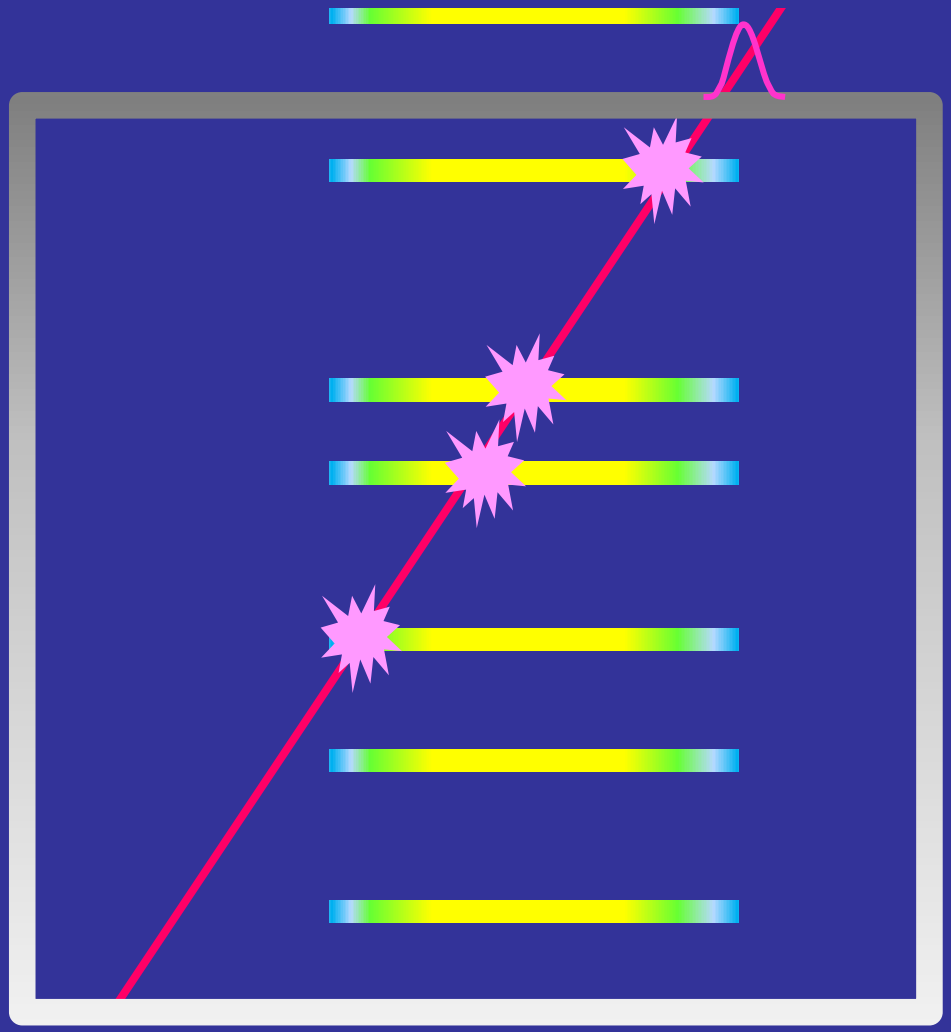


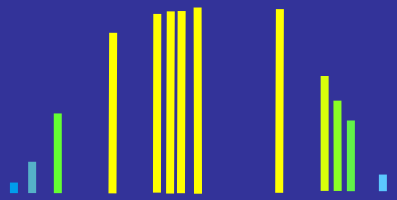


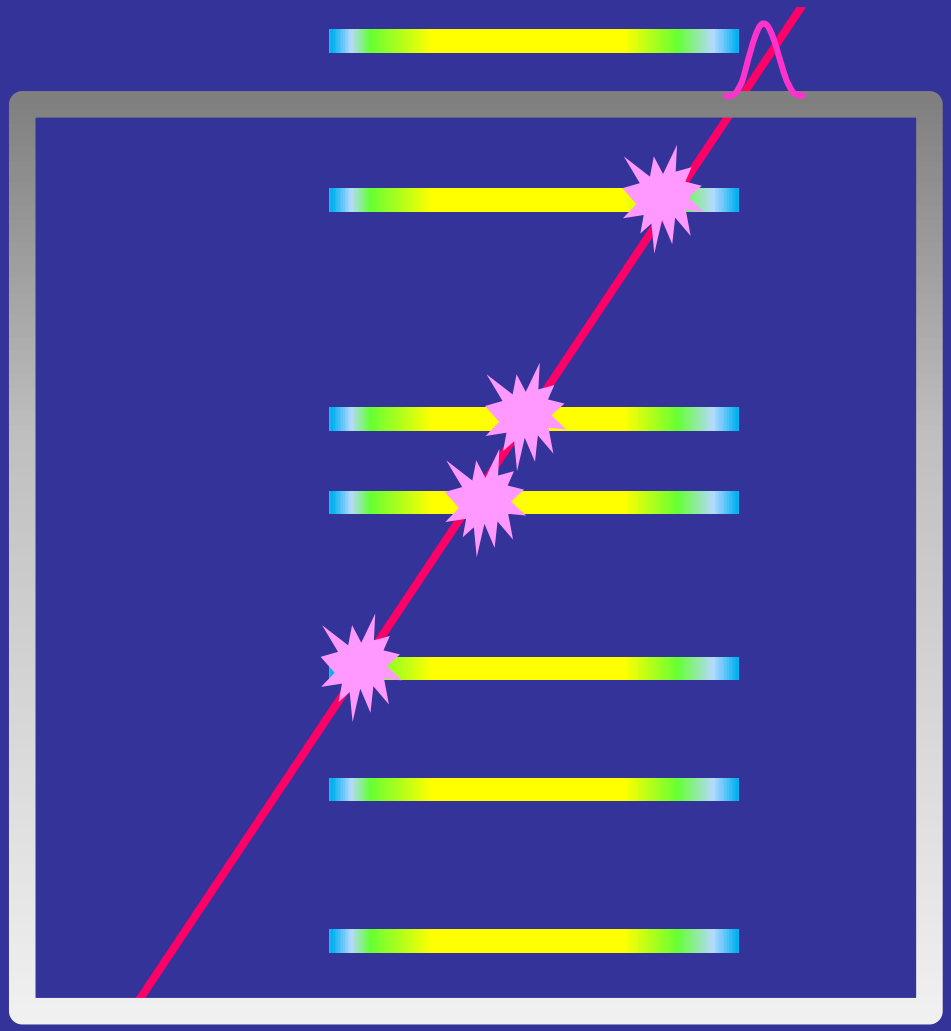


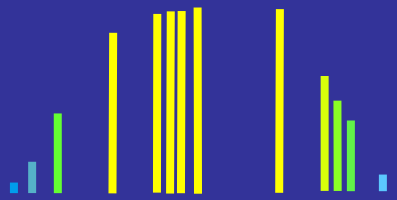


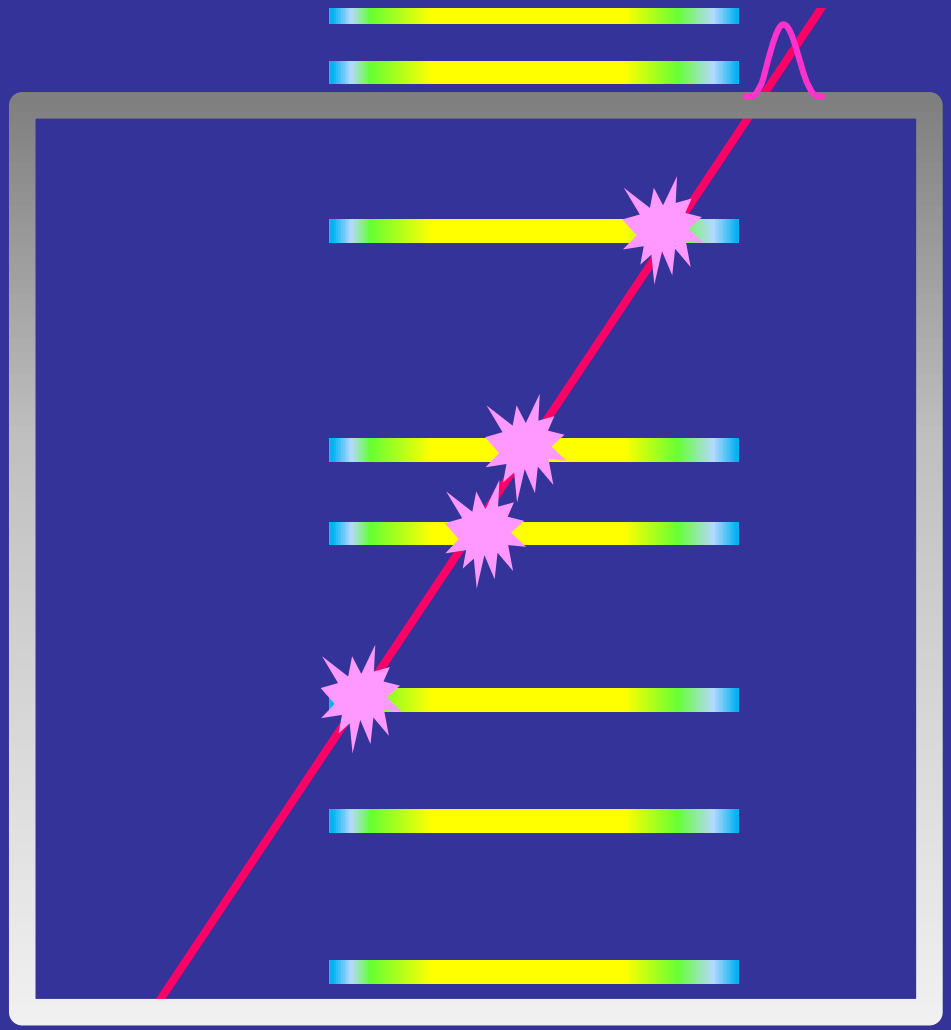


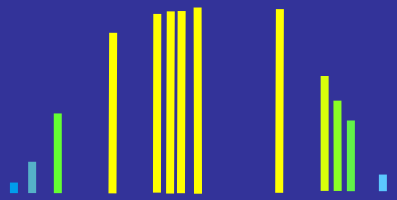


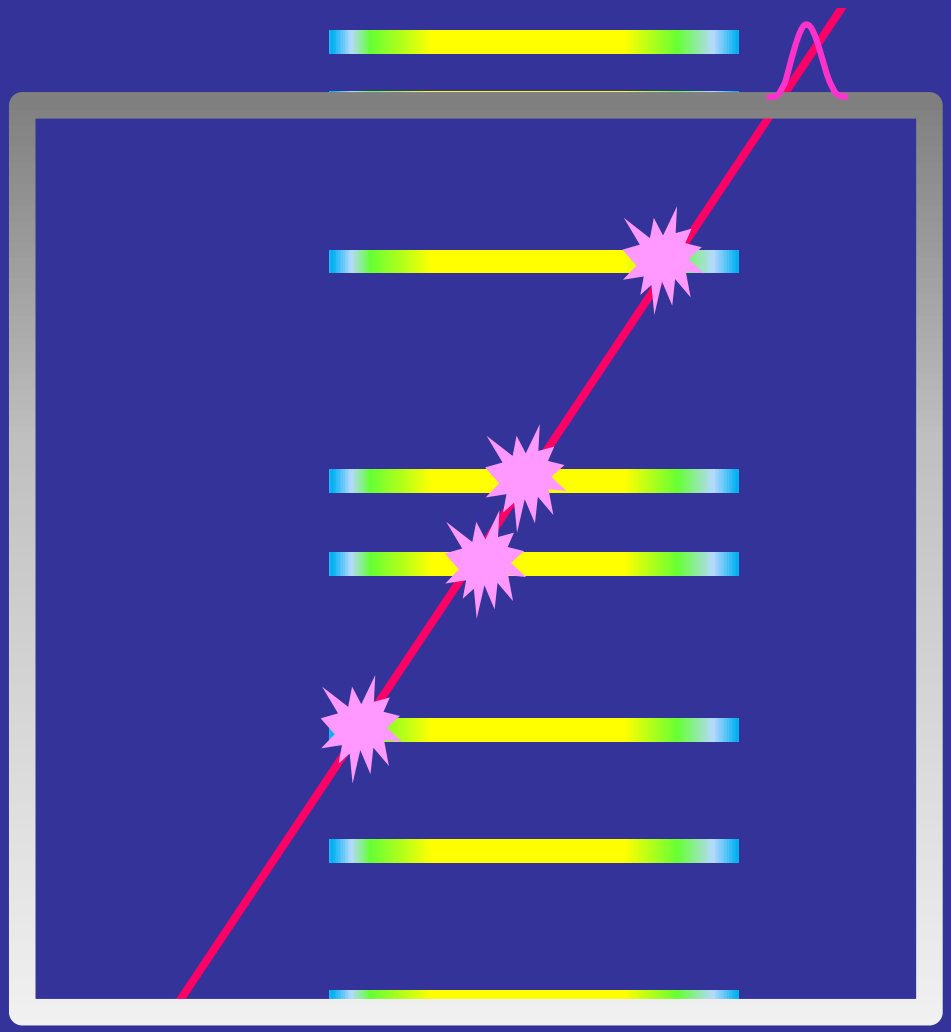


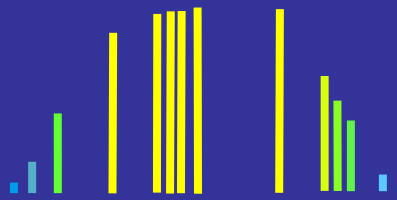


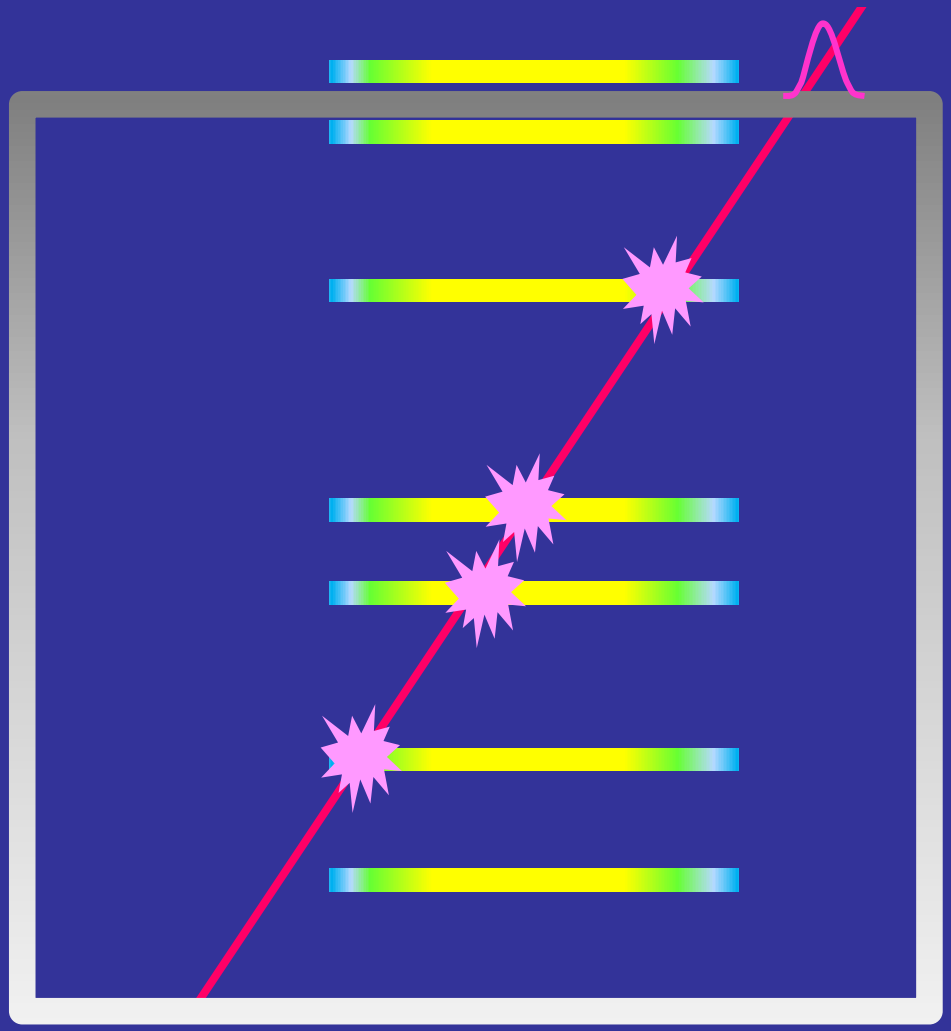


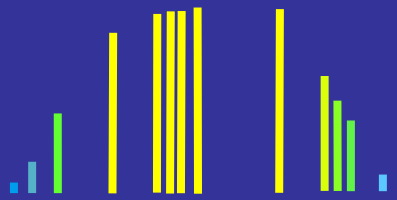


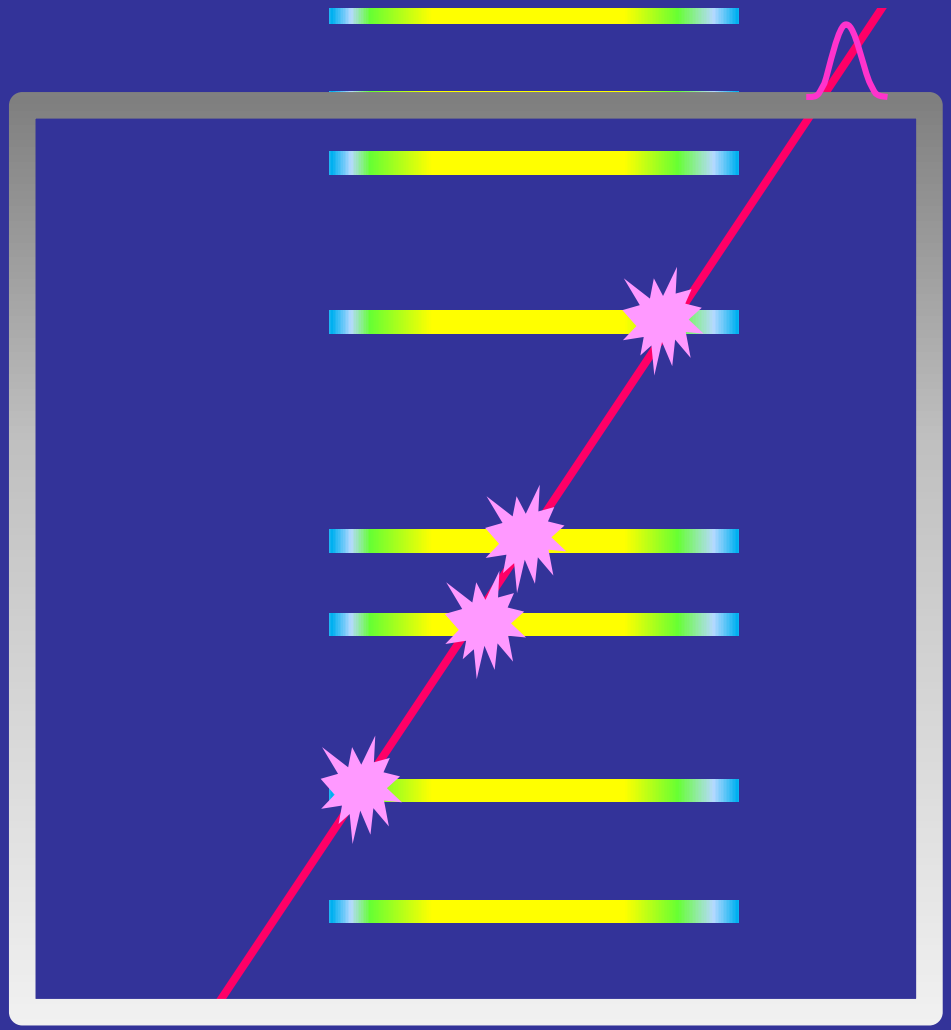


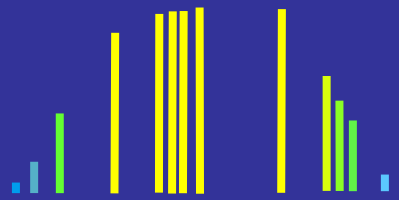


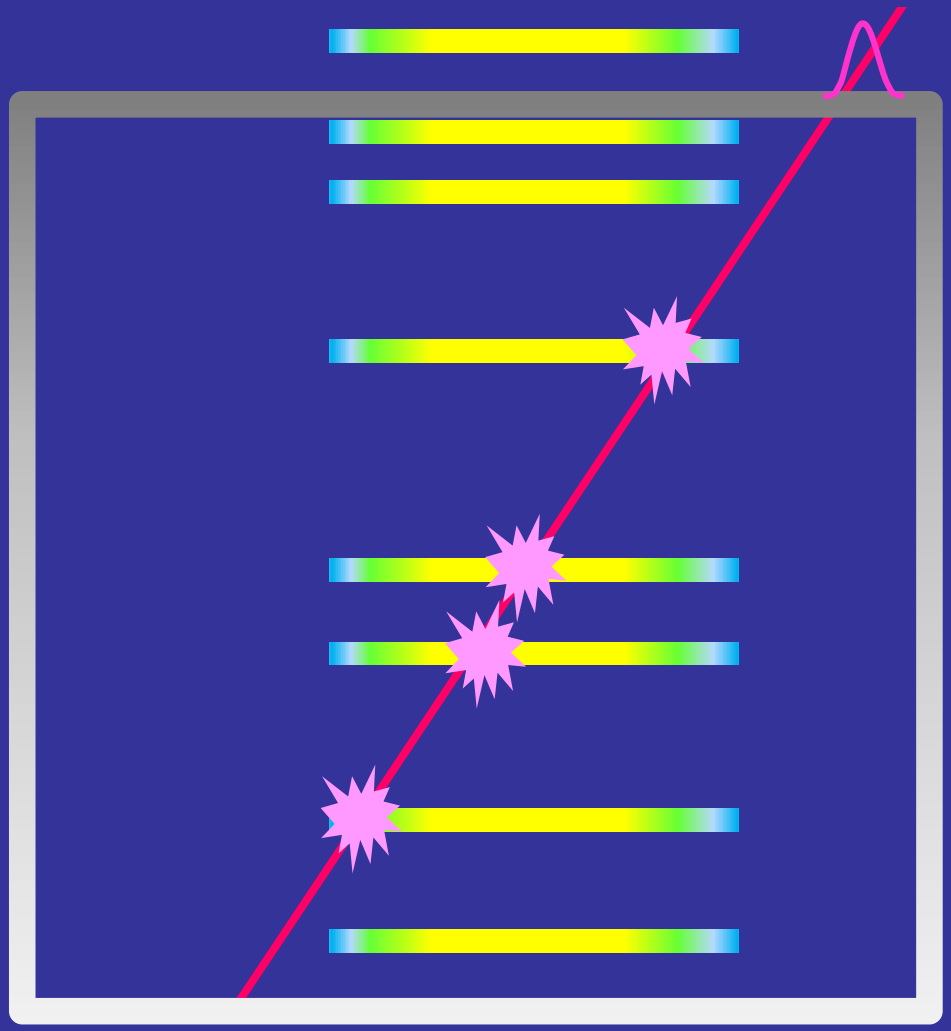


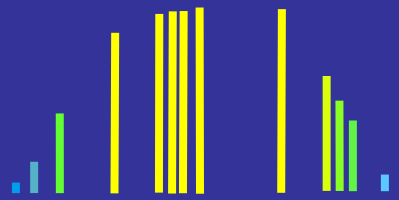


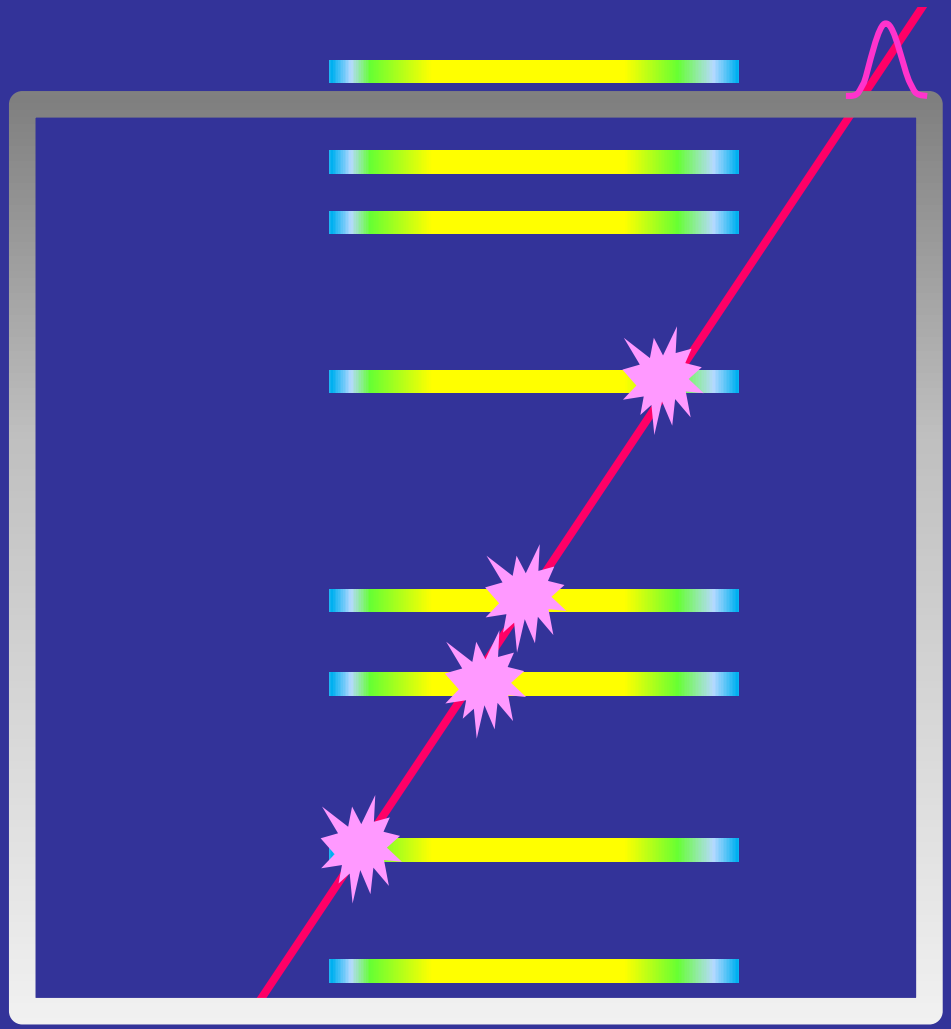


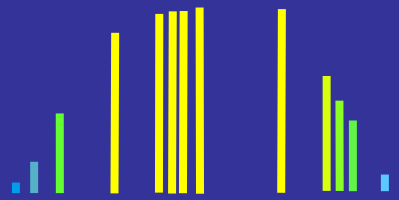


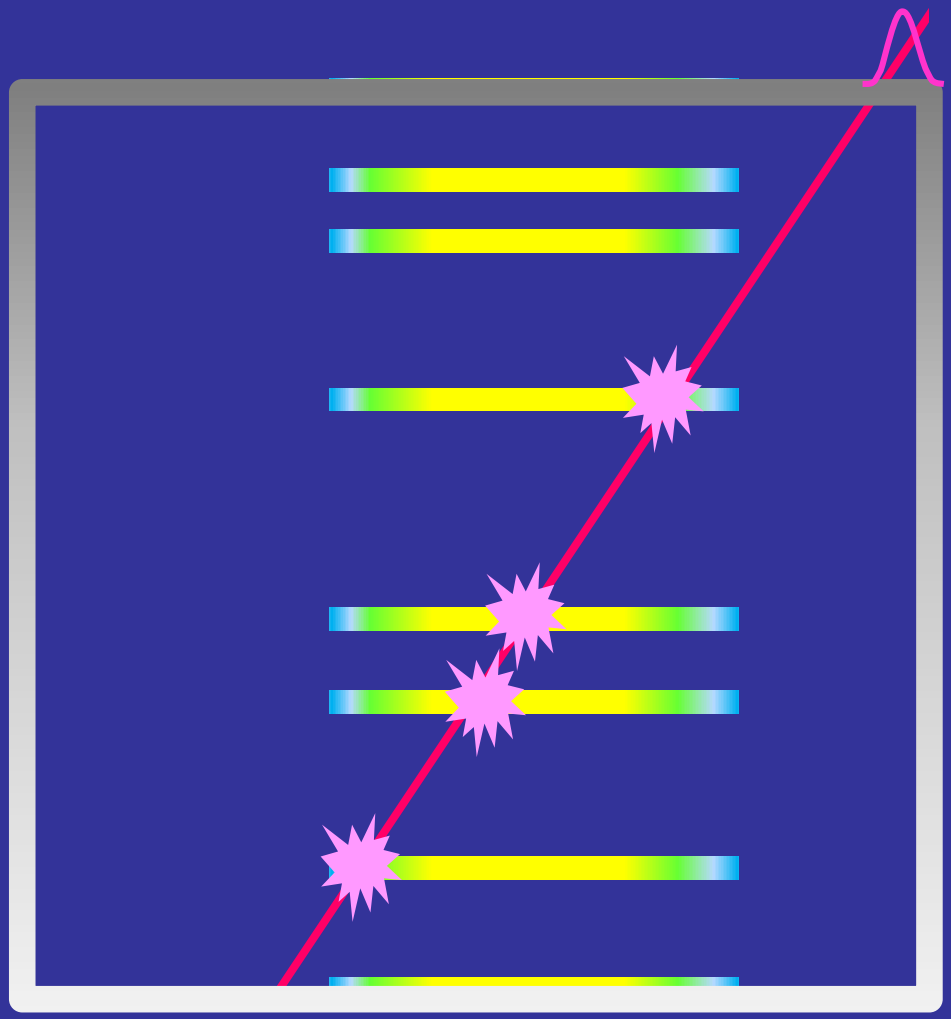


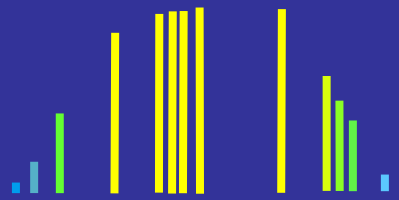


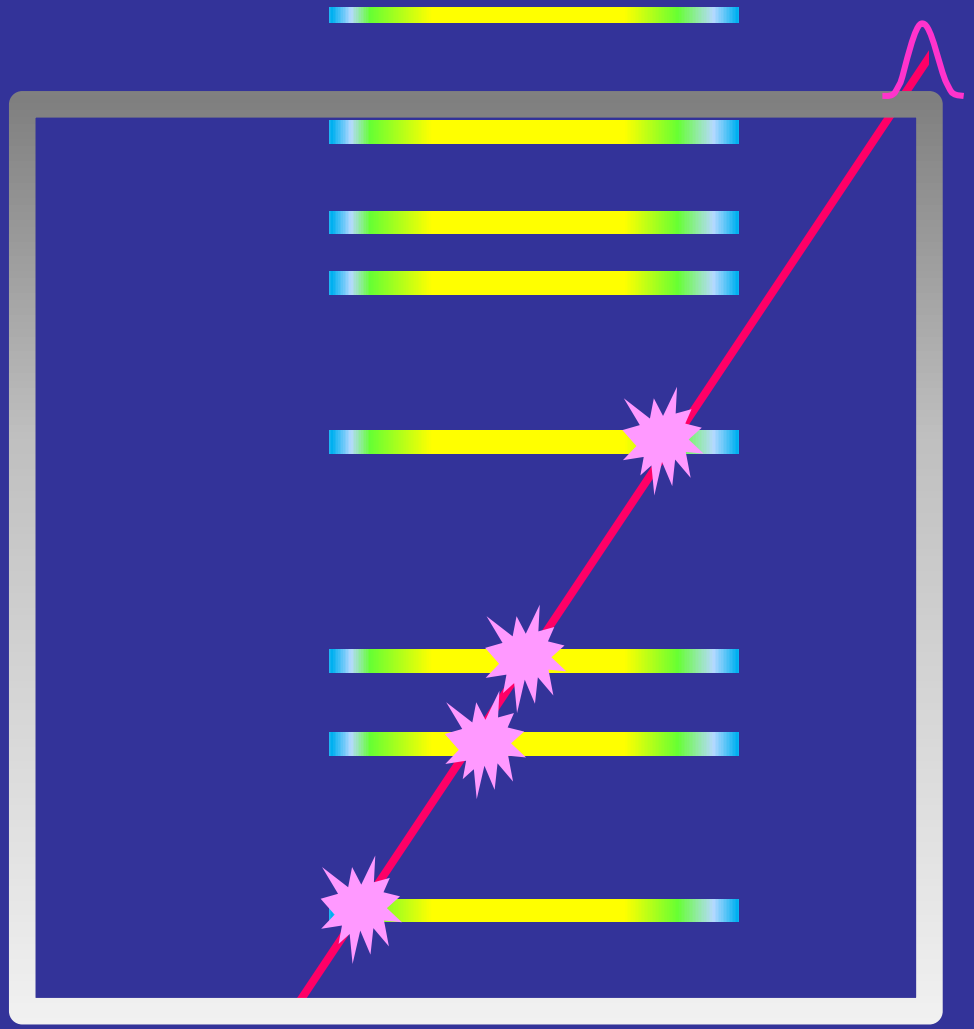


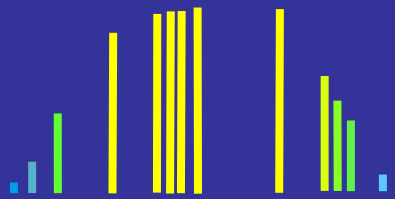


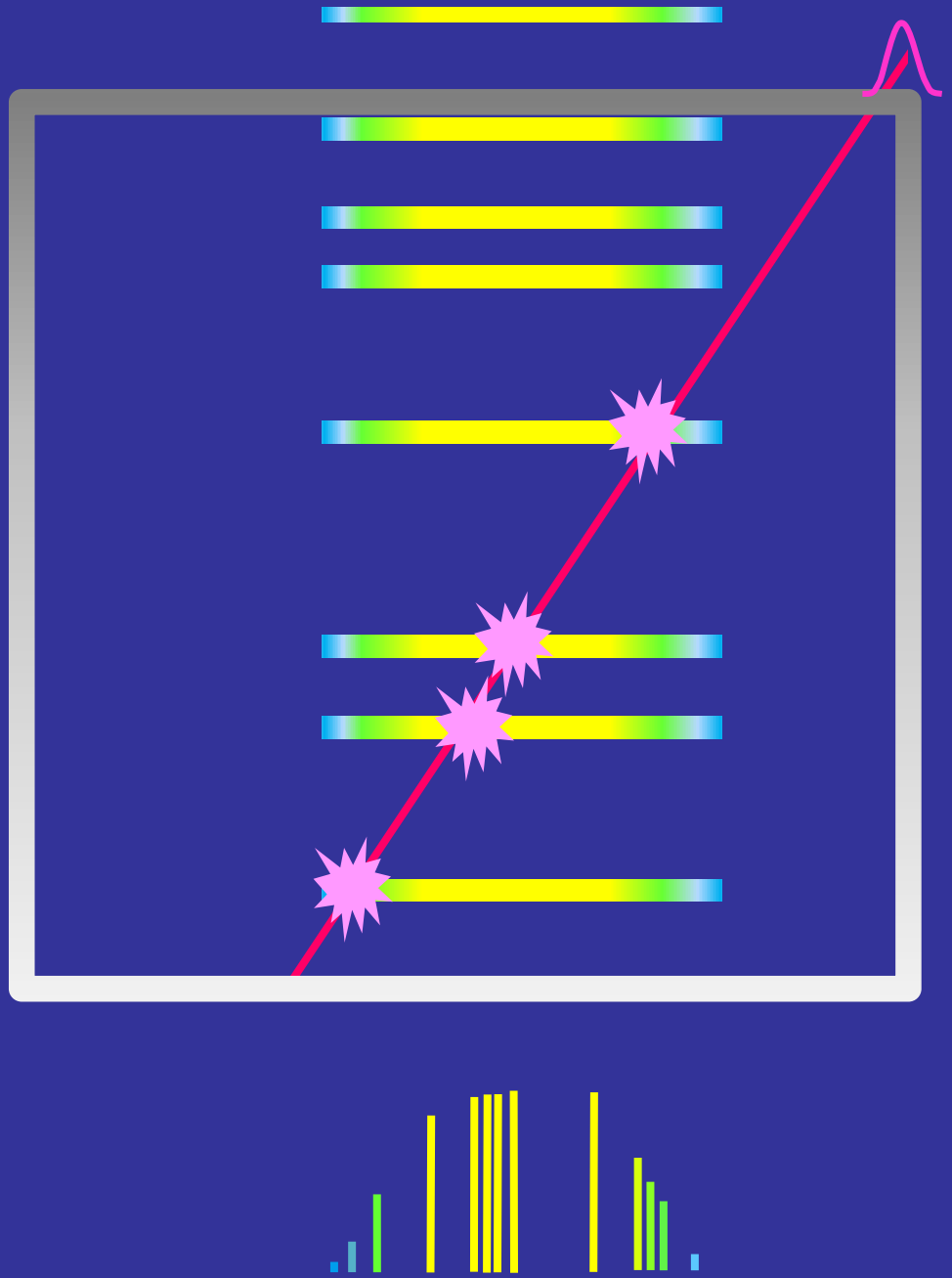








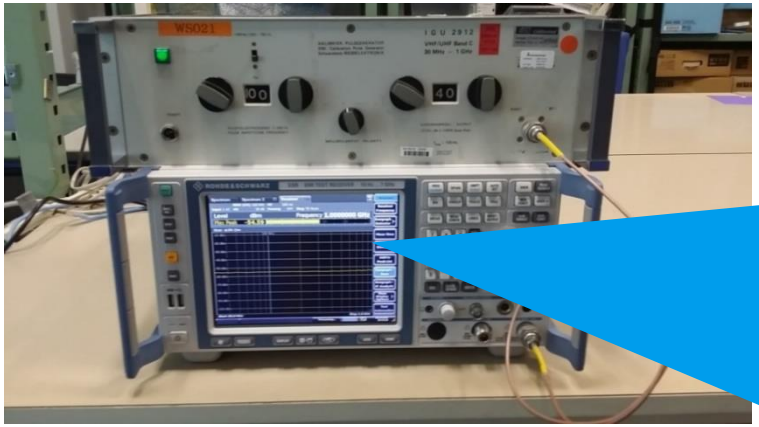




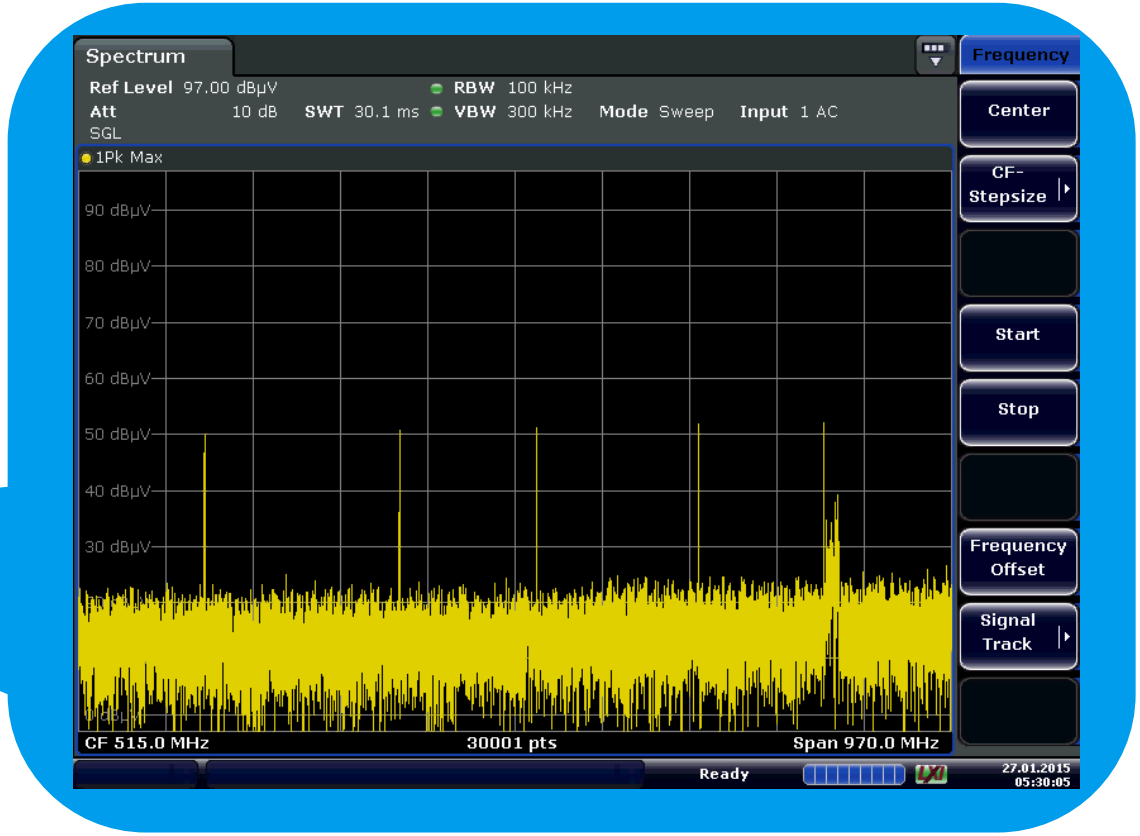
パルス性広帯域ノイズの特徴・測定の難しさ

スペクトラムアナライザ測定の難しさ

「高速スイープ」
スペクトラムアナライザで
のパルス測定



<1nsパルス(=1GHz幅)を、
10ms間隔(=100回/s)
にて出力



本来なら、「横線」のスペクトラムとして
観測されるはずが。。
スイープ時間 30ms の高速スイープスペアナでも
パルススペクトラム形状の把握に時間を要する。

パルス性広帯域ノイズの特徴・測定の難しさ

スペクトラムアナライザ測定の難しさ

- **ノイズの発生タイミングと掃引時間を考慮する必要がある**
  - **ノイズの発生タイミングについて**
    1秒間に100回発生するノイズ ＝ 10m秒おきに発生する
  - **発生タイミングを考慮した掃引時間**
    ポイント数　×　発生タイミング ＝ 考慮された掃引時間

スペクトラムアナライザの設定をノイズに合わせる

「低速スイープ」

スイープポイント：　30,001ポイント

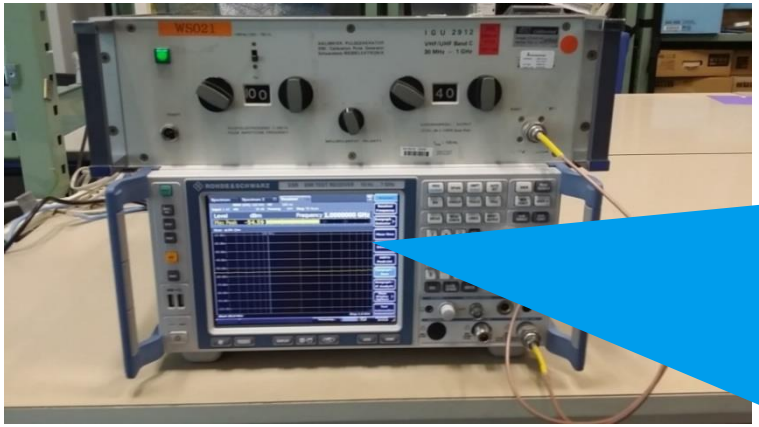
ノイズの発生タイミング：　10m秒おきに発生

スイープ時間 ＝ 30,001 × 10m秒 ＝ 300.01秒

パルス性広帯域ノイズの特徴・測定の難しさ

スペクトラムアナライザ測定の難しさ

「低速スイープ」
スペクトラムアナライザで
のパルス測定



<1nsパルス(=1GHz幅)を、
10ms間隔(=100回/s)
にて出力

一つのスイープポイント毎に
パルスの発生間隔以上「滞留」する事で
時間をかけてパルススペクトラム形状を把握

本日の内容

- パルス性広帯域ノイズの特徴・測定の難しさ

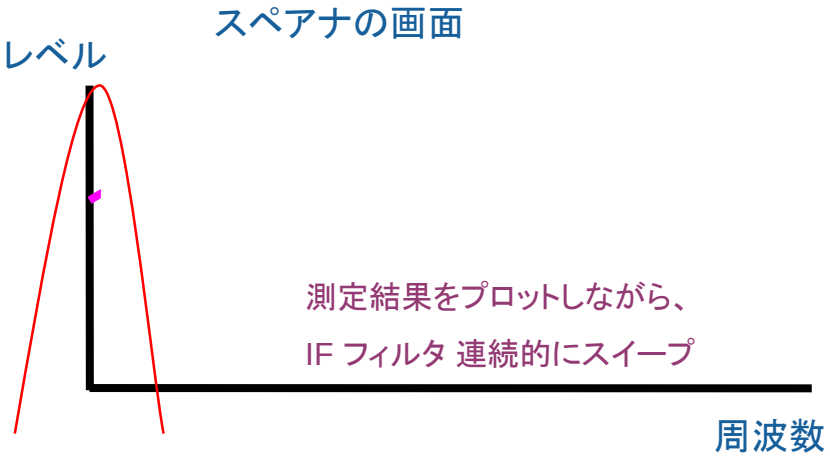
- パルス性広帯域ノイズ測定のために
  - FFTを活用した「タイムドメインスキャン」
  - 「タイムドメインスキャン」を生かすダイナミックレンジの重要性

パルス性広帯域ノイズ測定のために

FFTを活用した「タイムドメインスキャン」

スペクトラムアナライザのスイープ

通常、スペクトラムアナライザは、RBWの幅で
画面の左（周波数低）→右（周波数高）へ測定結果を描いていきます。



パルス性広帯域ノイズ測定のために

FFTを活用した「タイムドメインスキャン」

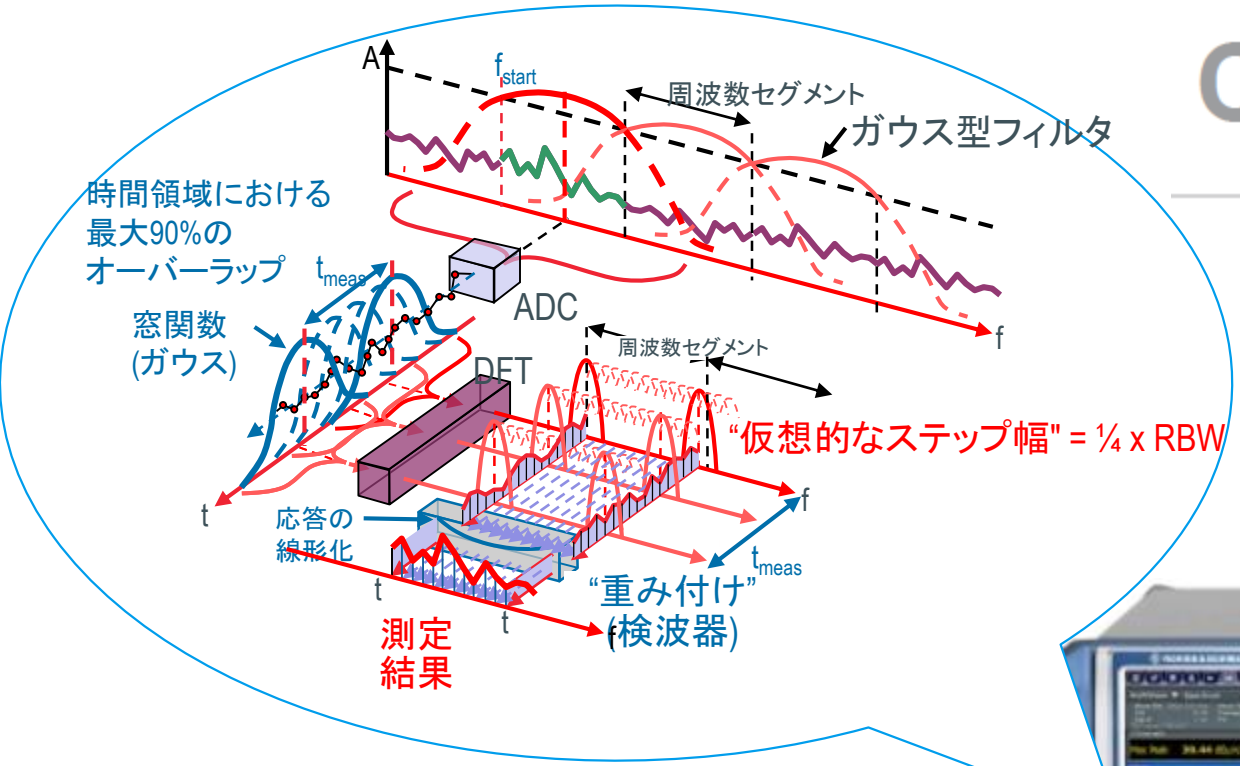
パルスノイズを、取りこぼし無くかつ高速に測定するには？

同時に測定できる幅が広ければ、
広い幅で滞留測定が可能 → 全体の測定時間の短縮

その後、従来のスペアナ・レシーバのRBWへの分割を行なう。（要相関）

パルス性広帯域ノイズ測定のために

FFTを活用した「タイムドメインスキャン」

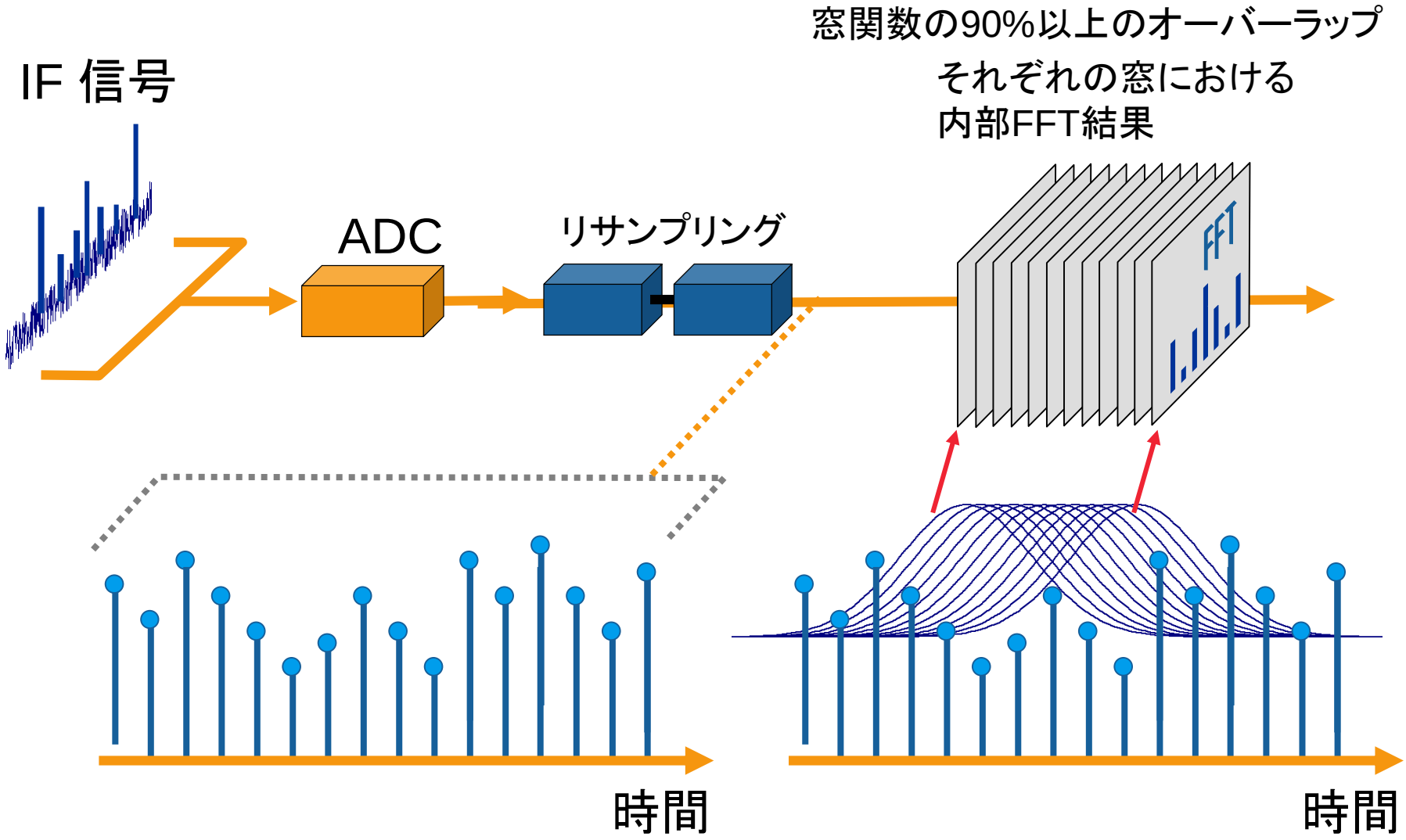


CISPR 16-1-1

Edition 3.0 2010-06

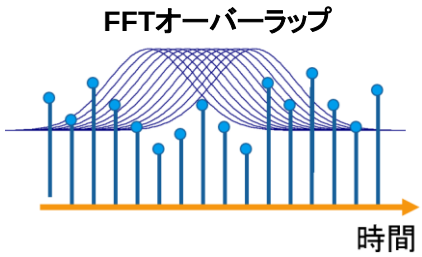
パルス性広帯域ノイズ測定のために

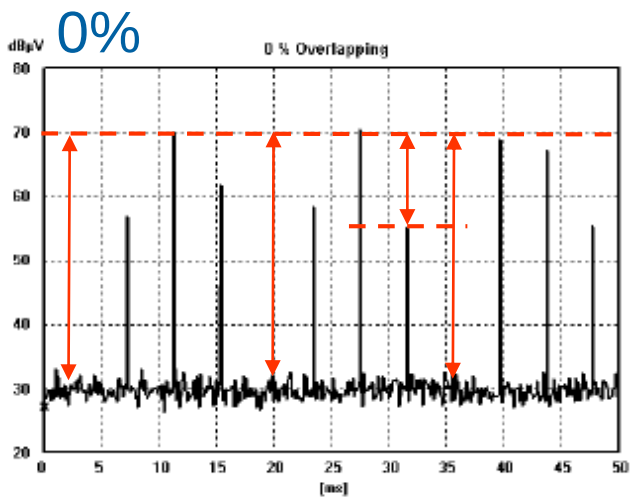
FFTを活用した「タイムドメインスキャン」 - 信号処理概要

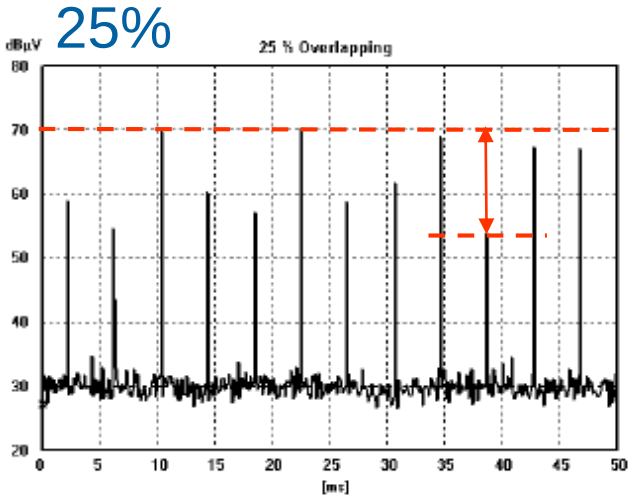


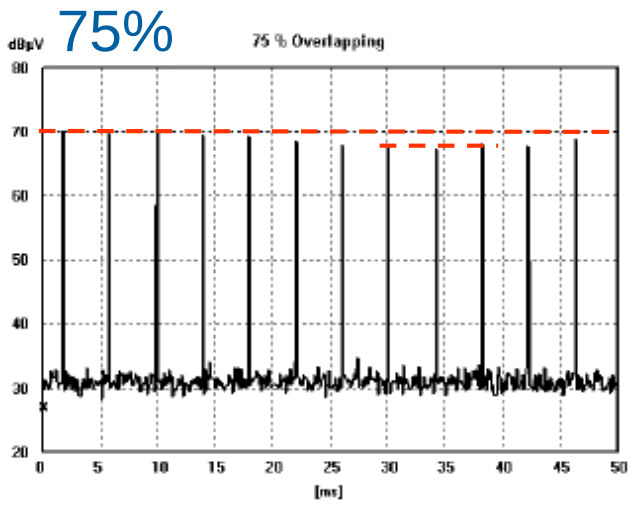
パルス性広帯域ノイズ測定のために

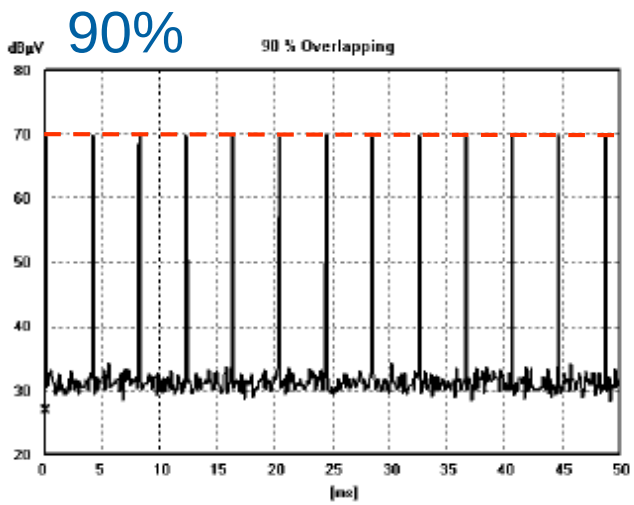
FFTを活用した「タイムドメインスキャン」- パルス測定のためのFFTオーバーラップ









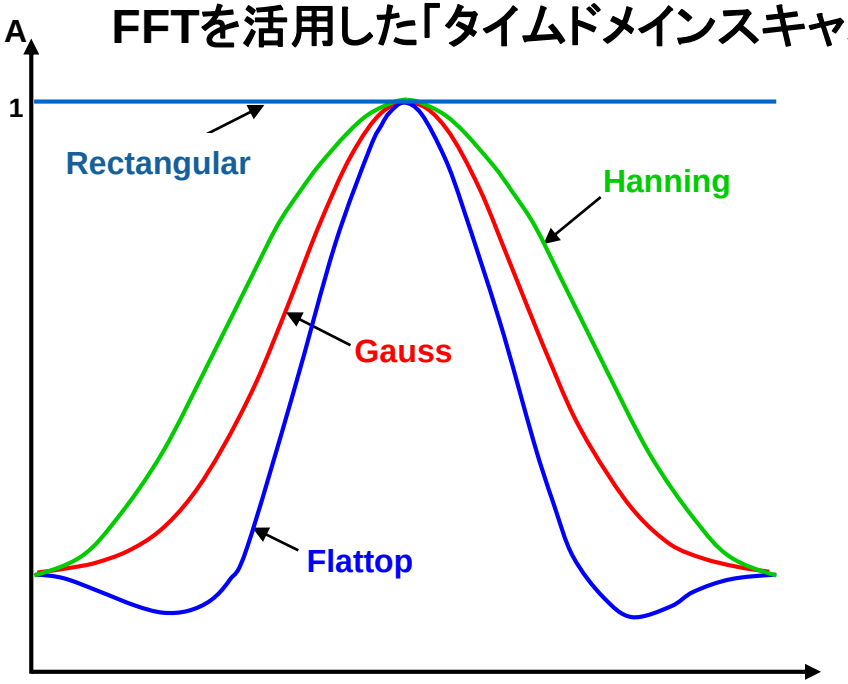


パルス信号に異なるオーバーラップ係数にてガウス窓の窓掛けを行なった際の出力（時間軸）

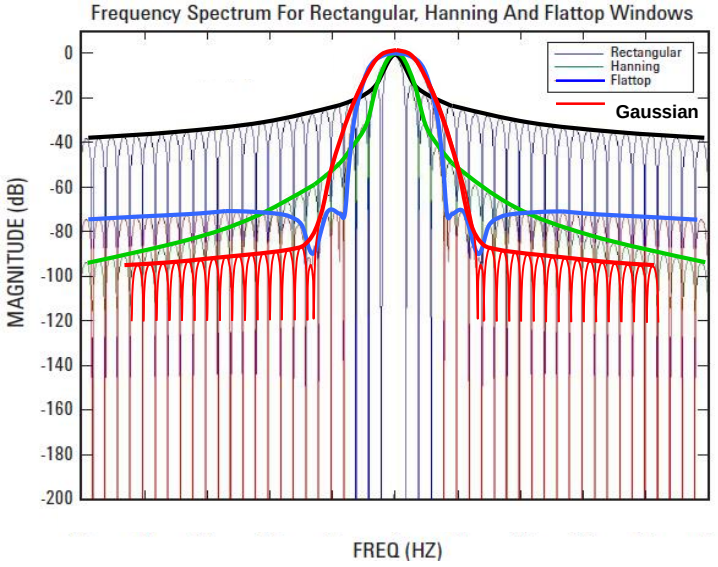
Reference: TR CISPR 16-3 © IEC:2010(E)

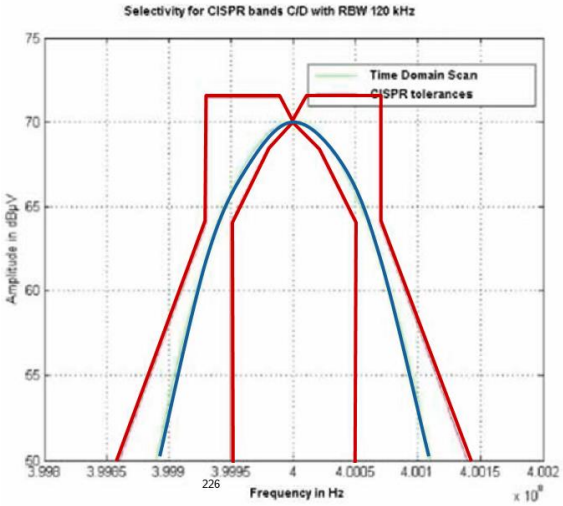
パルス性広帯域ノイズ測定のために

FFTを活用した「タイムドメインスキャン」- パルス測定のための窓関数



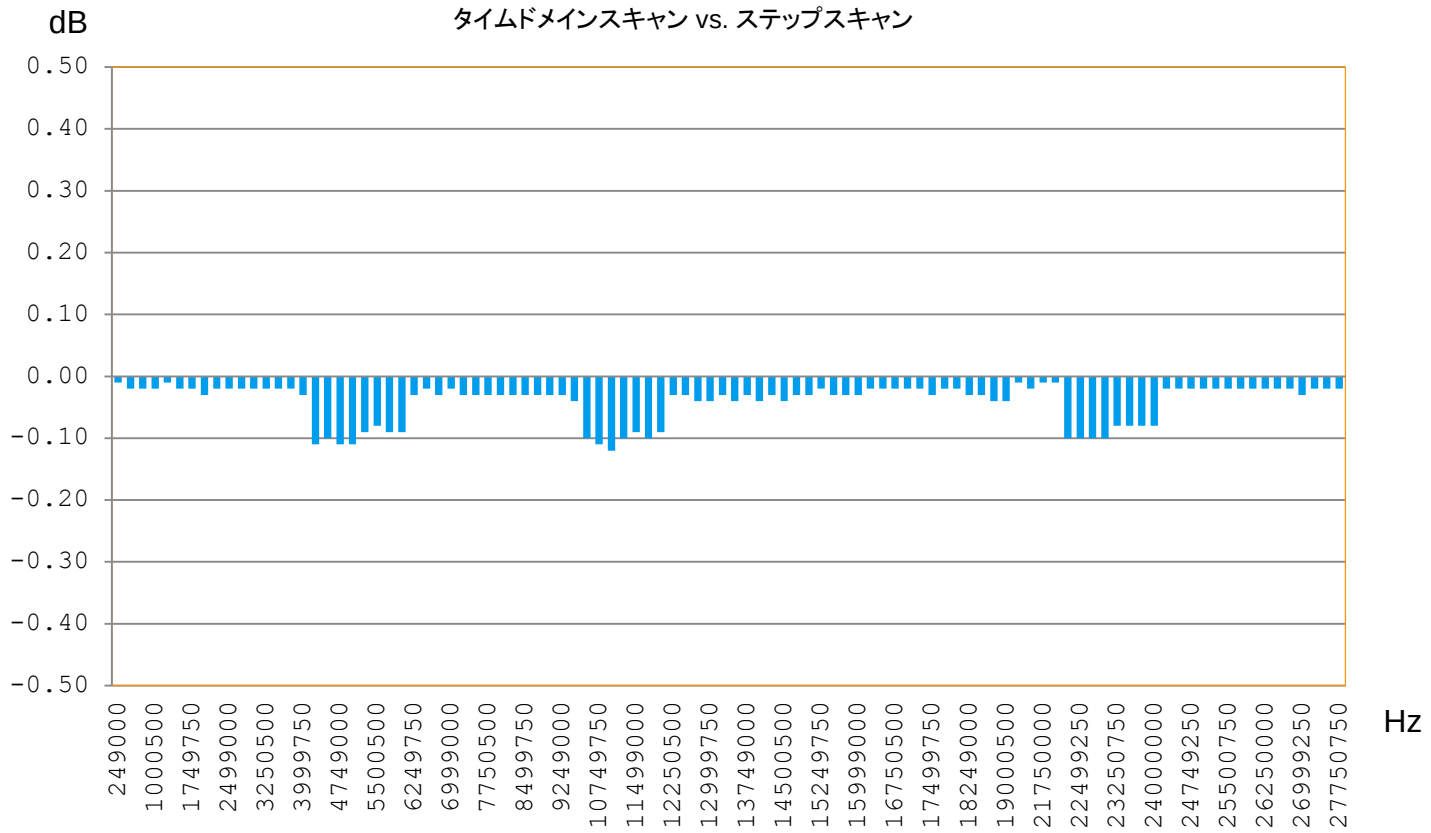
さまざまな時間軸の窓関数の例





パルス性広帯域ノイズ測定のために

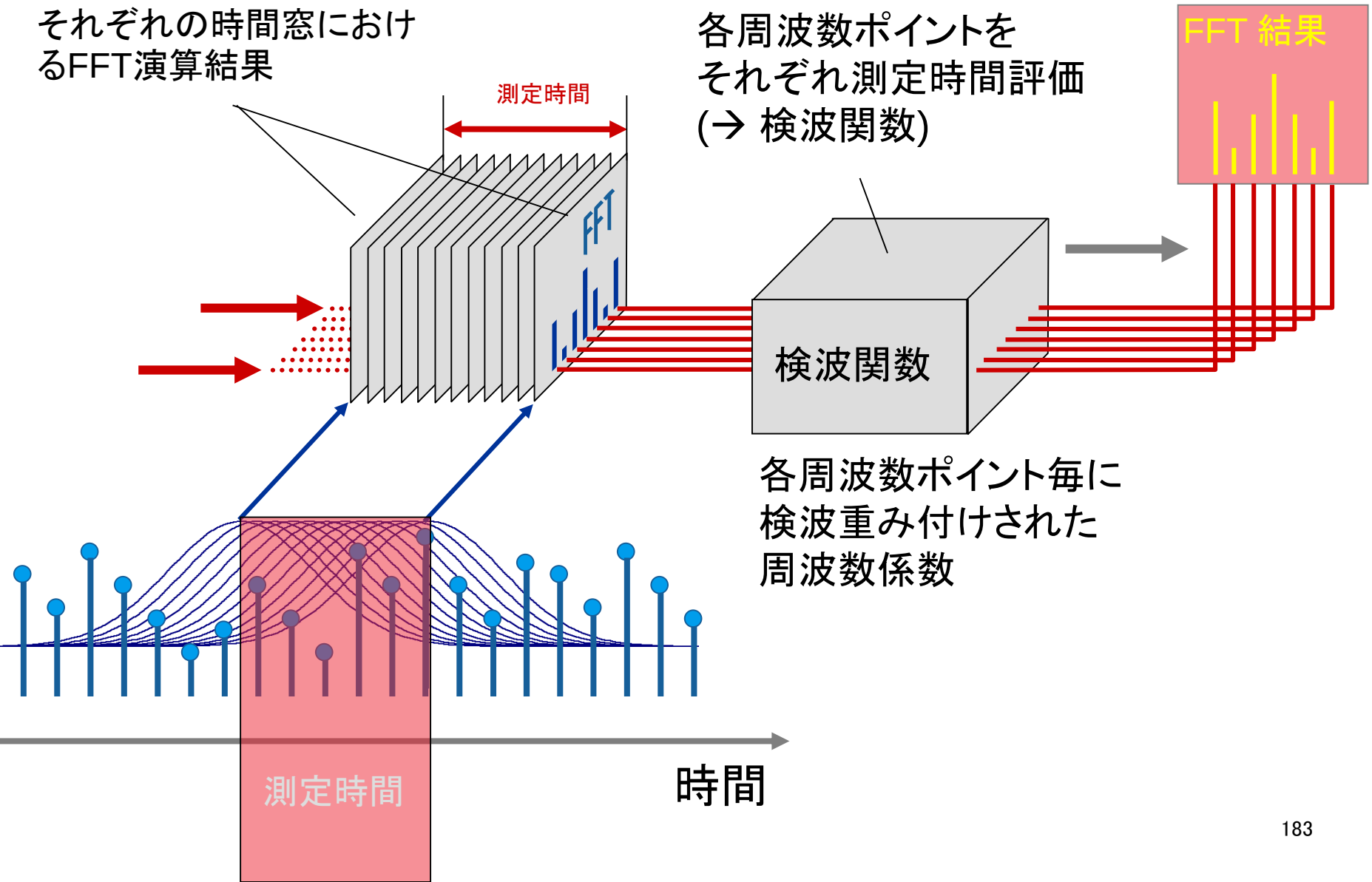
FFTを活用した「タイムドメインスキャン」 - 従来レシーバスキャンとの比較



y-軸: レベル差, x-軸: 周波数

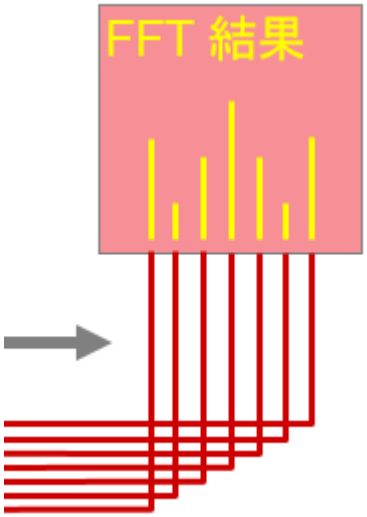
パルス性広帯域ノイズ測定のために

FFTを活用した「タイムドメインスキャン」 - 各周波数ポイント毎に検波

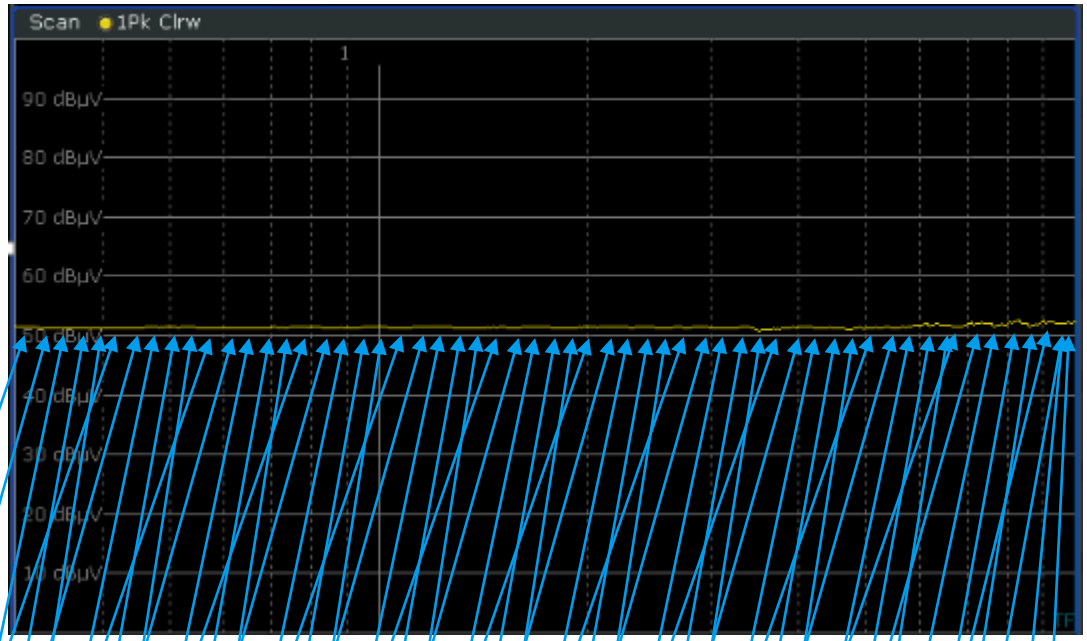


パルス性広帯域ノイズ測定のために

FFTを活用した「タイムドメインスキャン」 - 従来レシーバに置き換えてみると。。



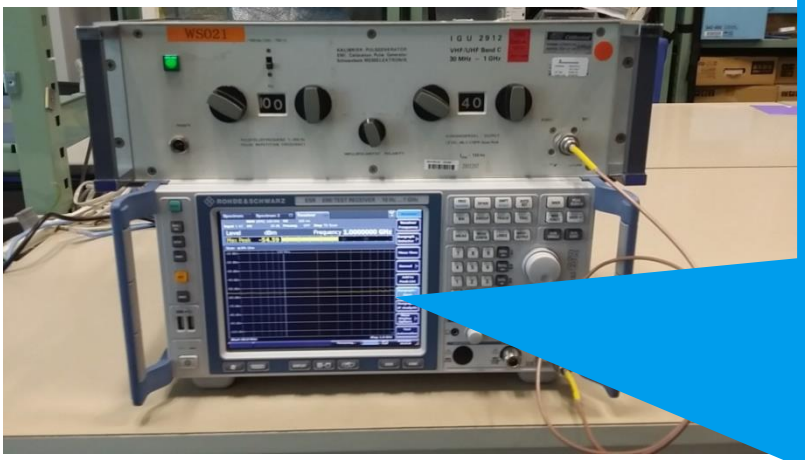
CISPR Band B (150 kHz ～ 30 MHz の場合）

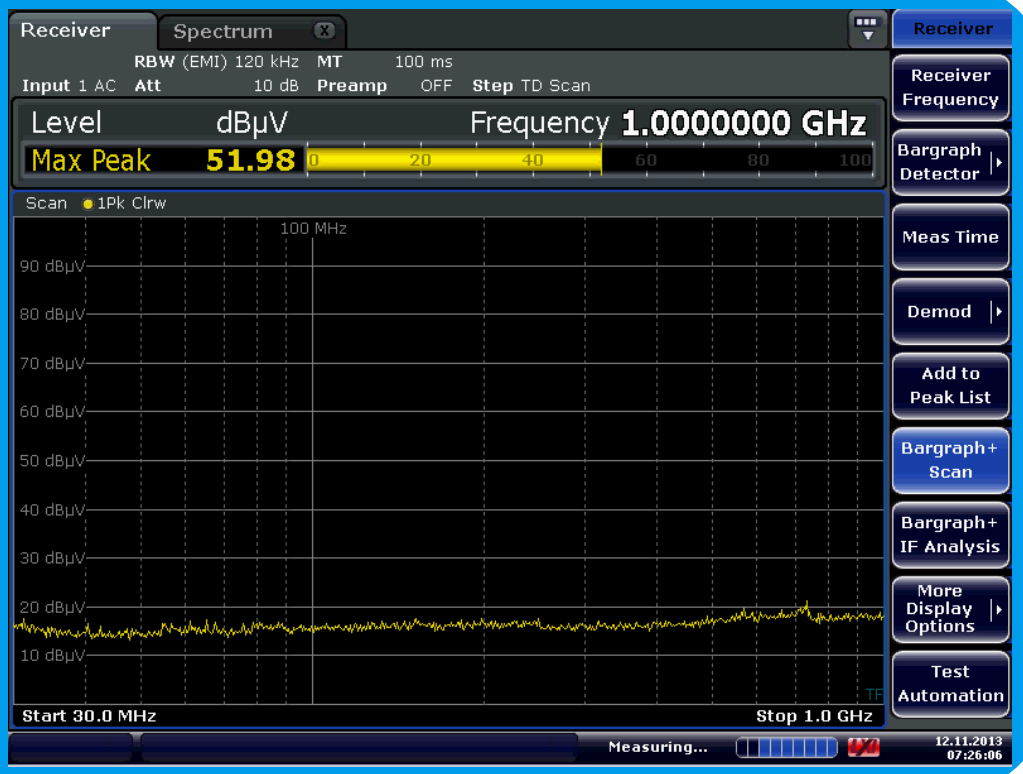


13,267台のレシーバが、
2.25 kHz 周波数をずらして
同時測定している。

パルス性広帯域ノイズ測定のために

FFTを活用した「タイムドメインスキャン」 - トータルでの測定時間を短縮





<1nsパルス(=1GHz幅)を、
10ms間隔(=100回/s)
にて出力

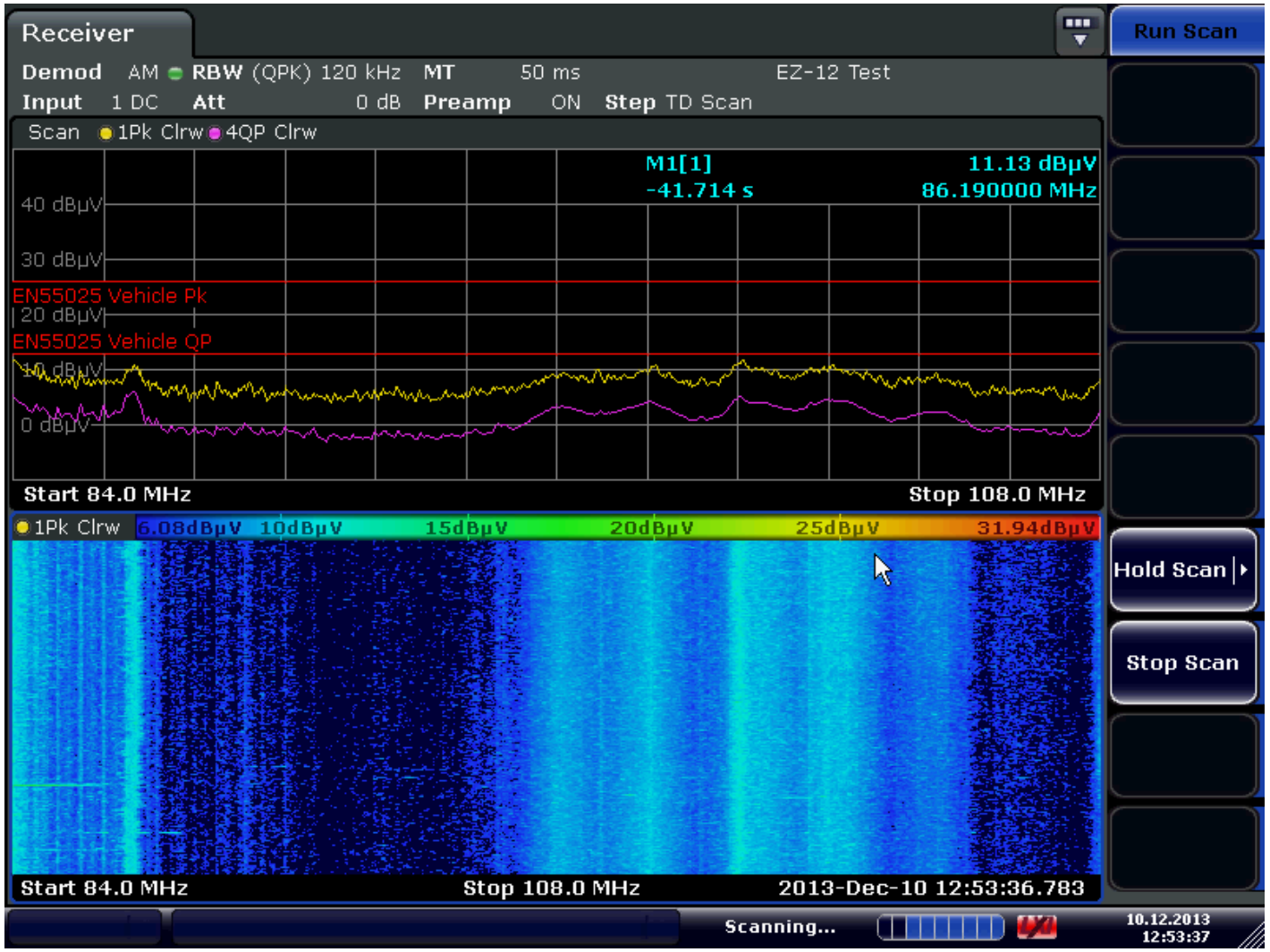
パルス性広帯域ノイズ測定のために

FFTを活用した「タイムドメインスキャン」 - TDSで再測定

- CISPR 25 – オンボード受信機の保護
- インピーダンス変換器 EZ12
- ピックアップされた車のアンテナを測定
- 周波数バンド全体をリアルタイムに観ることが出来る

パルス性広帯域ノイズ測定のために

FFTを活用した「タイムドメインスキャン」 - TDSで再測定



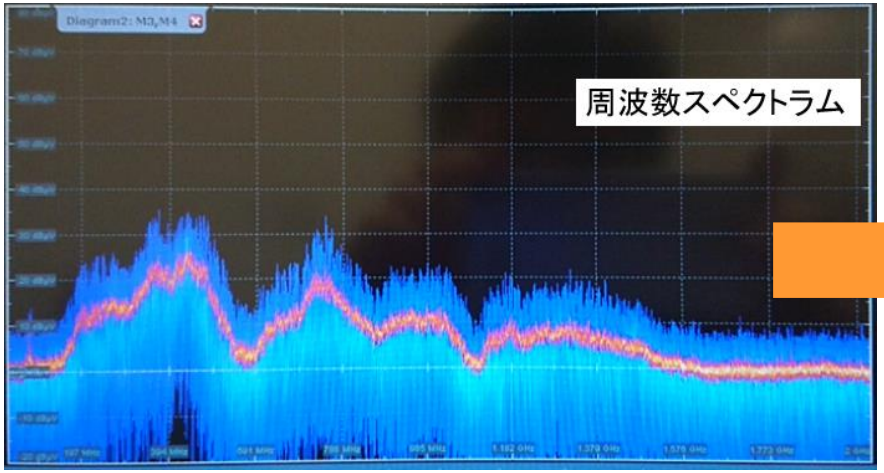
本日の内容

- パルス性広帯域ノイズの特徴・測定の難しさ

- **パルス性広帯域ノイズ測定のために**
  - FFTを活用した「タイムドメインスキャン」
  - **「タイムドメインスキャン」を生かすダイナミックレンジの重要性**

パルス性広帯域ノイズ測定のために

レシーバのダイナミックレンジ性能の重要性



広帯域にわたるパルスノイズスペクトラムの全てが
測定器に入力されると、、、

パルス性広帯域ノイズ測定のために

レシーバのダイナミックレンジ性能の重要性 -

レシーバのアナログ性能向上による ダイナミックレンジの改善

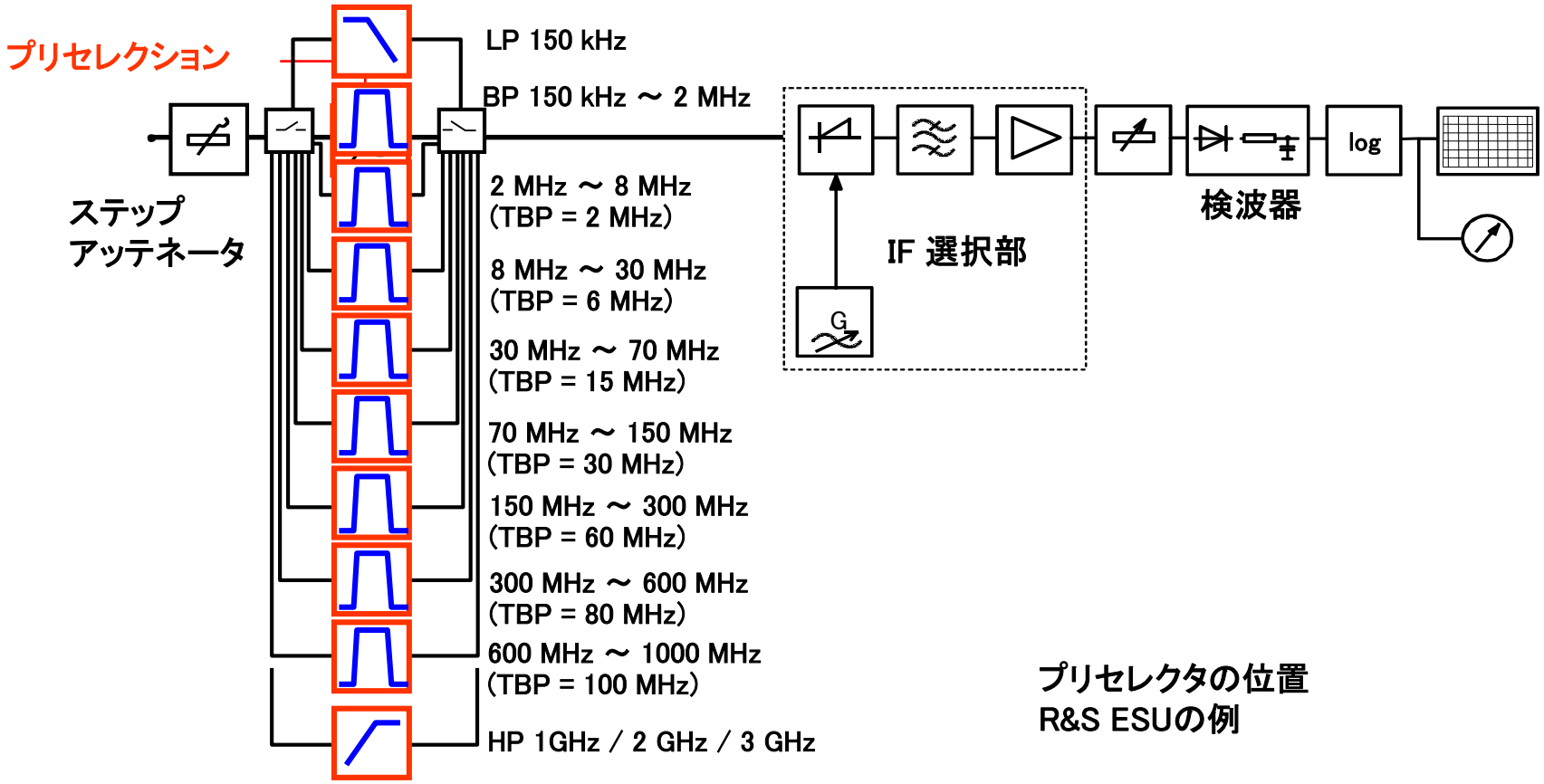
Third-order intercept point (TOI)	RF attenuation = 0 dB, level 2 × –15 dBm, Δf > 5 × RBW, preselection off [3], preamplifier off, LNA off [4]	
	R&S®ESW8, R&S®ESW26, R&S®ESW44	
	f_{in} < 10 MHz	28 dBm (nom.)
	10 MHz ≤ f_{in} < 1 GHz	> 20 dBm, typ. 25 dBm
	1 GHz ≤ f_{in} < 3 GHz	> 20 dBm, typ. 25 dBm
	3 GHz ≤ f_{in} < 8 GHz	> 17 dBm, typ. 20 dBm

R&S ESW は、10 MHz 未満の歪特性を明記

パルス性広帯域ノイズ測定のために

レシーバのダイナミックレンジ性能の重要性 -

プリセレクタによるダイナミックレンジ改善

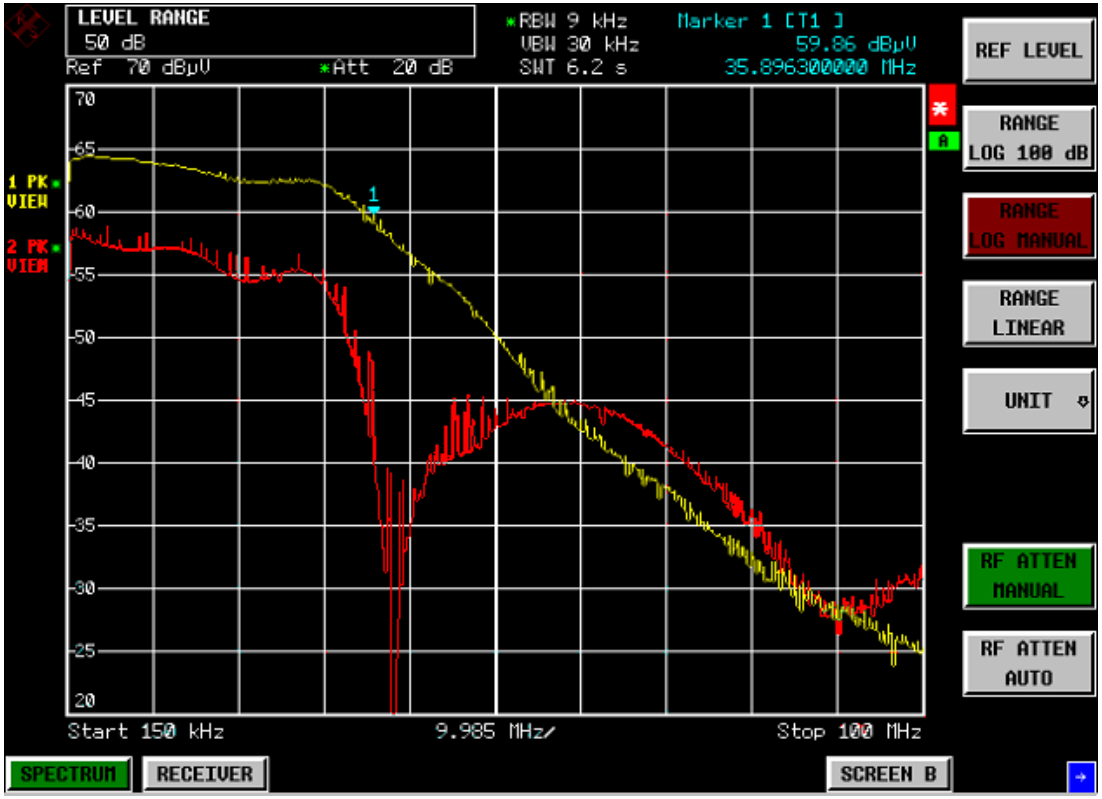


プリセレクタの位置
R&S ESUの例

パルス性広帯域ノイズ測定のために

レシーバのダイナミックレンジ性能の重要性 -

プリセレクタによるダイナミックレンジ改善



1 PK VIEW

プリセレクタ「使用時」
ダイナミックレンジ「良」

2 PK VIEW

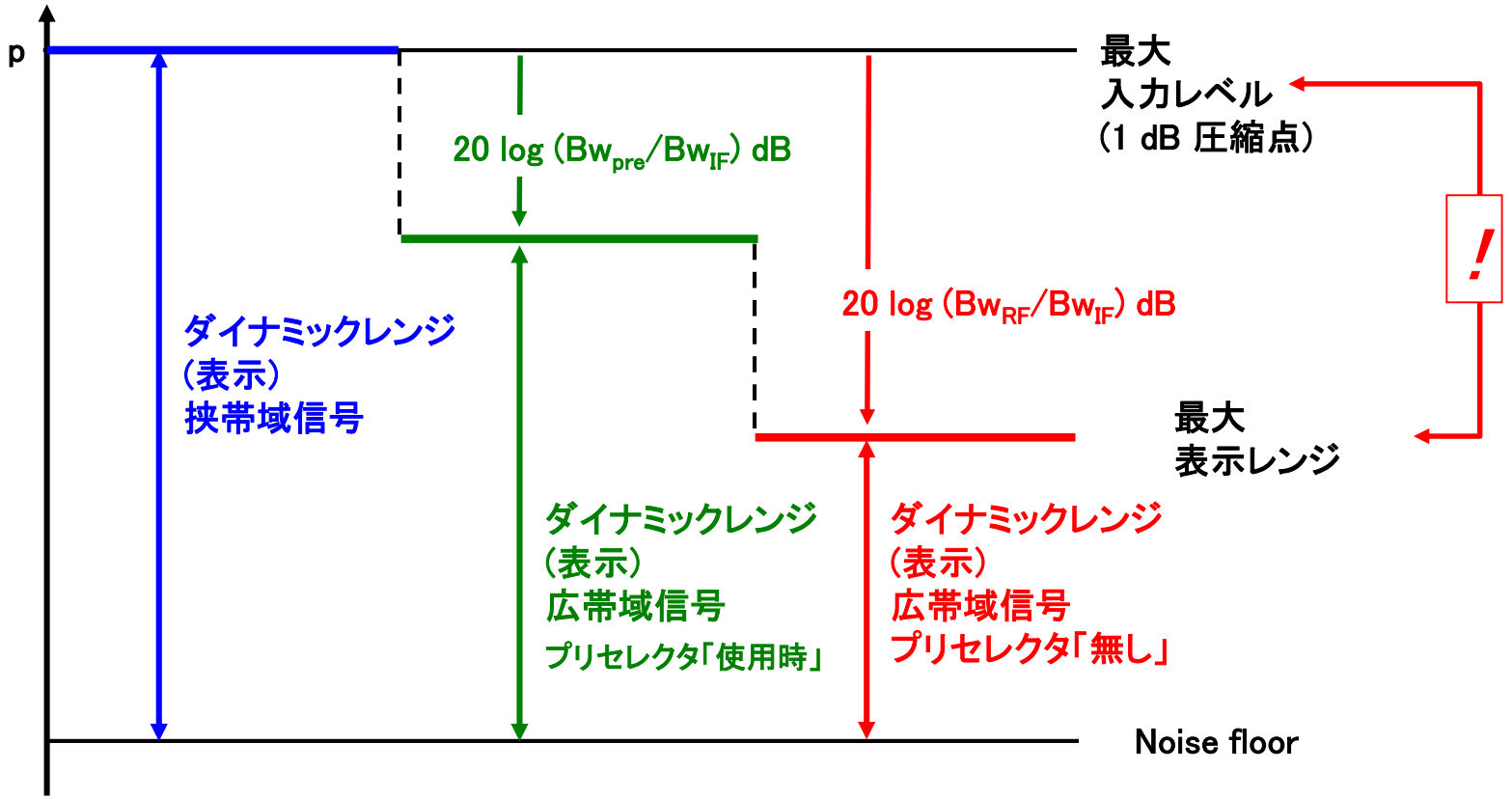
プリセレクタ「無し」
ダイナミックレンジ「悪」

広帯域にわたるノイズスペクトラムの全てが
測定器に入力されると(ミキサー)歪が生じるため、
プリセレクタによる帯域選択でのダイナミックレンジを改善している

パルス性広帯域ノイズ測定のために

レシーバのダイナミックレンジ性能の重要性 -

プリセレクタによるダイナミックレンジ改善

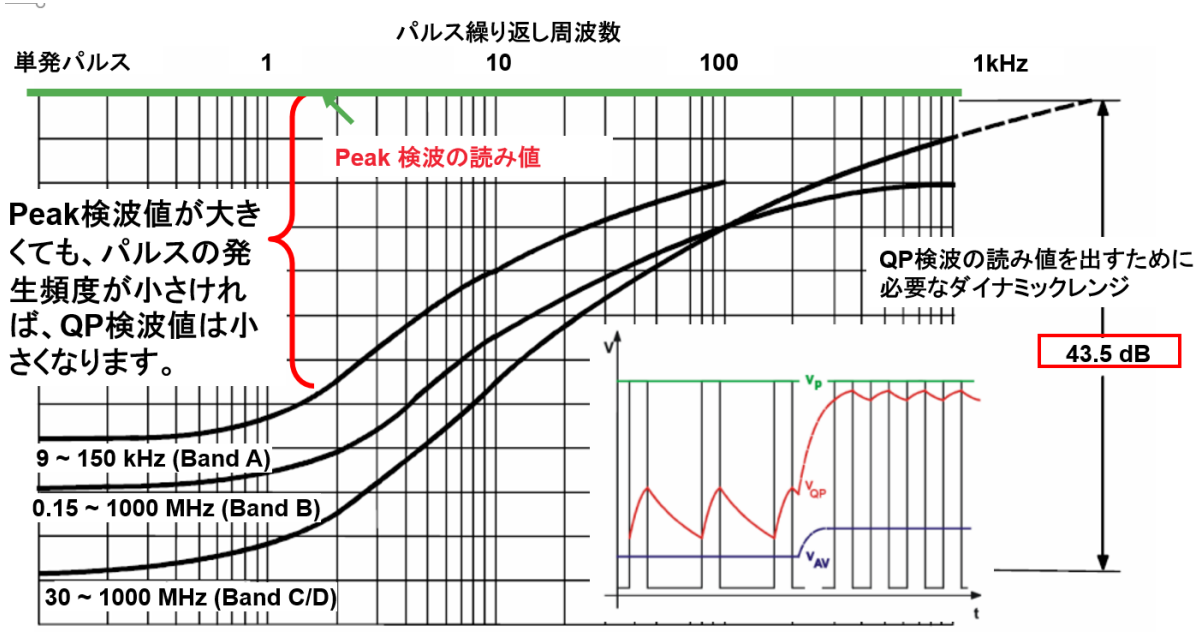


パルス性広帯域ノイズ測定のために

レシーバのダイナミックレンジ性能の重要性 -
プリセレクタによるダイナミックレンジ改善

広帯域パルス測定において

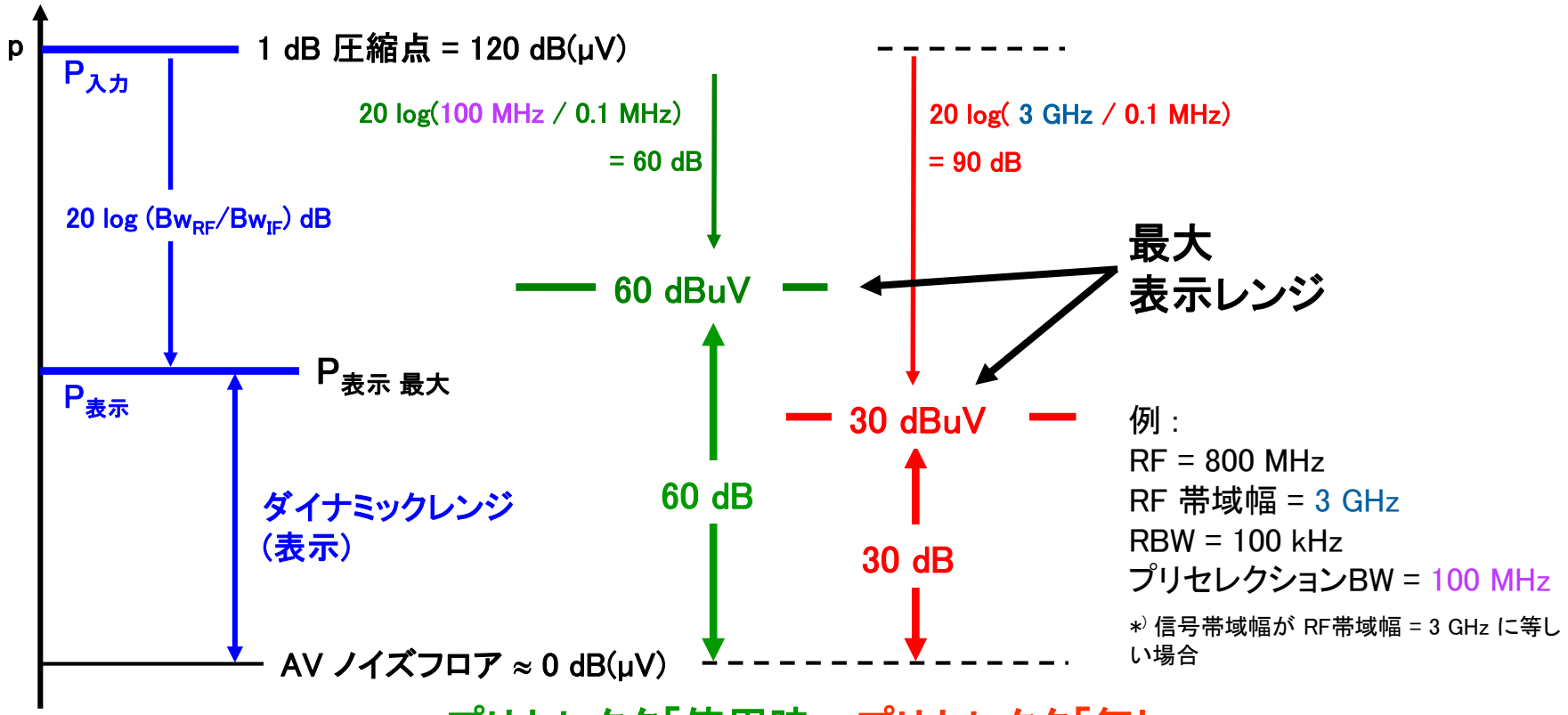
QP検波器動作に必要な
ダイナミックレンジ



パルス性広帯域ノイズ測定のために

レシーバのダイナミックレンジ性能の重要性 -

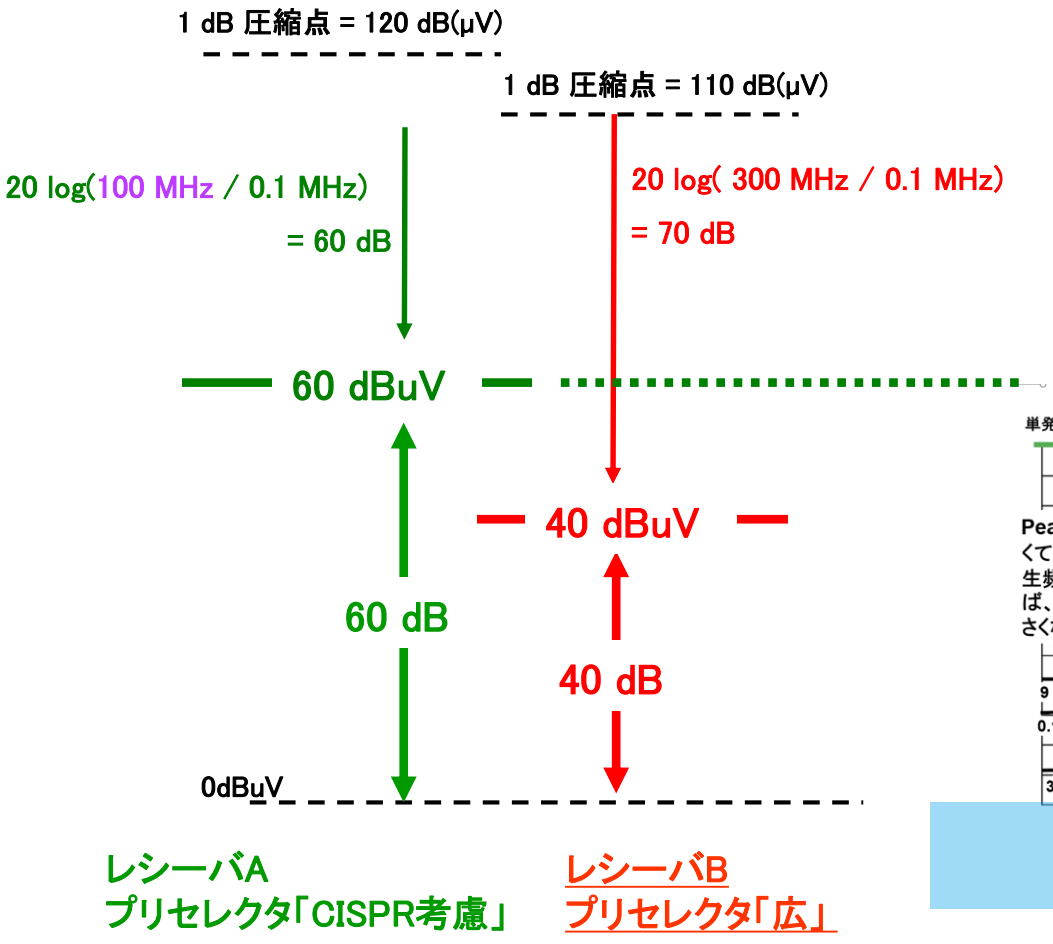
プリセレクタによるダイナミックレンジ改善



パルス性広帯域ノイズ測定のために

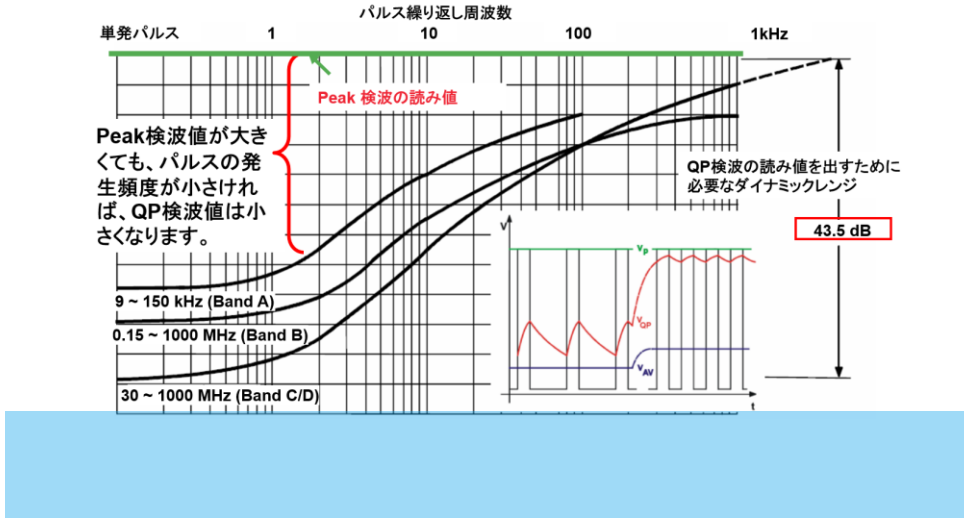
レシーバのダイナミックレンジ性能の重要性 -

プリセレクタによるダイナミックレンジ改善



広帯域パルス測定において

QP検波器動作に必要な
ダイナミックレンジ

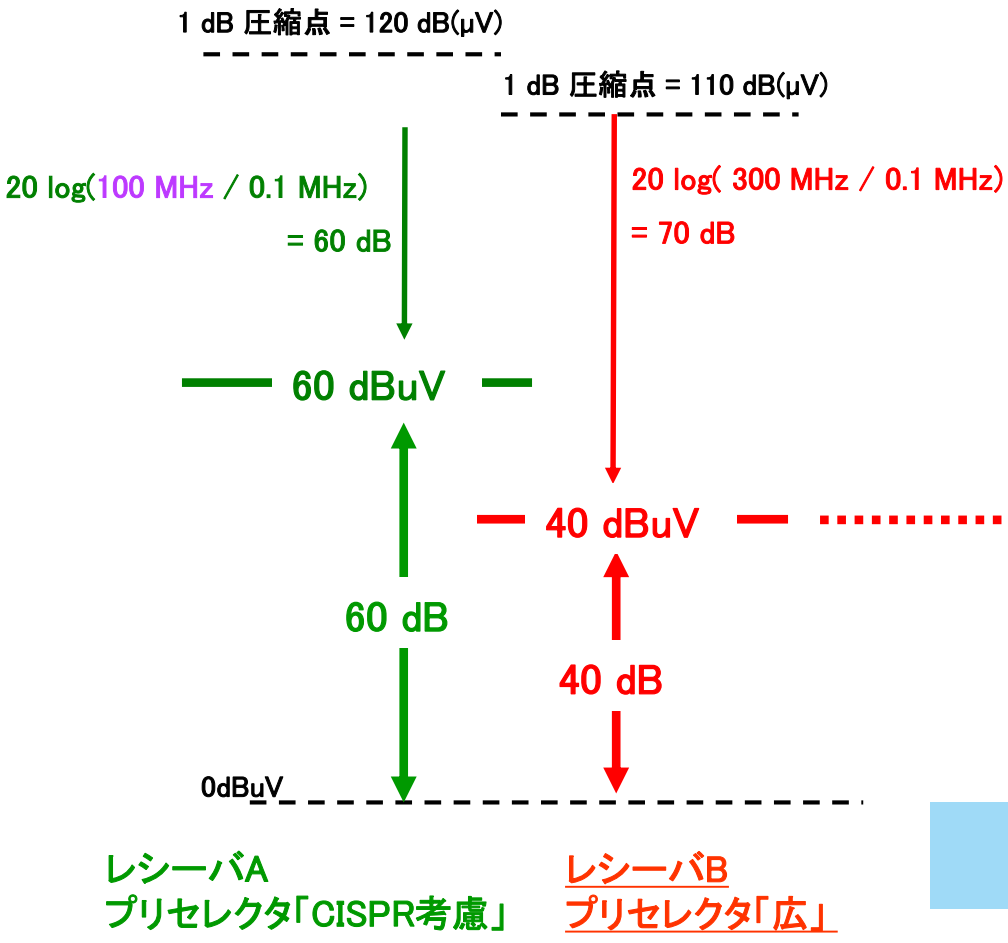


QP検波に必要なダイナミックレンジ

パルス性広帯域ノイズ測定のために

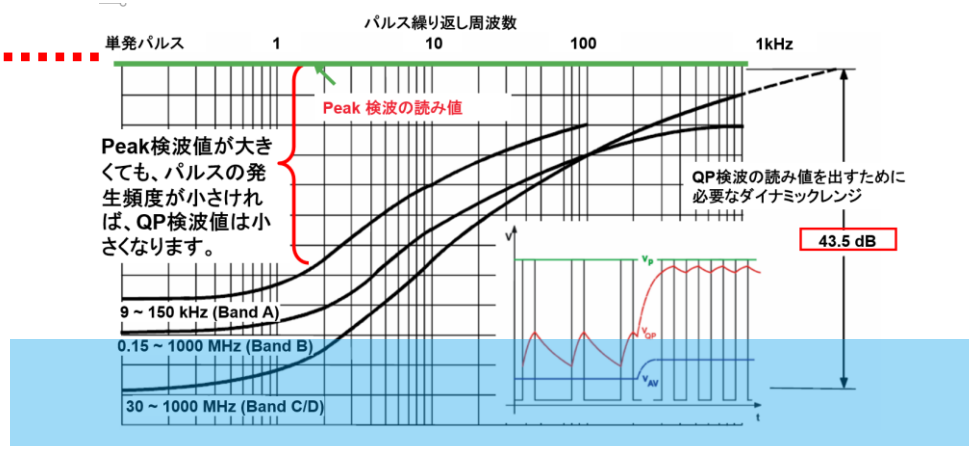
レシーバのダイナミックレンジ性能の重要性 -

プリセレクタによるダイナミックレンジ改善



広帯域パルス測定において

QP検波器動作に必要な
ダイナミックレンジ



ダイナミックレンジが不足すると、
発生頻度の低いノイズをQP検波できない

ご清聴ありがとうございました。

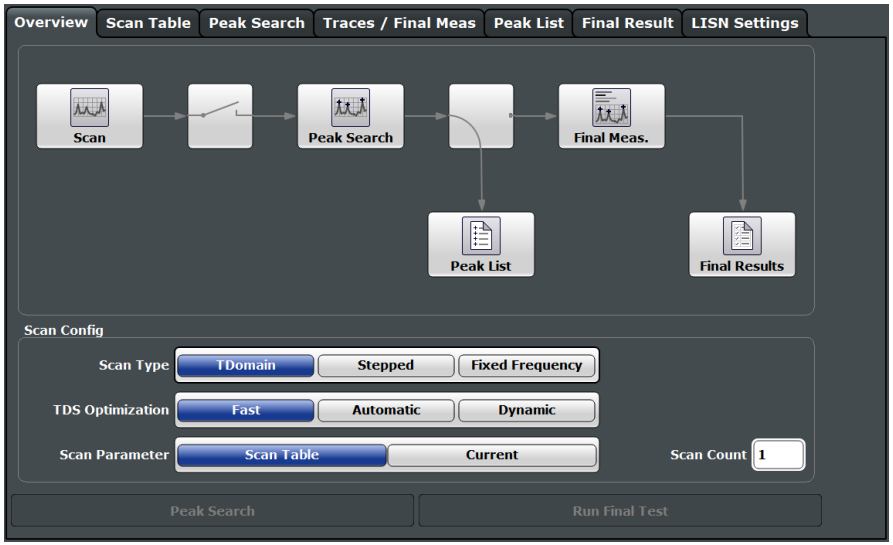
参考資料

ESWアップデート

2020/06/22

ROHDE&SCHWARZ
Make ideas real

ESWアップデート　TDスキャン高速化



- Time domain scan with 3 optimization modes
  - **Automatic**
    full compliant to CISPR 16-1-1
  - **Fast**
    Compliant to CISPR 16-1-1 for pulses with a repetition frequency ≥ 10 Hz
  - **Dynamic**
    Enhanced dynamic in CISPR band D for applications with requirements beyond CISPR 16-1-1

Measurement times	R&S ESW	
	Automatic TDS (full compliant)	**Fast TDS**
150 kHz – 30 MHz 9 kHz, QP + CAV, 1 s	2 s	2 s
150 kHz – 30 MHz 9 kHz, Peak, 100 ms	110 ms	110 ms
30 MHz – 1000 MHz 120 kHz, Peak, 10 ms	380 ms	380 ms
30 MHz – 1000 MHz 9 kHz, QP + CAV, 1 s	64 s (- 37 %)	40 s
30 MHz – 1000 MHz 120 kHz, QP + CAV, 1 s	50 s (- 20 %)	40 s
1 GHz – 6 GHz 1 MHz, Peak + CAV, 100 ms	216 s (- 51 %)	111 s
1 GHz – 18 GHz 1 MHz, Peak, 10 ms	8 s	8 s
1 GHz – 26.5 GHz 1 MHz, Peak + AV, 10 ms	13 s	13 s
1 GHz – 40 GHz 1 MHz, Peak, 10 ms	21 s	21 s

CISPR 25 Automotive

CISPR 11 Microwave oven

FCC

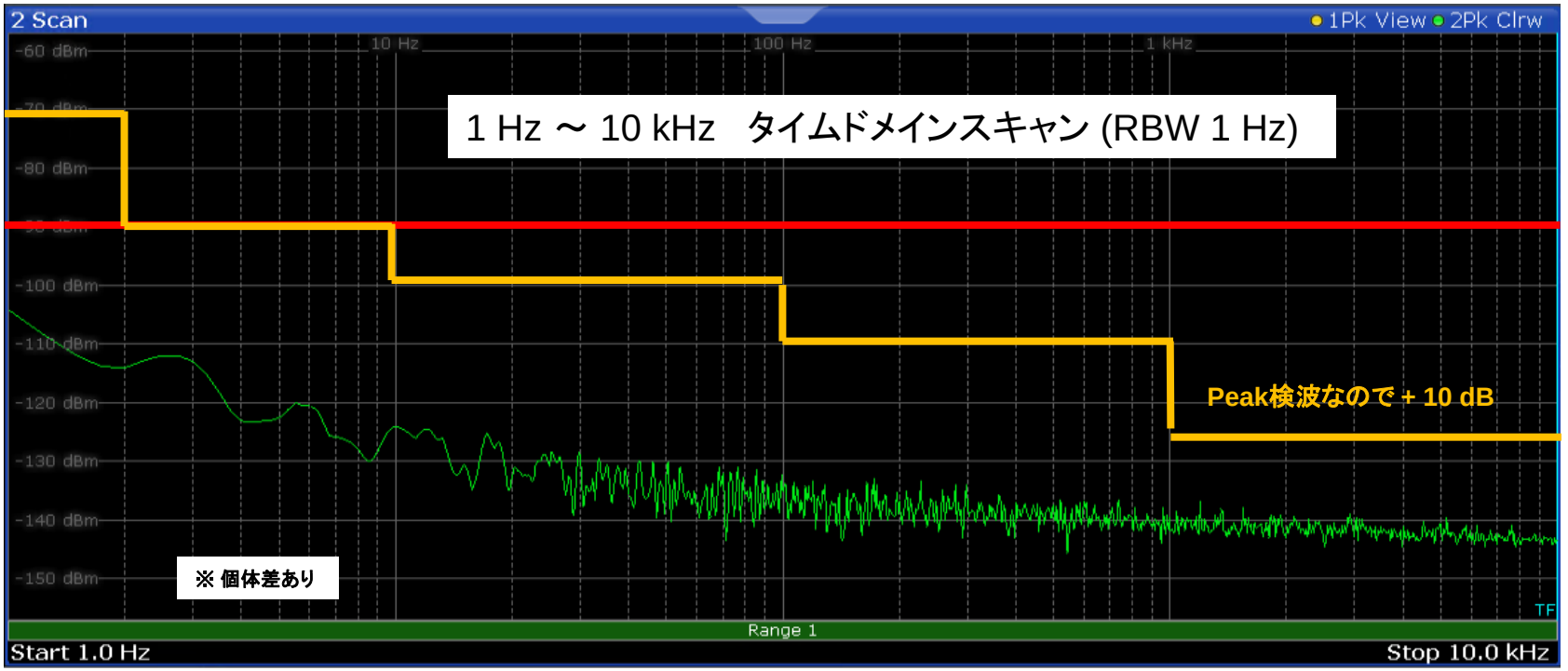
MIL

ESWアップデート　1 Hz ～ 測定可能

Frequency

Frequency range	R&S®ESW8	
	input 1, DC coupled	1 Hz to 8 GHz
	input 1, AC coupled	10 MHz to 8 GHz
	R&S®ESW26	
	input 1, DC coupled	1 Hz to 26.5 GHz
	input 1, AC coupled	10 MHz to 26.5 GHz
	R&S®ESW44	
	input 1, DC coupled	1 Hz to 44 GHz
	input 1, AC coupled	10 MHz to 44 GHz
	all models	
	input 2, DC coupled	1 Hz to 1 GHz
	input 2, AC coupled [1]	10 MHz to 1 GHz
Frequency resolution		0.01 Hz

EMI filters		
Bandwidths (–6 dB)	standard	1 Hz, 10 Hz, 100 Hz, 200 Hz, 1 kHz, 9 kHz, 10 kHz, 100 kHz, 120 kHz, 1 MHz,10 MHz
	with R&S®ESW-B8E option	20 MHz, 30 MHz, 40 MHz additionally [3]
	with R&S®ESW-B8 option	20 MHz, 30 MHz, 40 MHz, 50 MHz, 80 MHz additionally [3]



Displayed average noise level of instruments without R&S®ESW-B24 option (analyzer mode)		
Preselection off/on [5], preamplifier off	RF attenuation = 0 dB, termination = 50 Ω, normalized to 1 Hz RBW, trace average, average mode = log, sample detector, +5 °C to +40 °C	
	1 Hz ≤ f < 2 Hz	–80 dBm (nom.)
	2 Hz ≤ f < 10 Hz	–100 dBm, typ. –110 dBm
	10 Hz ≤ f ≤ 100 Hz	–110 dBm, typ. –120 dBm
	100 Hz < f ≤ 1 kHz	–120 dBm, typ. –130 dBm
	1 kHz < f < 9 kHz	–135 dBm, typ. –147 dBm

Residual spurious response	RF attenuation = 0 dB	
	f ≤ 1 MHz	< –90 dBm
	1 MHz < f ≤ 8900 MHz	< –110 dBm
	8900 MHz < f ≤ 26.5 GHz	< –100 dBm
	26.5 GHz < f ≤ 44 GHz	< –100 dBm
	f = receive frequency	

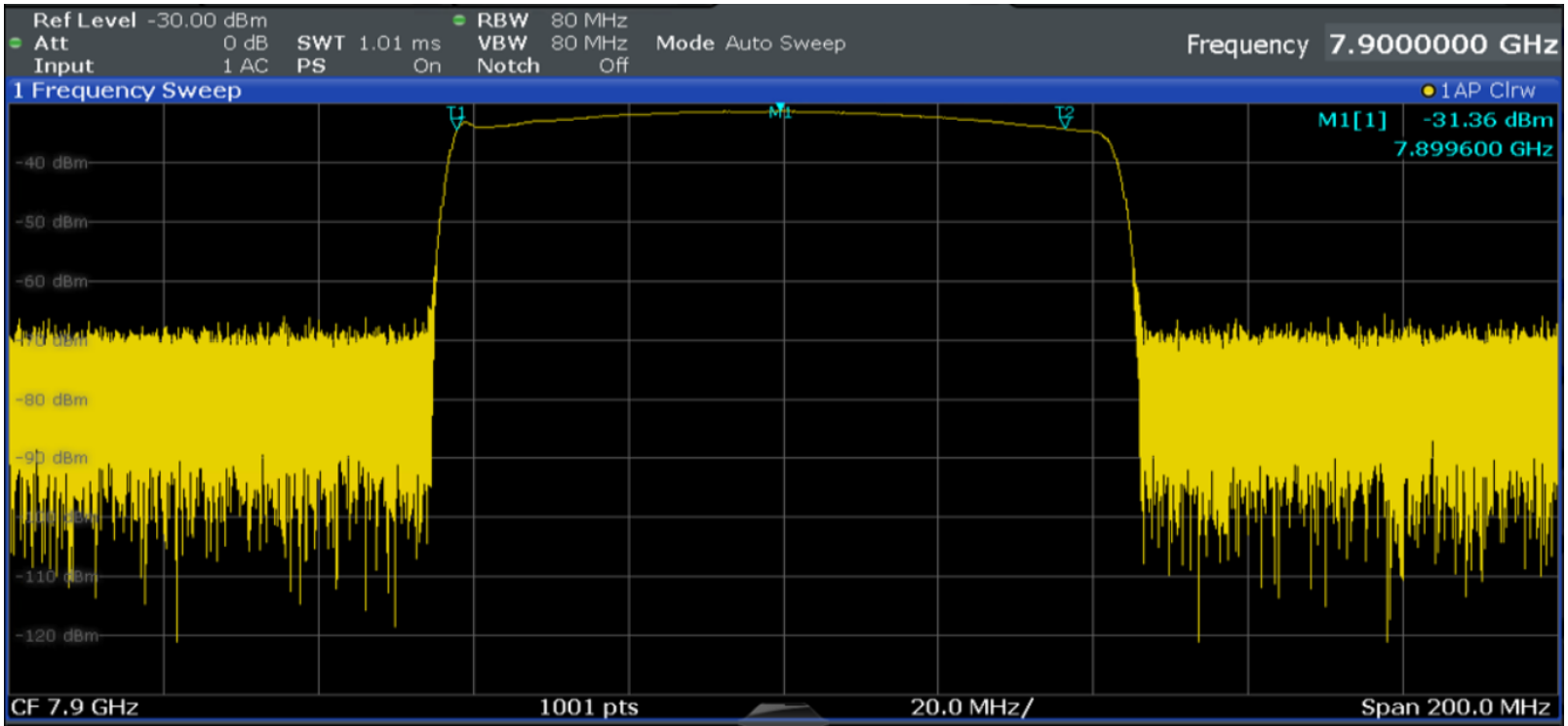
ESWアップデート　RBW max 80 MHz (ESW-B8)

IF and resolution bandwidths

IF filters, sweep filters and FFT filters		
Resolution bandwidths (–3 dB)	standard	1 Hz to 10 MHz in 1/2/3/5 sequence
	with R&S®ESW-B8E option	20 MHz, 30 MHz, 40 MHz additionally [3]
	with R&S®ESW-B8 option	20 MHz, 30 MHz, 40 MHz, 50 MHz, 80 MHz additionally [3]

EMI filters		
Bandwidths (–6 dB)	standard	1 Hz, 10 Hz, 100 Hz, 200 Hz, 1 kHz, 9 kHz, 10 kHz, 100 kHz, 120 kHz, 1 MHz, 10 MHz
	with R&S®ESW-B8E option	20 MHz, 30 MHz, 40 MHz additionally [3]
	with R&S®ESW-B8 option	20 MHz, 30 MHz, 40 MHz, 50 MHz, 80 MHz additionally [3]

[3] For f ≥ 8 GHz the bandwidth may be limited by the YIG preselector.



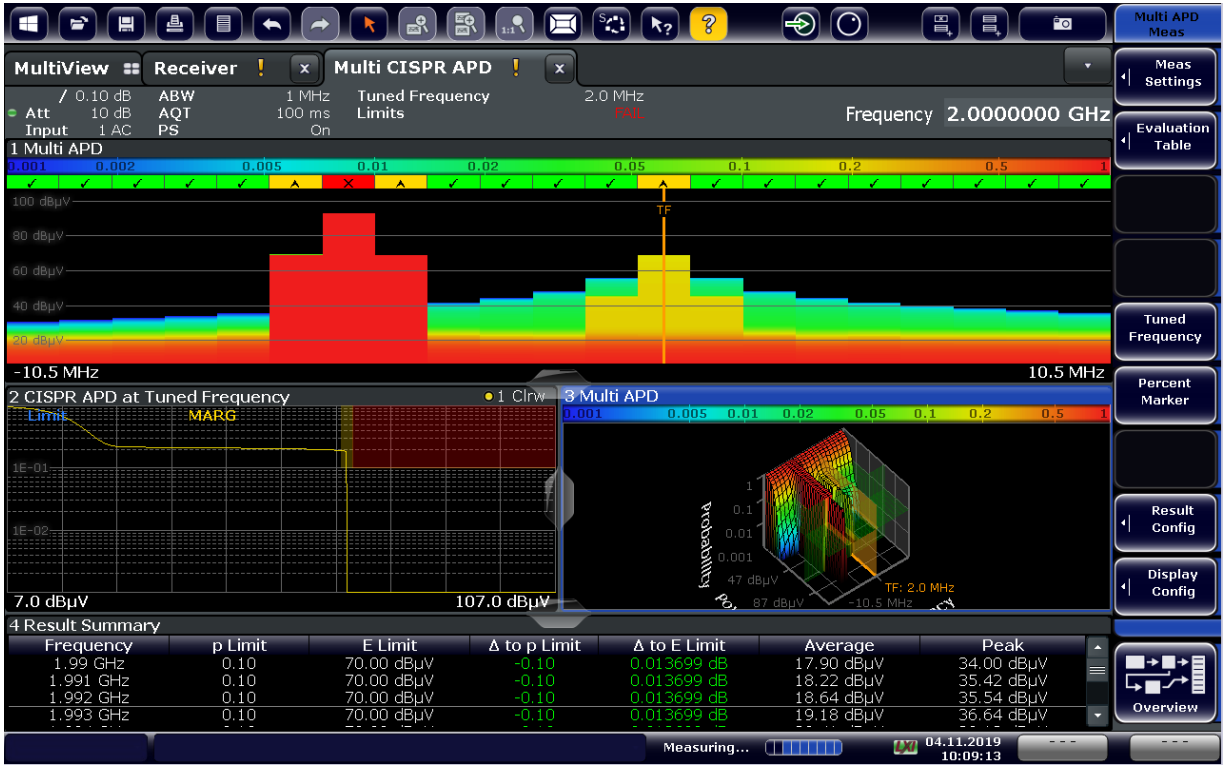
ESWアップデート　マルチチャンネルAPD (opt ESW-K58)

Up to **20 MHz span**
(21 channels at 1 MHz ABW)

or **8 MHz span**
(67 channels at 120 kHz ABW)

Cumulative Amplitude
Probability Distribution
@ Tuned frequency

Channel list with
limit check



ご清聴ありがとうございました