Particle Identification in SPD

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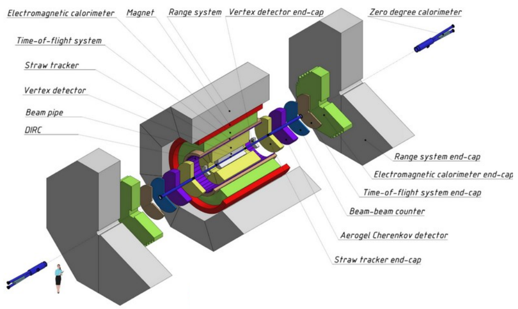
NICA – Nuclotron-based Ion Collider fAcility

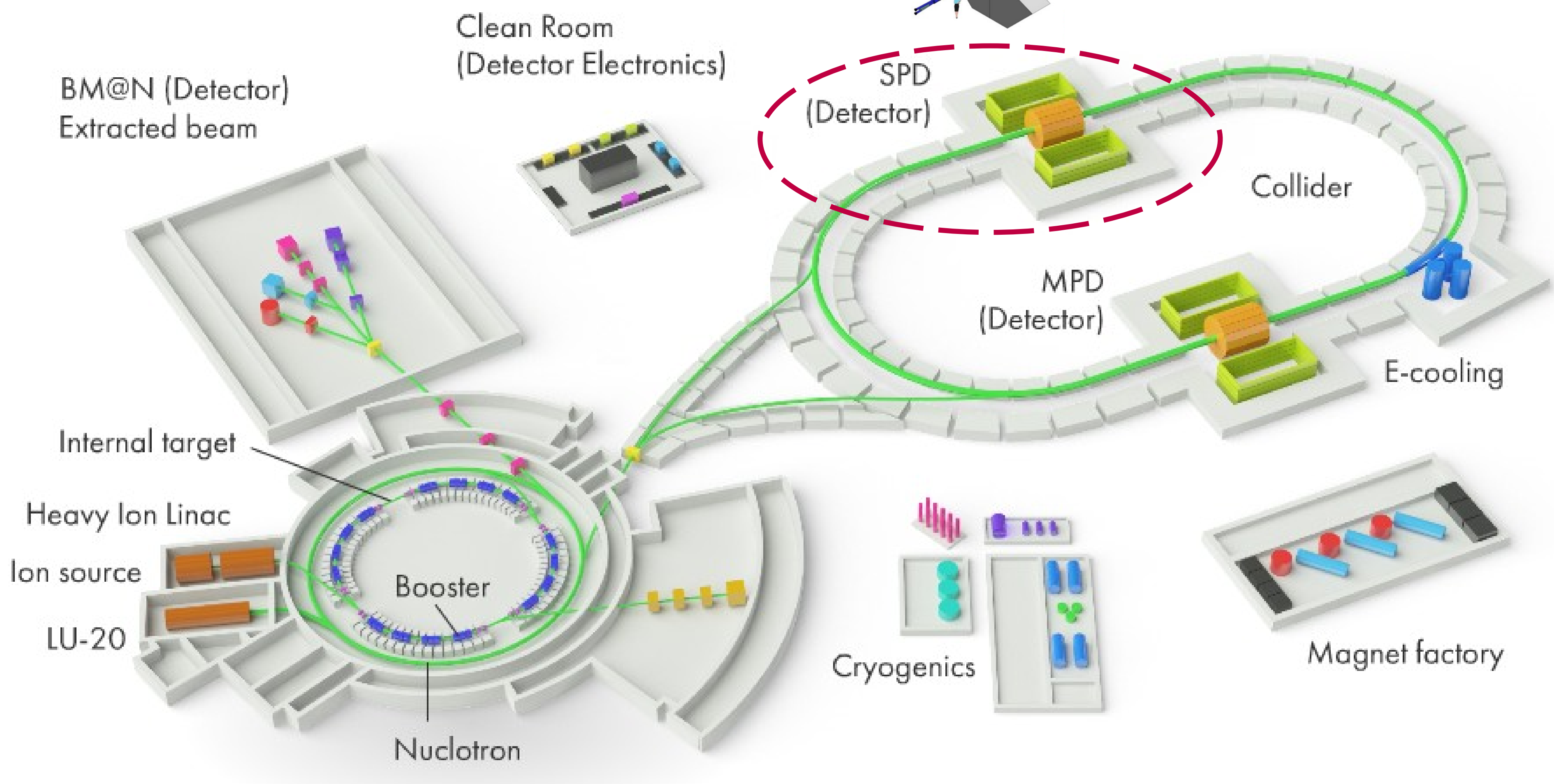
Polarized beams

$p^{\uparrow} p^{\uparrow}\ at \sqrt{s} \leq 27\ GeV$
$d^{\uparrow} d^{\uparrow}\ at \sqrt{s} \leq 13.5\ GeV$
$p^{\uparrow} d^{\uparrow}\ at \sqrt{s} \leq 19\ GeV$

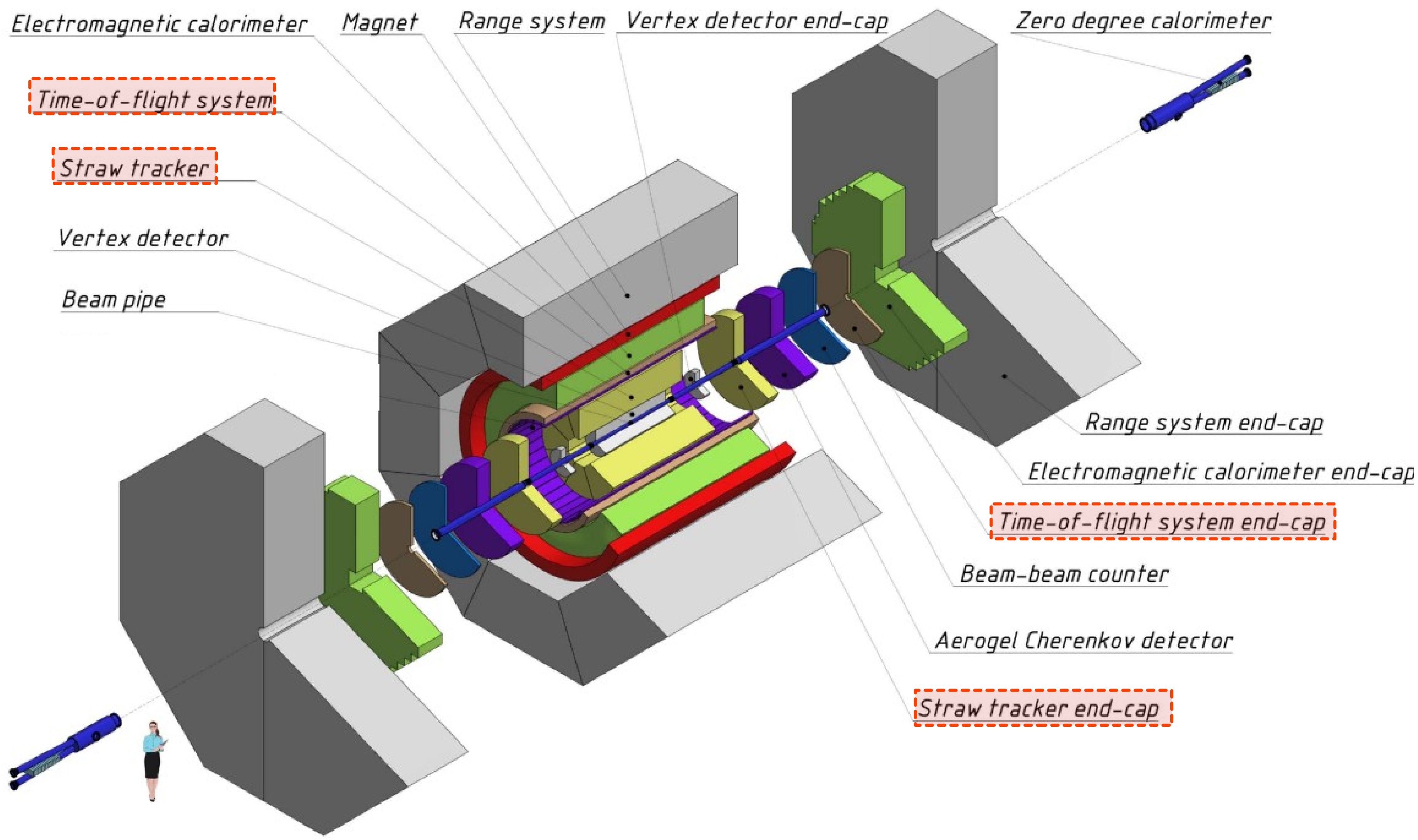
longitudinal and
transverse polarization
(UU, LL, TT, UT, LT)
> 70%

Spin Physics Detector





Particle identification in SPD



In this talks, particle identification via <u>time-of-flight</u> and <u>straw tubes</u> is discussed.

Typical PID approach

For a detector with a Gaussian response

What we expect for a given *m* hypothesis

Observed signal from a detector

PID discrimination variable

$$n_{\sigma_\alpha^i} = \frac{S_\alpha - \hat{S}(H_i)_\alpha}{\sigma_\alpha^i}$$

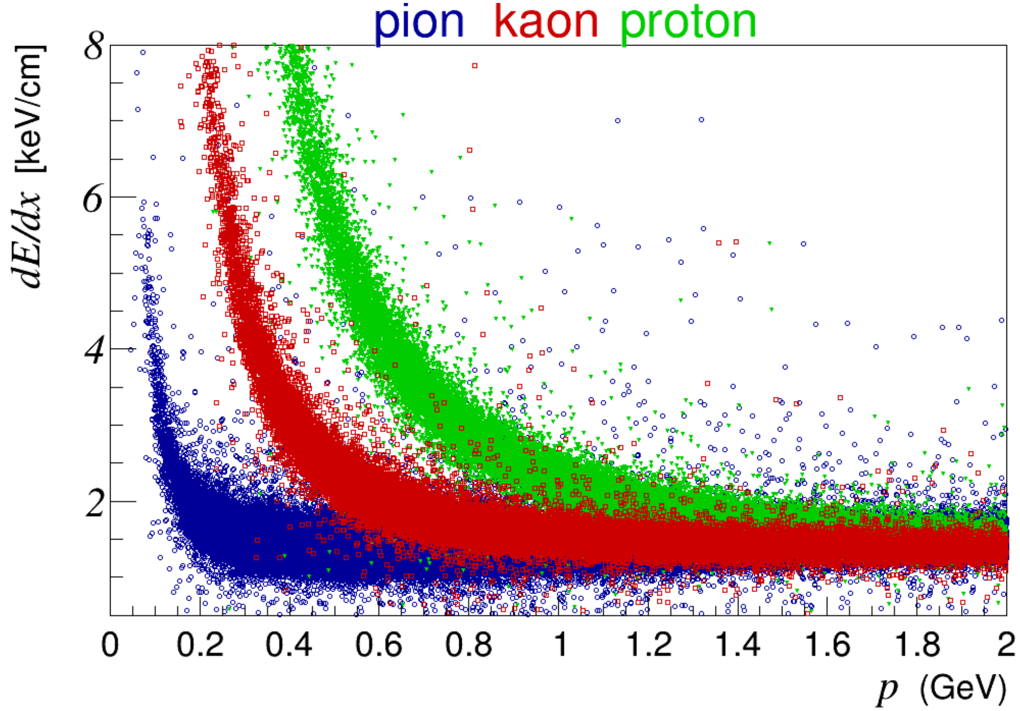
$\alpha = STRAW, TOF \ldots$

$i = \pi, K, p \ldots$

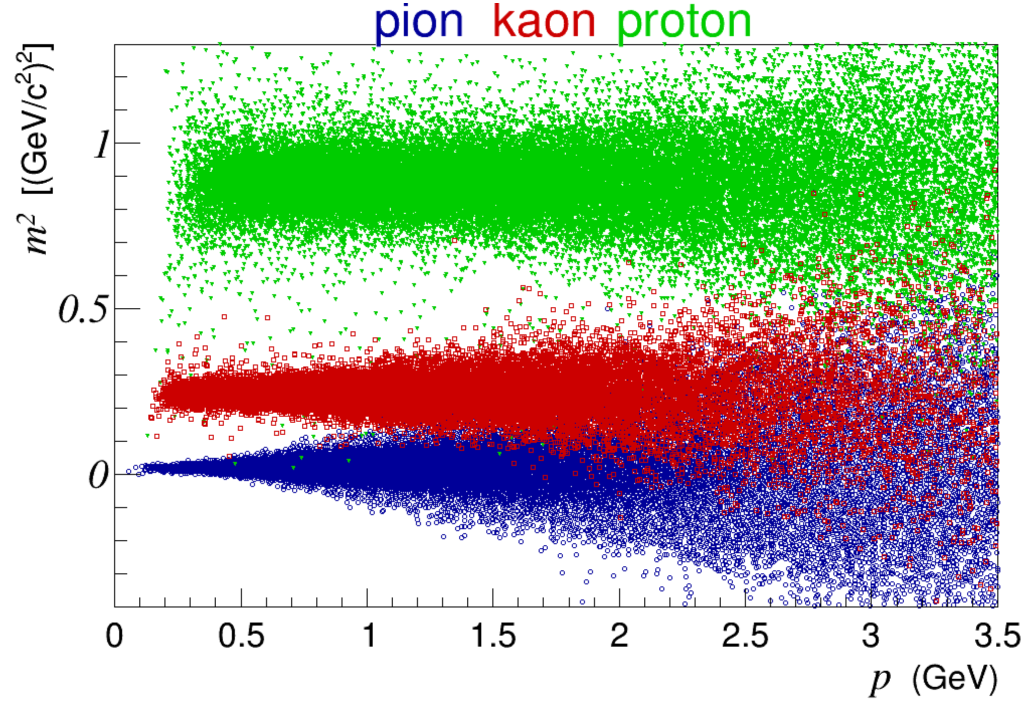
detector resolution

PID detectors

Straw tracker

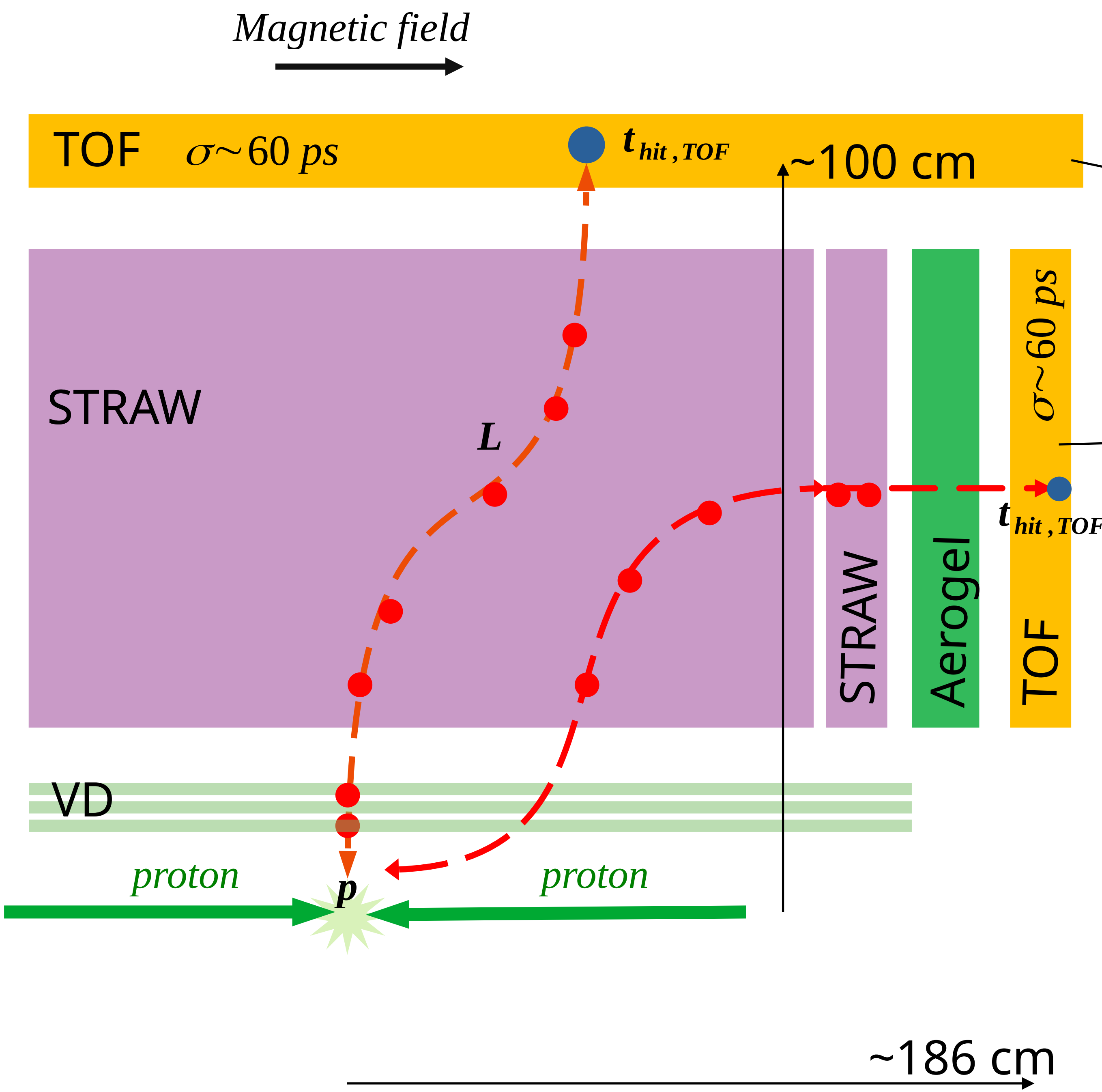


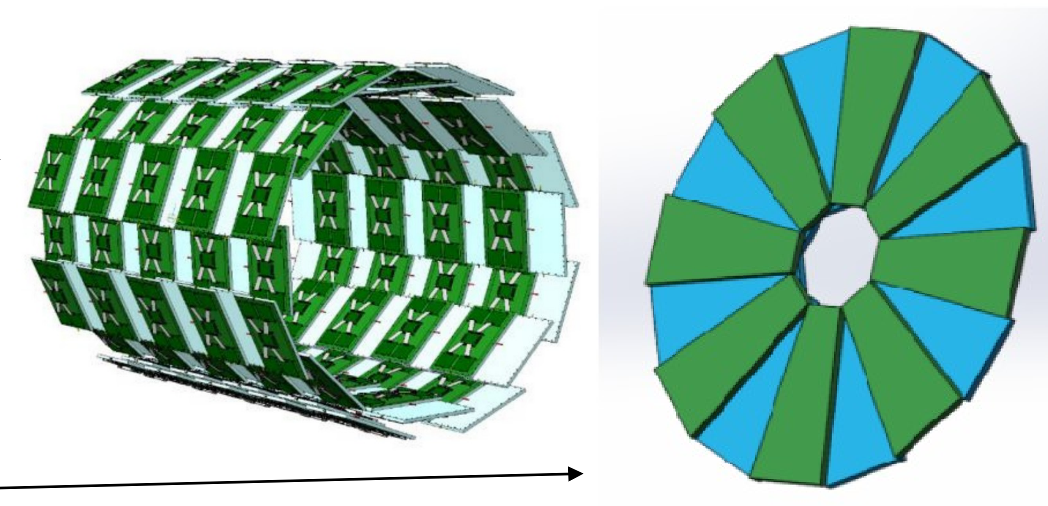
TOF



Detector	Signal
Straw tracker	ionization energy loss (dE/dx)
TOF	time of flight

Time-of-Flight system





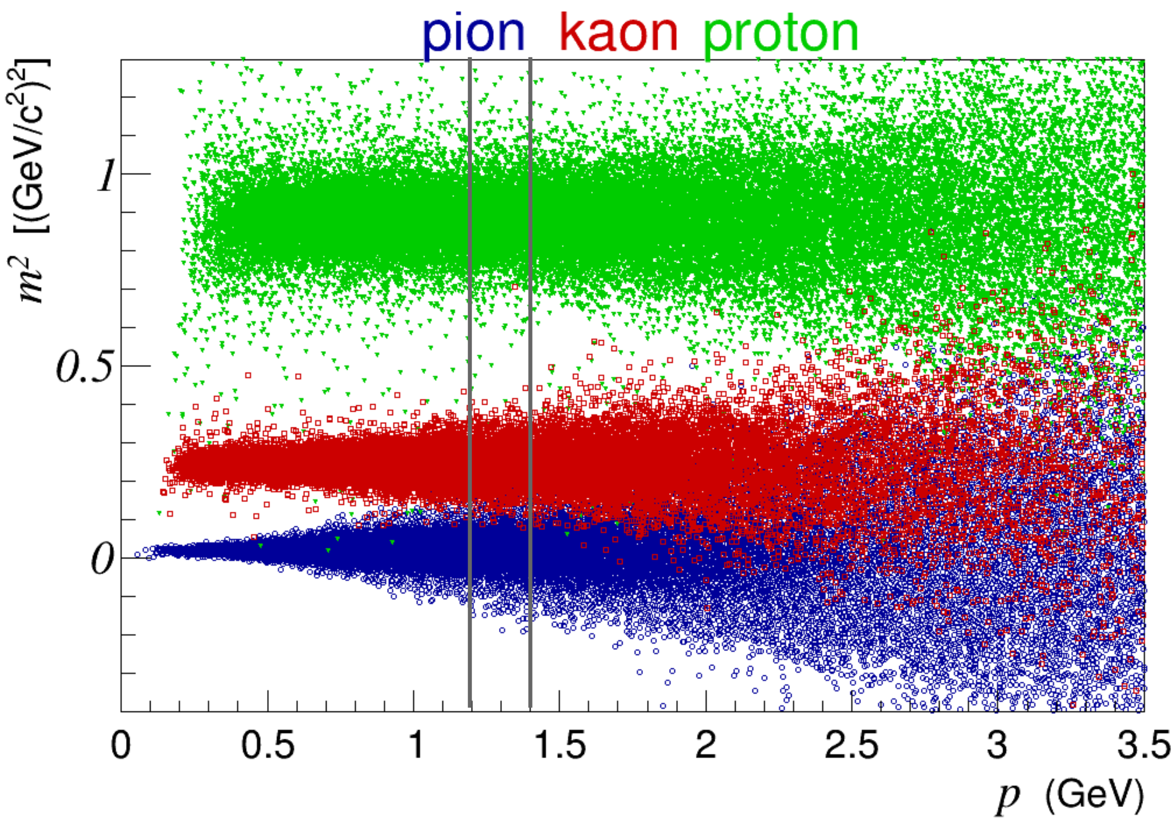
$$m^2 = \frac{p^2}{c^2}\left[\frac{t_{TOF}^2 c^2}{L^2} - 1\right]$$

$$\sigma_{m^2}^2 = 4m^4\left(\frac{\sigma_p}{p}\right)^2 + 4E^4\left(\frac{\sigma_t}{t}\right)^2 + 4E^4\left(\frac{\sigma_L}{L}\right)^2$$

$\sigma \sim 2\%$ | $\sigma_{TOF} = 60\ ps$ | from reconstruction

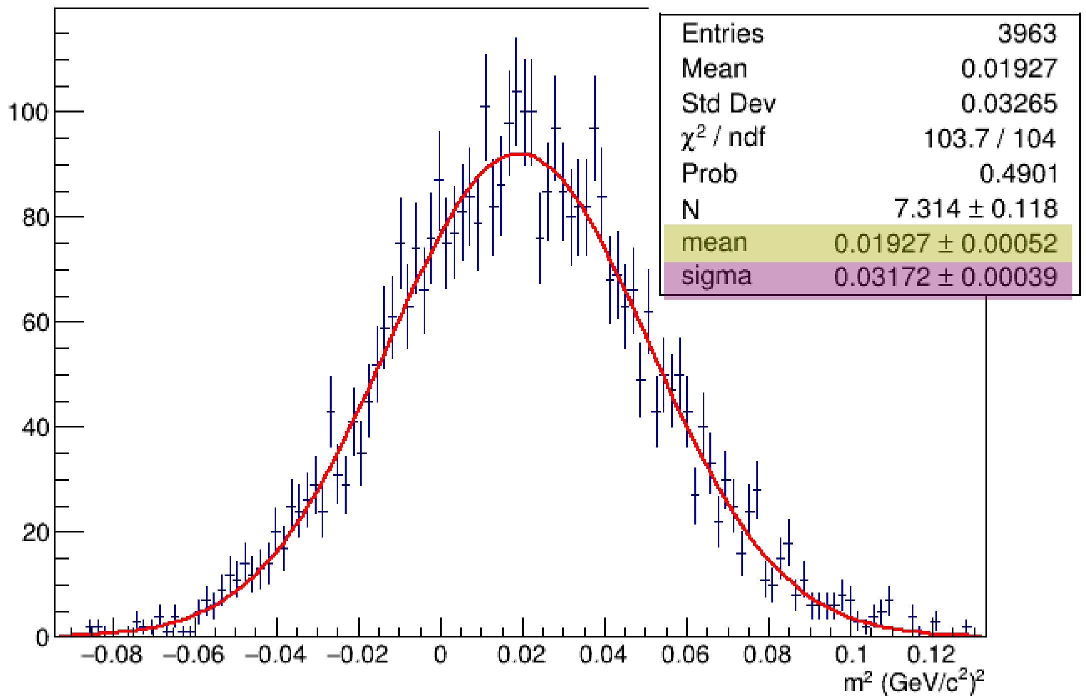
Parametrization

Fit m^2 distribution in 40 bins of momentum



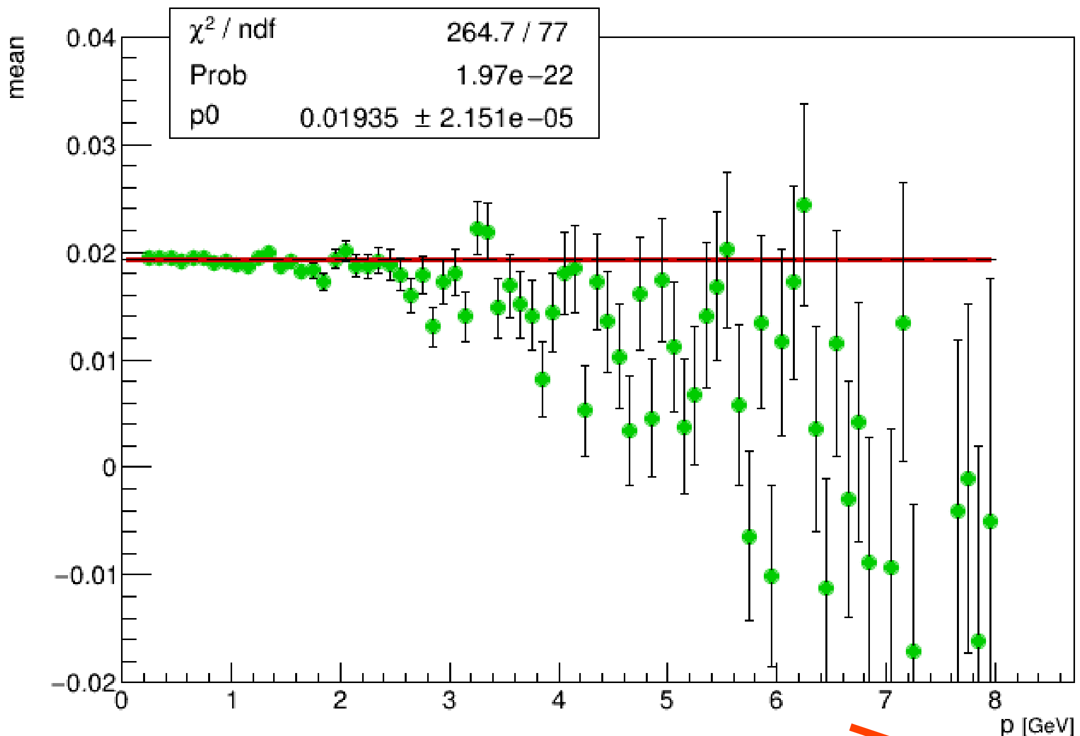
pion

P_{bin}= 1.2 – 1.4 GeV

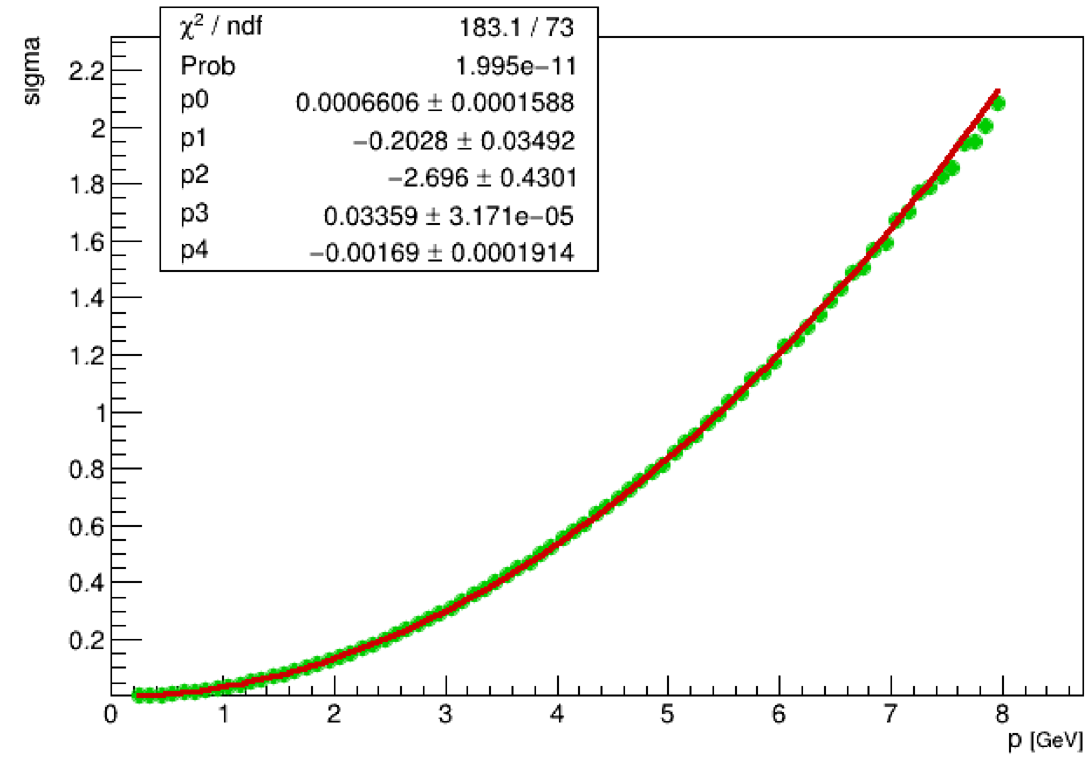


Pion parametrization

mean



sigma



Observed signal from a detector

$$m^2=\frac{p^2}{c^2}\left[\frac{t_{TOF}^2 c^2}{L^2}-1\right]$$

$$n_{\sigma_\alpha^i}=\frac{S_\alpha-\hat{S}(H_i)_\alpha}{\sigma_\alpha^i}$$

$\alpha=STRAW, TOF\ldots$

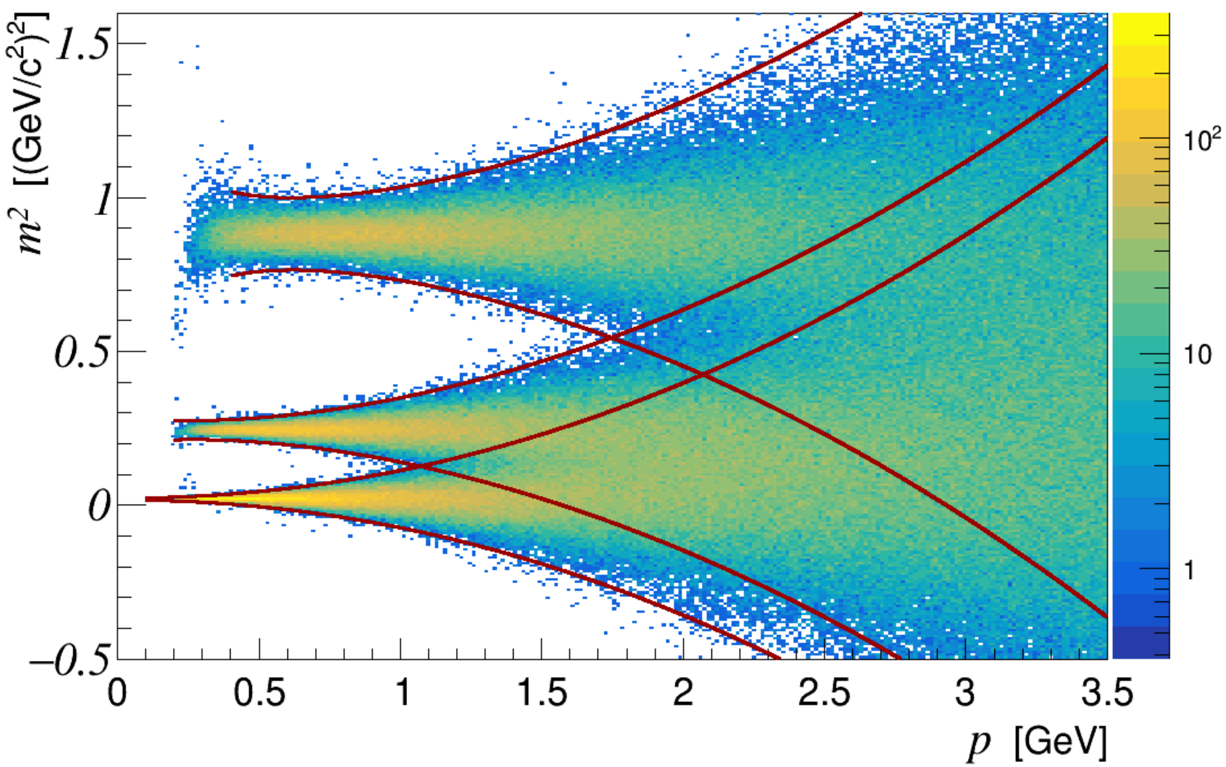
$i=\pi, K, p\ldots$

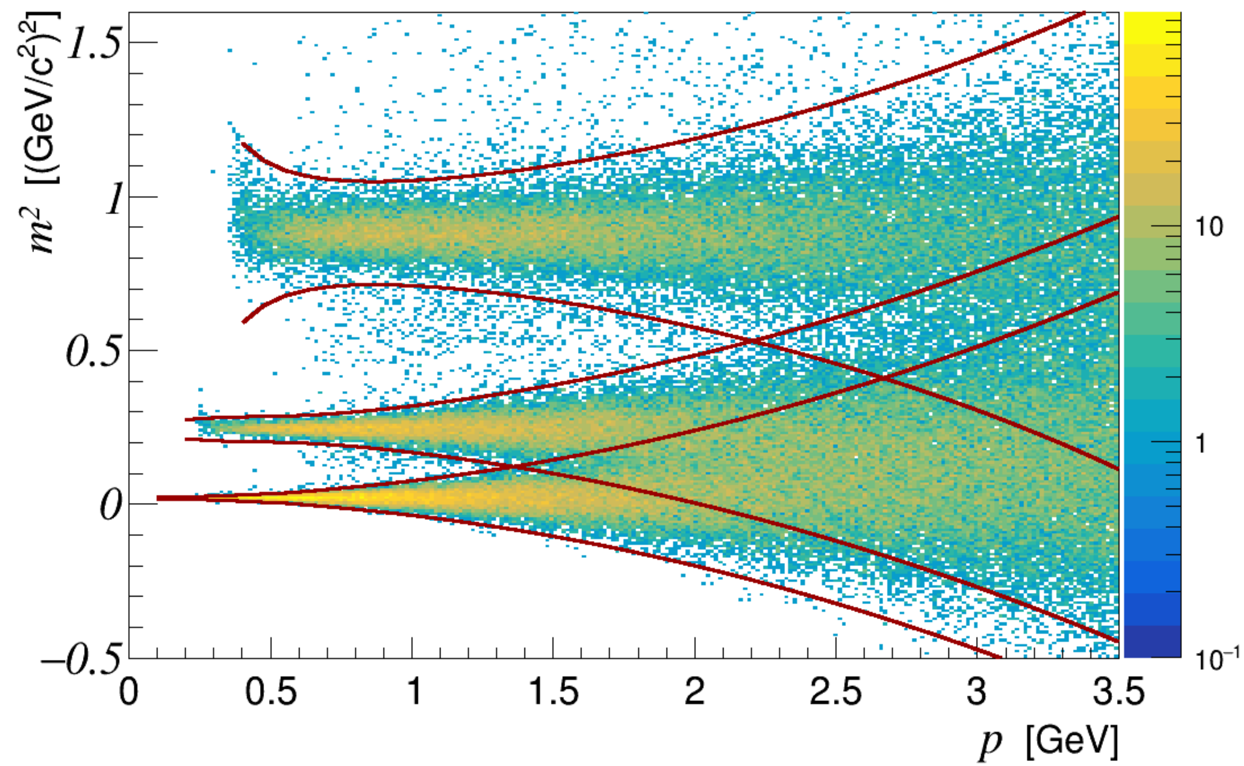
m^2 vs p

Barrel

End-Cap

curves with $3\,\sigma$

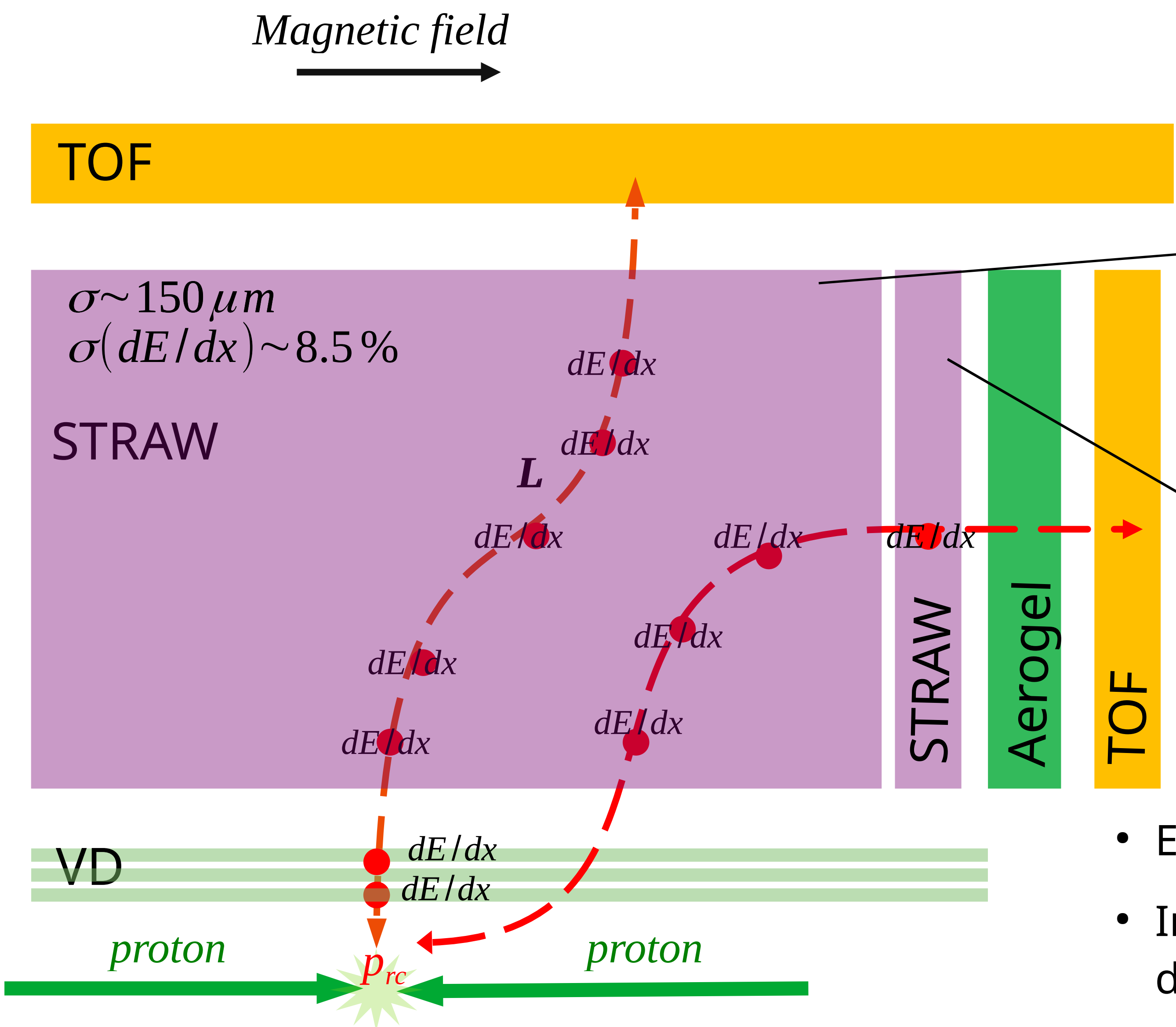


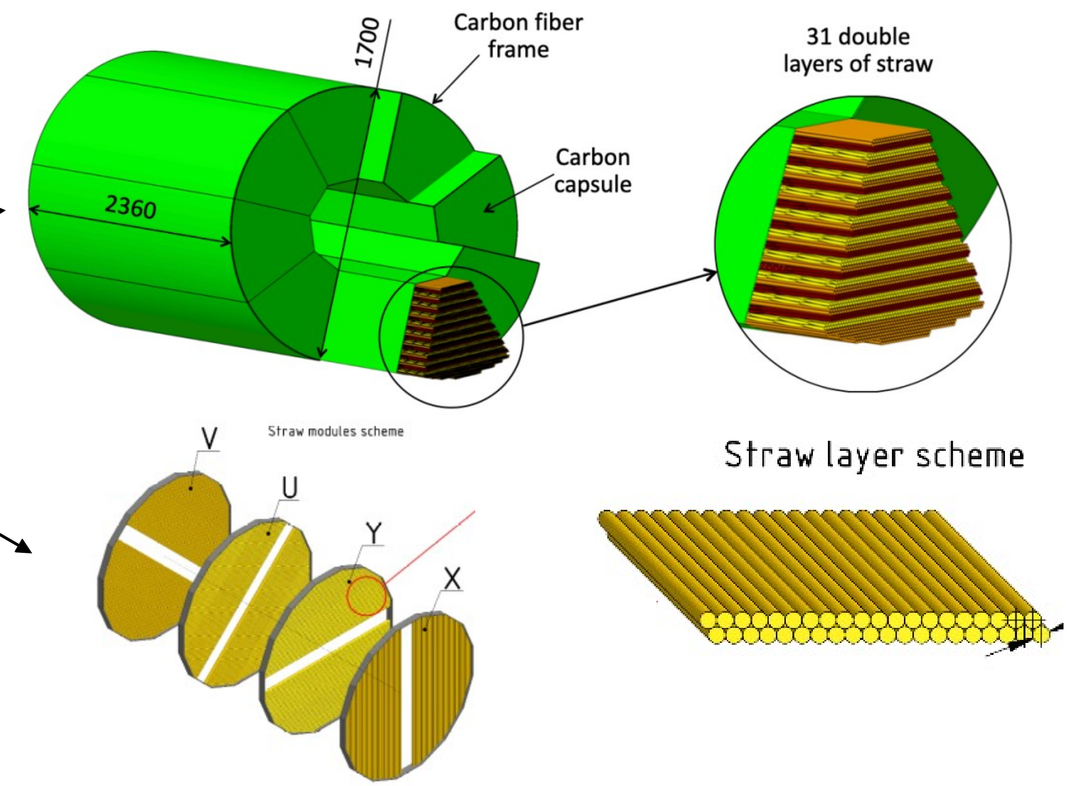


n_{sigma}=3	p_{max}(pion/kaon), GeV	p_{max}(kaon/proton), GeV
Barrel	1.2	2.0
End-Cap	1.6	2.7

Straw tracker

Barrel: 31 double layers
End-Cap: 8 double layers



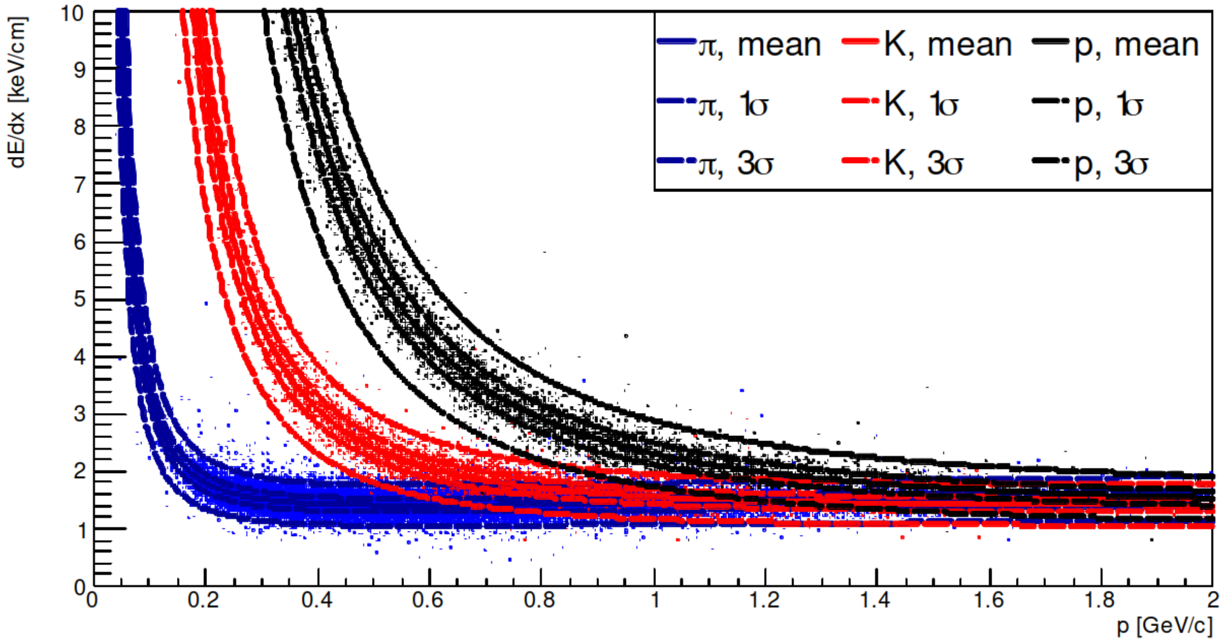


- Each track crosses several straw tubes.
- In simplest case, we calculate mean value of dE/dx for each track
- Energy loss per unit path length (dE/dx) is described by the Bethe-Bloch formula

Parametrization dE/dx vs p for STRAW

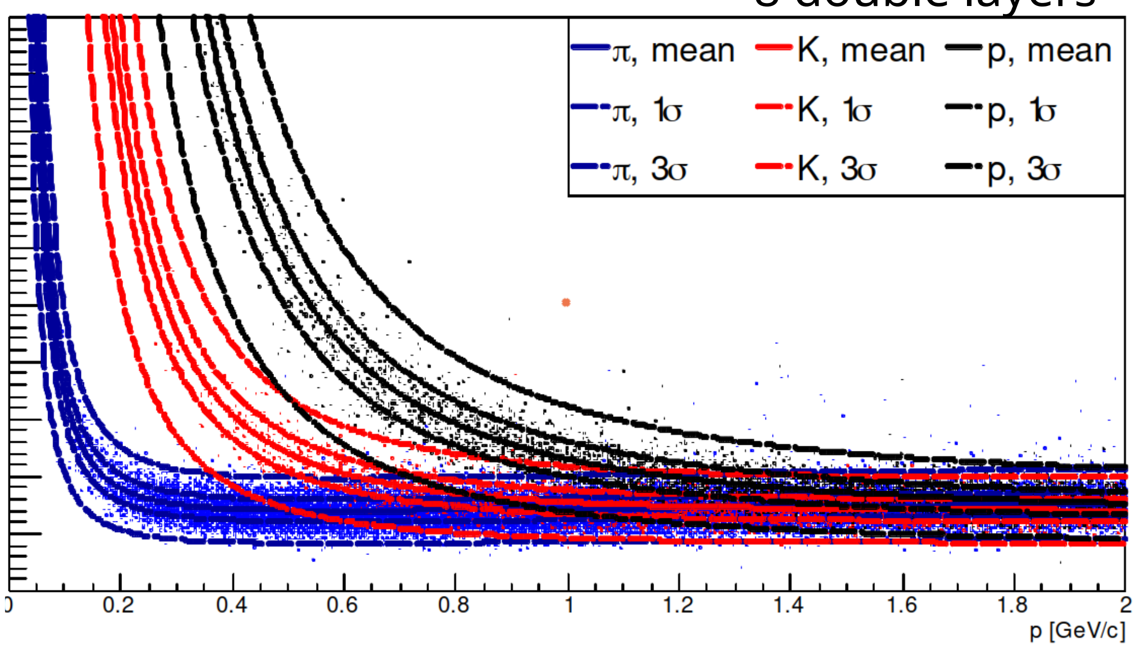
Barrel

31 double layers



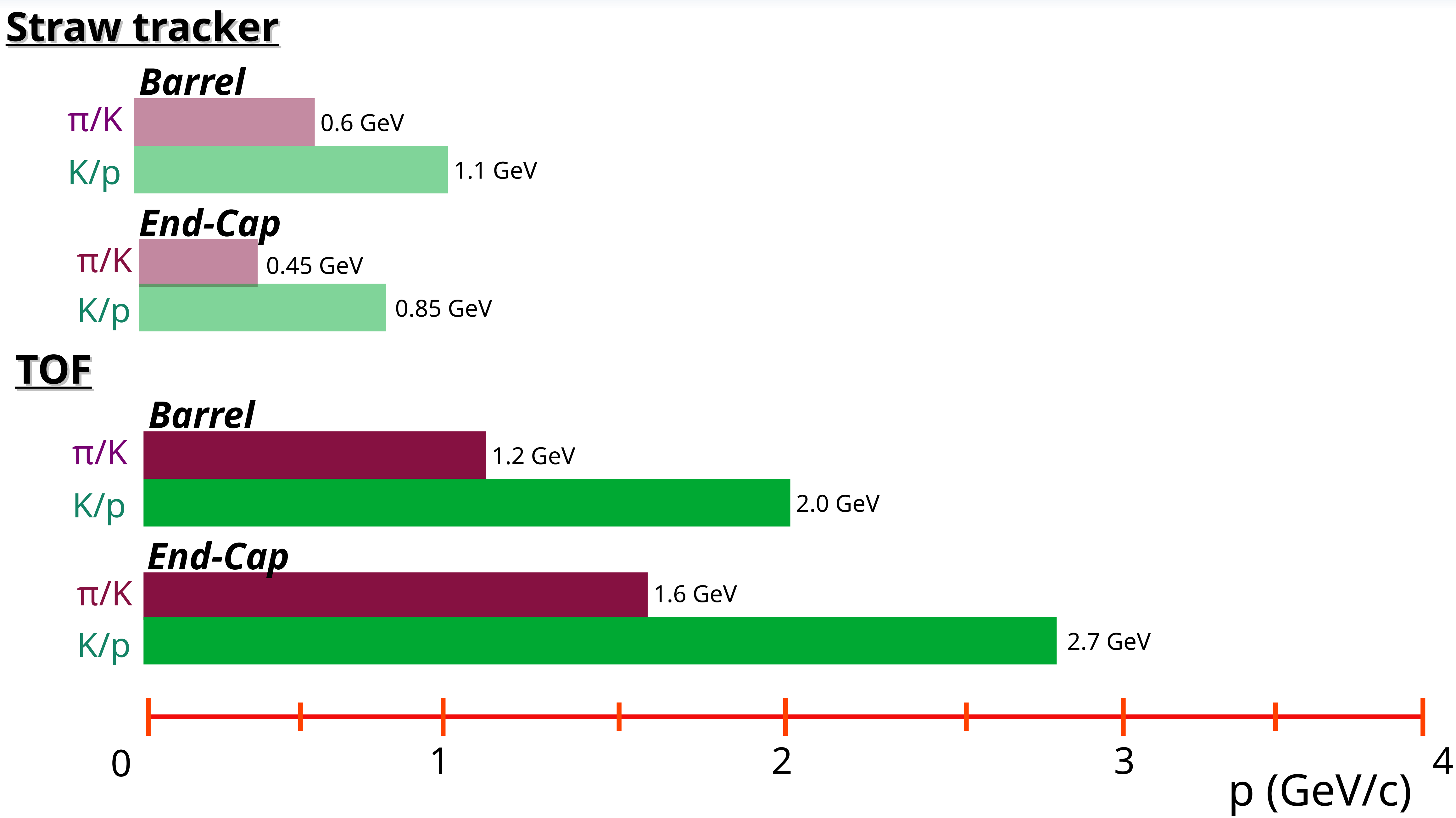
End-Cap

8 double layers



n_{sigma}=3	p_{max}(pion/kaon), GeV	p_{max}(kaon/proton), GeV
Barrel	0.6	1.1
End-Cap	0.45	0.85

Particle identification in SPD



PID methods

1. Define a cut on $n\sigma<k$, k=1,2,3 in single detector analysis
2. Define a multiple-cuts on $n\sigma$ for several detectors
3. Define a cut on a combined-$n\sigma$ variable

$$n\,\sigma_{comb}=\sqrt{n\,\sigma_{STRAW}^{2}+n\,\sigma_{TOF}^{2}\ldots}$$

4. The Bayesian approach:

   combine information from different PID detectors,

   with and without Gaussian responses

Bayes approach

S - a raw signal from a detector
S(H_i) - expected average signal for a given species $H_i(\pi, K, p, \ldots)$

The Bayes theorem

probability that the particle is of species H_i, given $\vec{S}$

$$P(H_i|\vec{S}) = \frac{P(\vec{S}|H_i)\,C(H_i)}{\sum_{k=\pi,K,p} P(\vec{S}|H_k)\,C(H_k)}$$

a posterior probability

A priori probability for H_i

$$P(S|H_i) = \frac{1}{\sqrt{2\pi}\sigma} e^{\frac{-(S-S(H_i))^2}{2\cdot\sigma^2}}$$

One detector

The conditional probability that a particle of species H_i produces a signal S (in this case expressed with a Gaussian response)

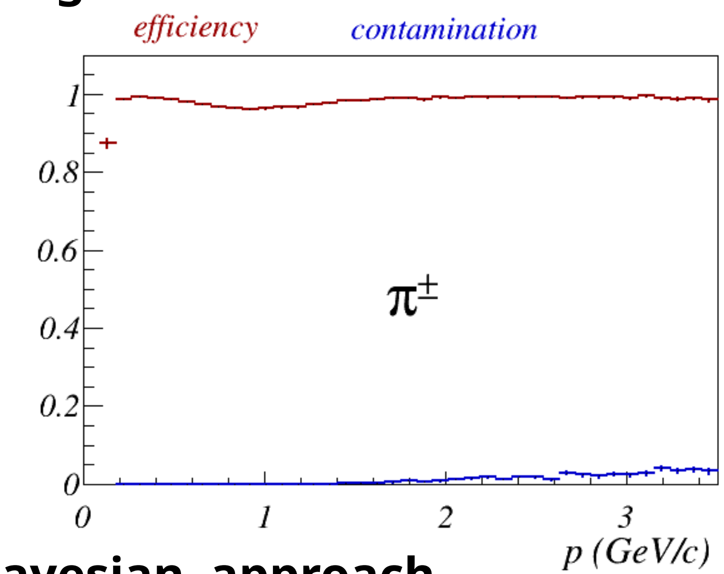
$$P(\vec{S}|H_i) = \prod_{\alpha=TOF,STAW,\ldots} P_\alpha(S_\alpha|H_i)$$

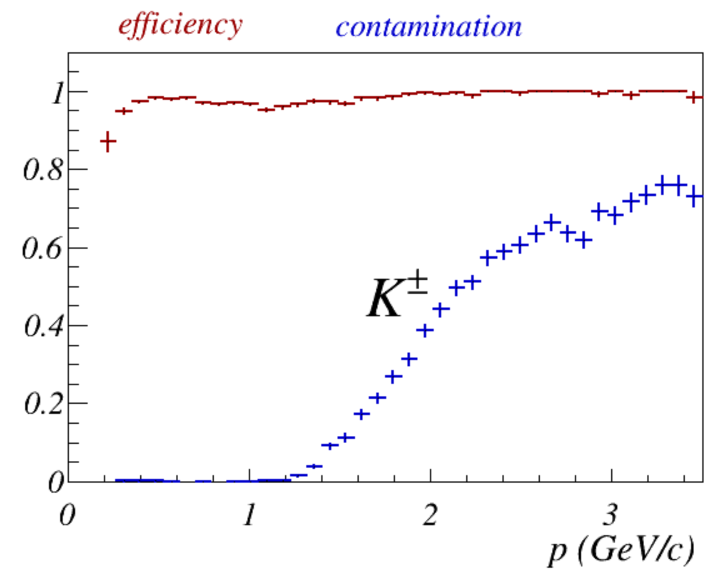
Many detectors

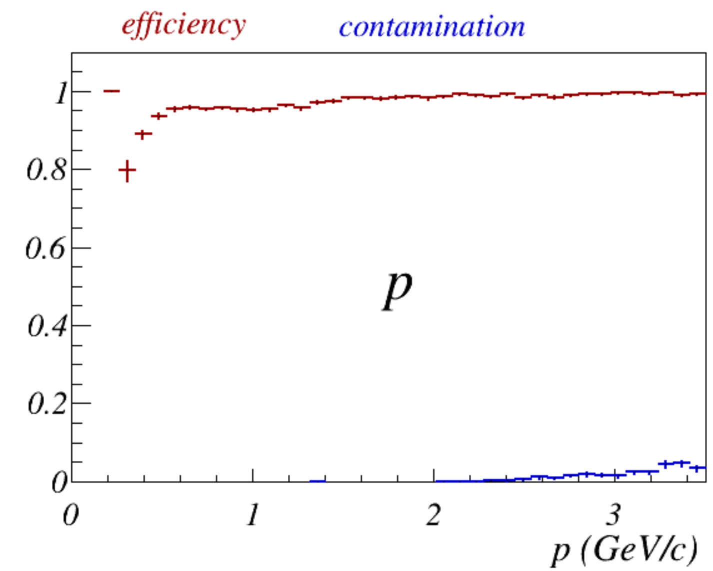
The conditional probability that a particle of species H_i produces the set of signals

n-sigma and Bayesian approach for STRAW and TOF

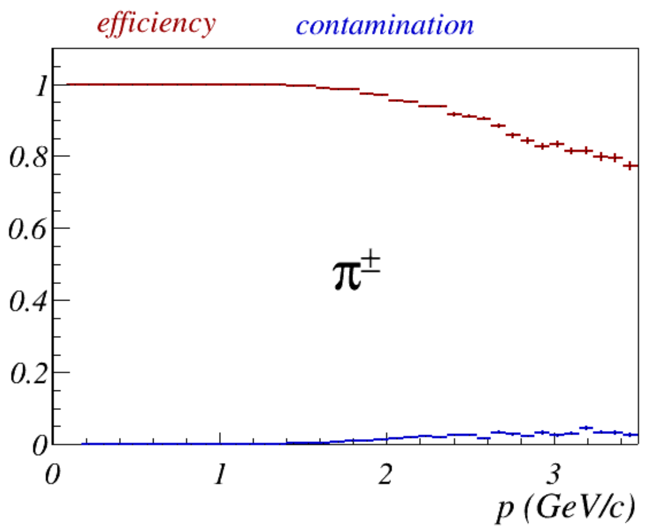
n-sigma

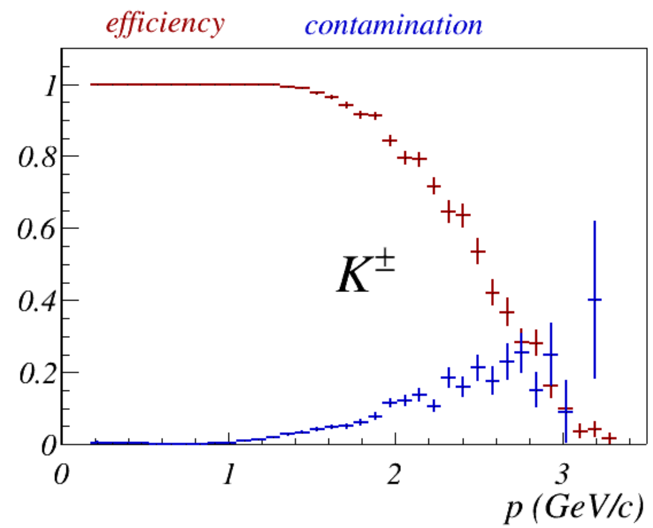


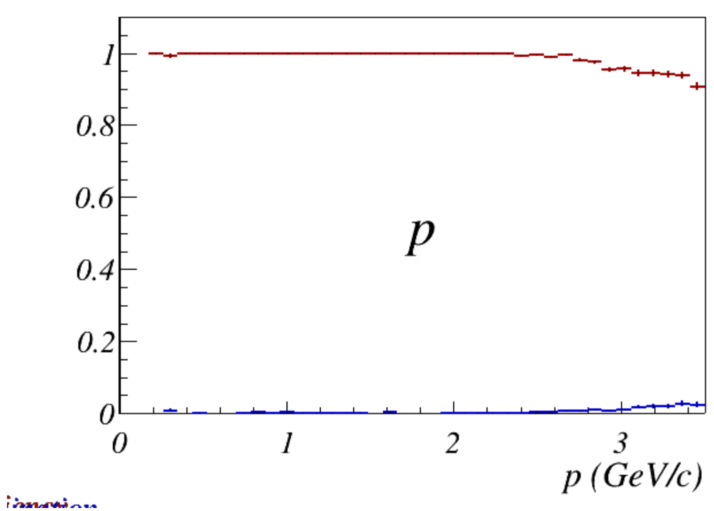




Bayesian approach







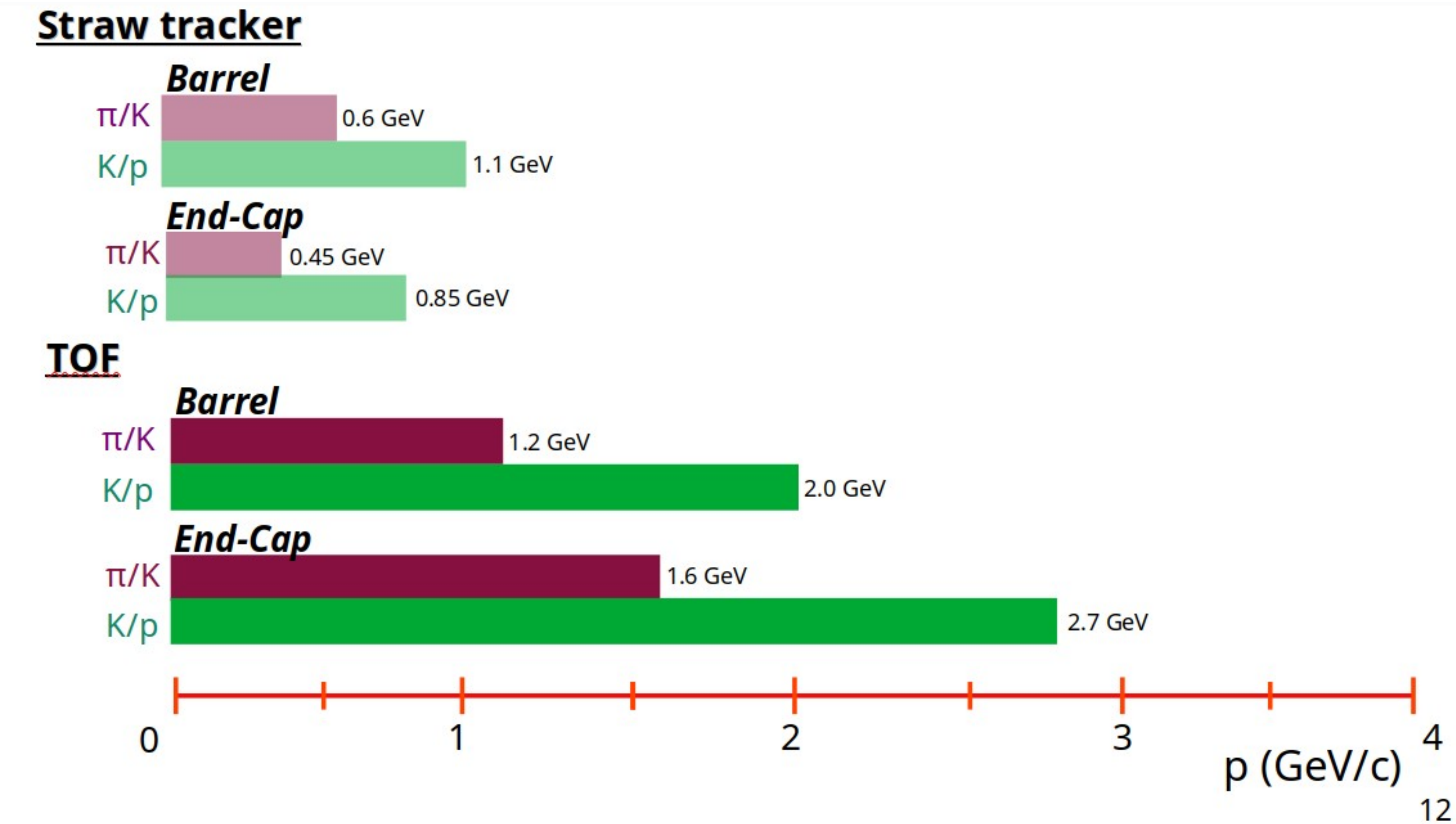
n-sigma: fixed cut -> a constant efficiency

Bayesian: the selection on probability allows to maximize(minimize) efficiency(contamination)

Conclusion

- Methodology for particle identification (pions, kaon and protons) in SPD for straw tracker and time-of-flight system was developed.

- The maximum limits of applicability for particle identification straw tracker and TOF have been determined.



Thank you for your attention