dE/dx and TOF performance at SPD

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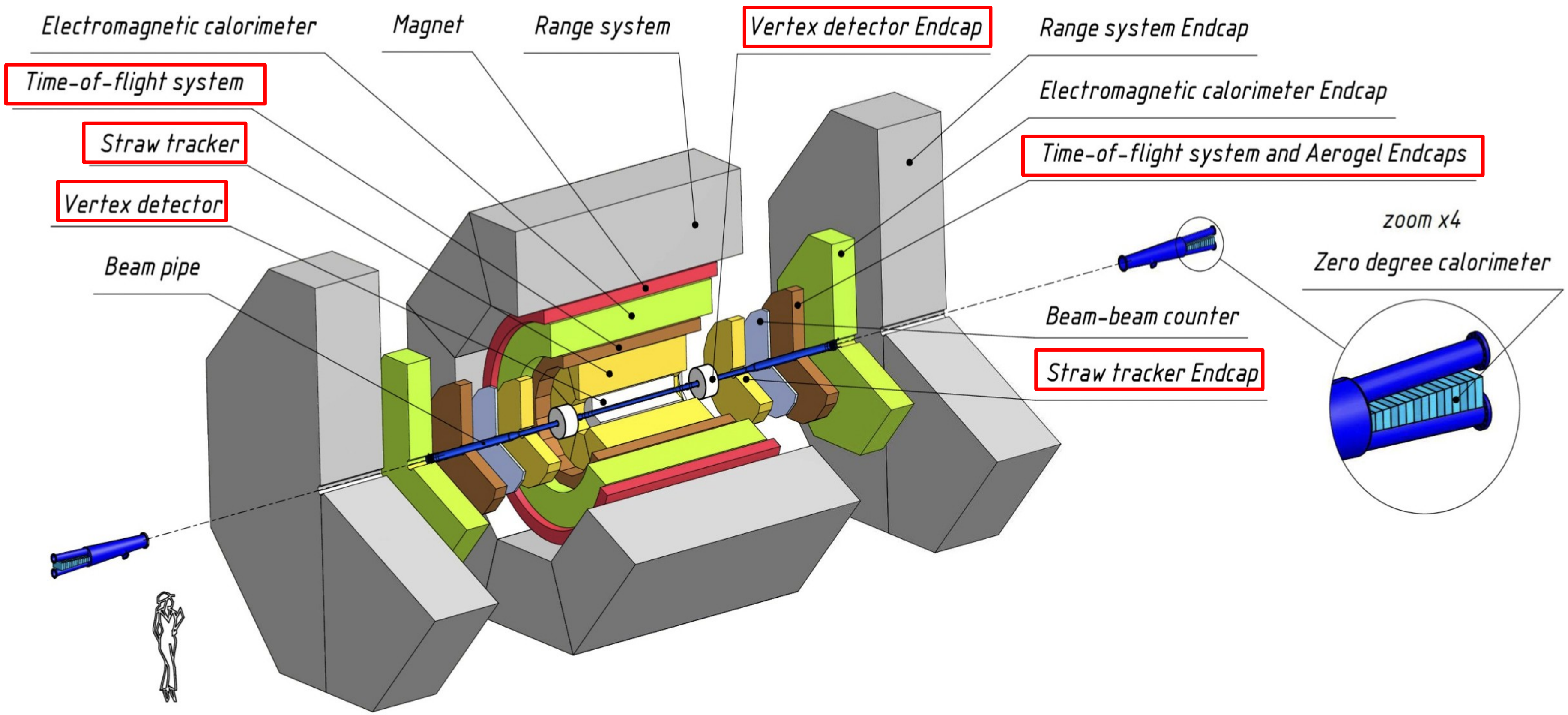
SPD Collaboration Meeting
6.10.2022

Particle identification in SPD

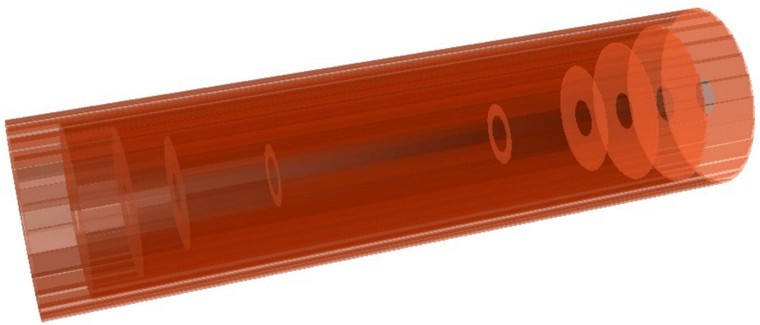


Not discussed in this talk: particle identification via **RS** (muons) and **ECAL** (electron and photon)

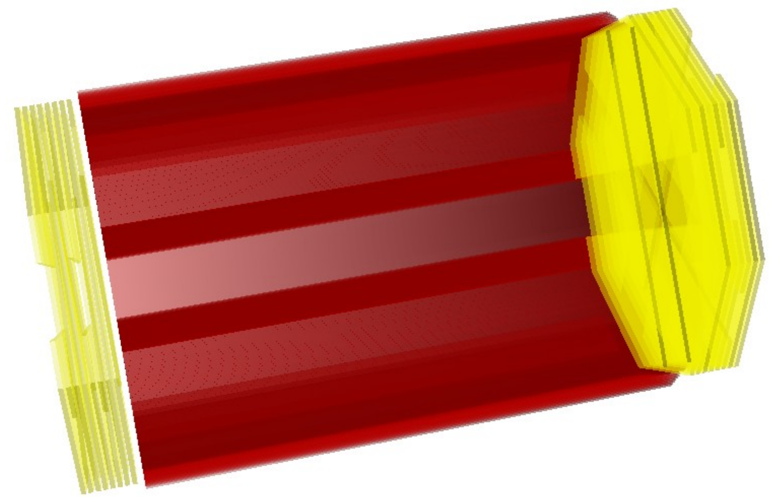
Particle identification in SpdRoot

VD (5 layers DSSD)

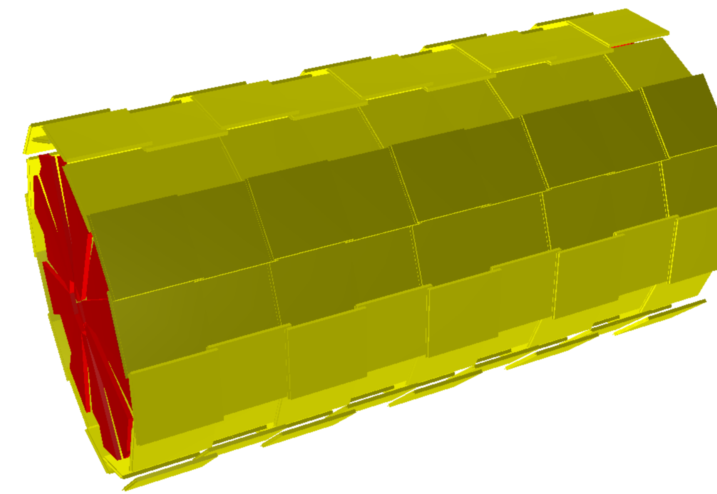
(TDR→3 layers)



Straw

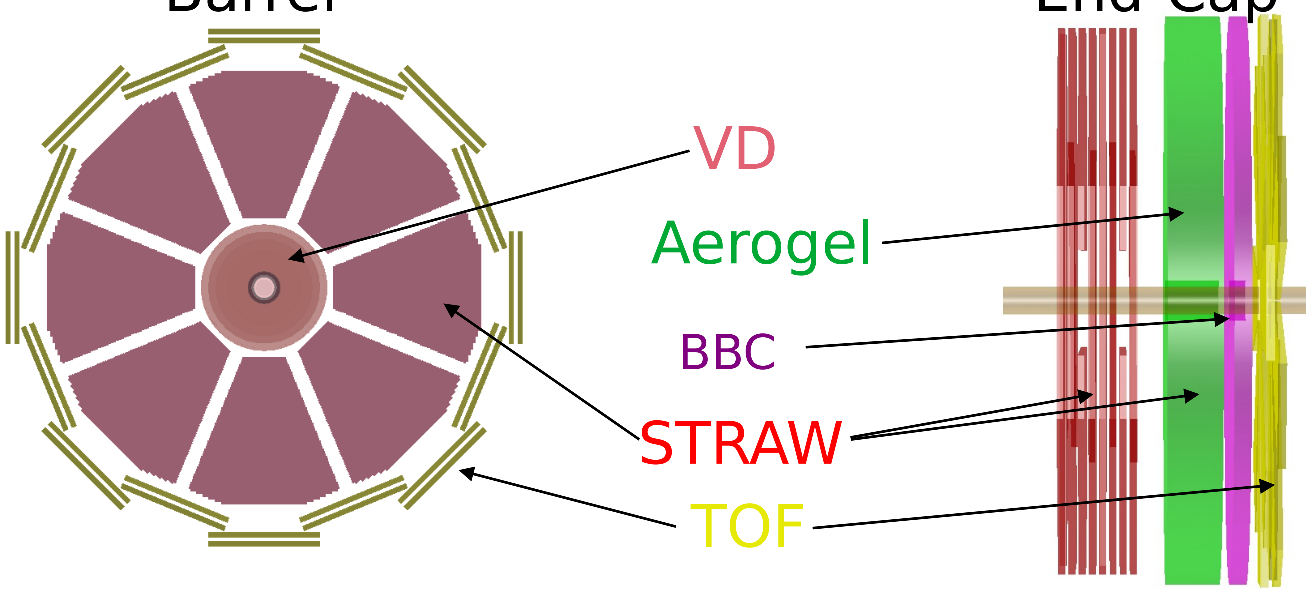


TOF



Barrel

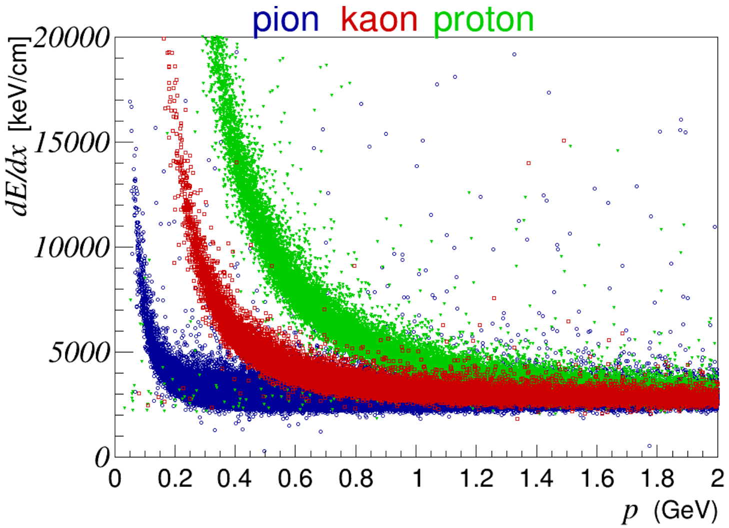
End-Cap



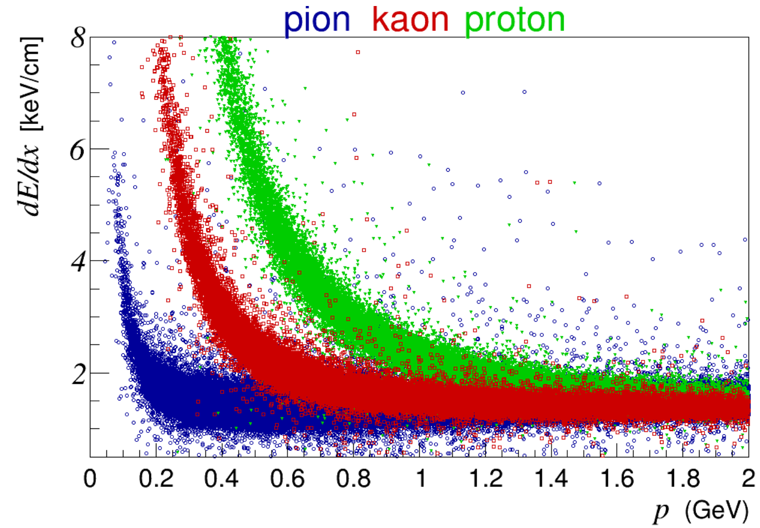
Aerogel

Particle identification in SpdRoot

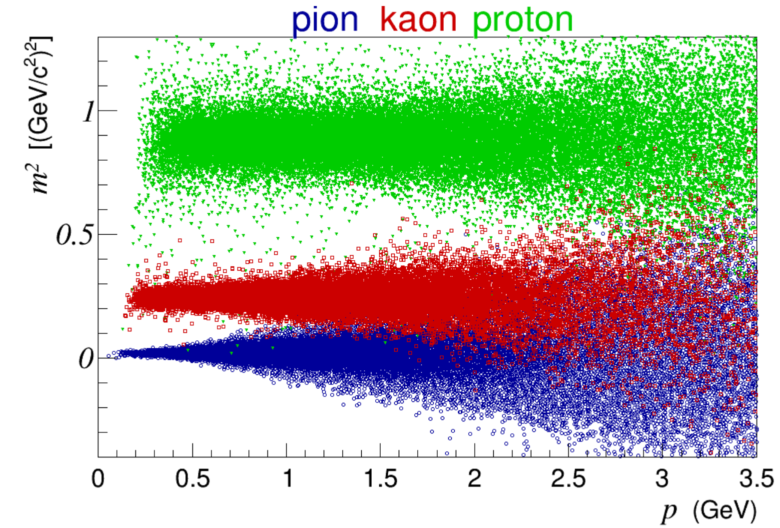
VD



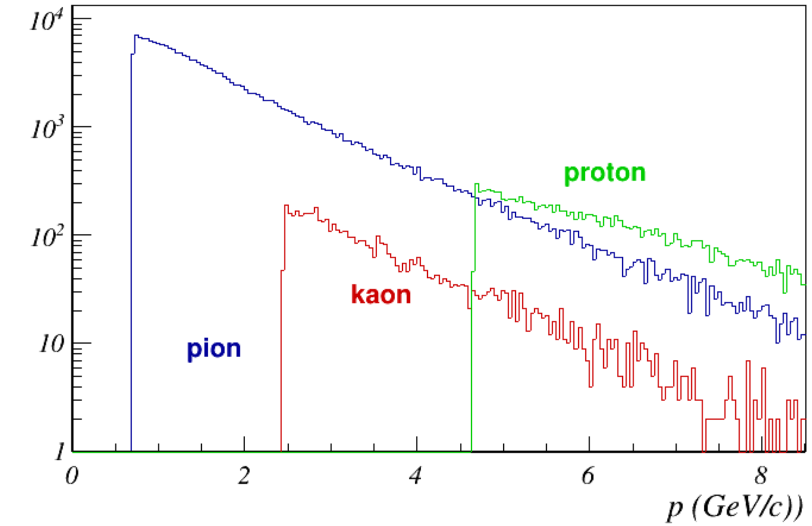
Straw



TOF



Aerogel



Detector	Signal
VD	ionization energy loss (dE/dx)
Straw	ionization energy loss (dE/dx)
TOF	time of flight
Aerogel	Cerenkov radiation

Typical PID approaches

For a detector with a Gaussian response

What we expect for a given *m* hypothesis

Observed signal from a detector

PID discrimination variable

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

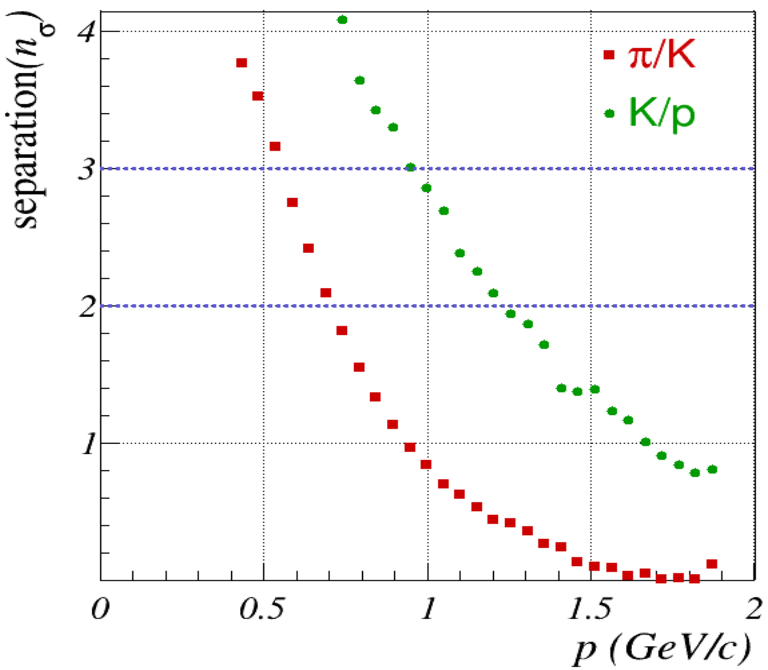
$\alpha = VD, STRAW, TOF \ldots$

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

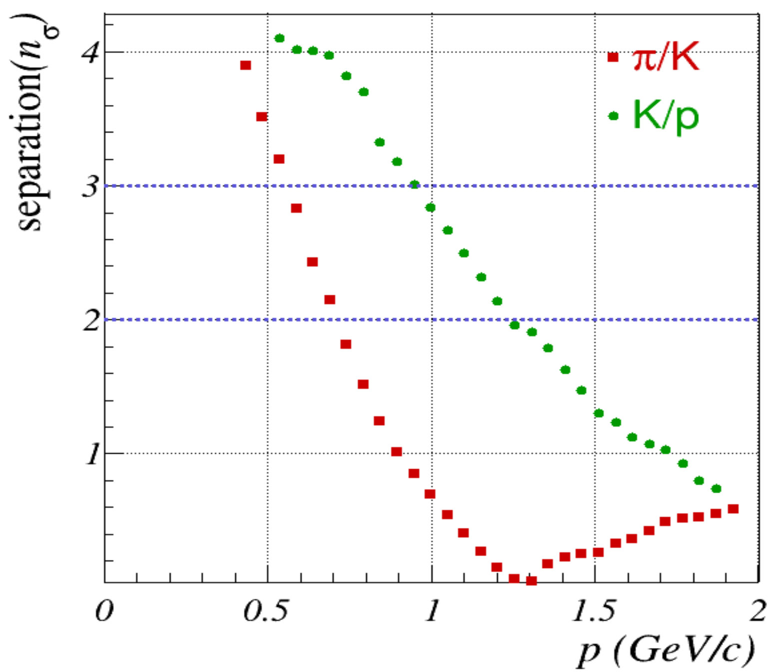
detector resolution

Separation power

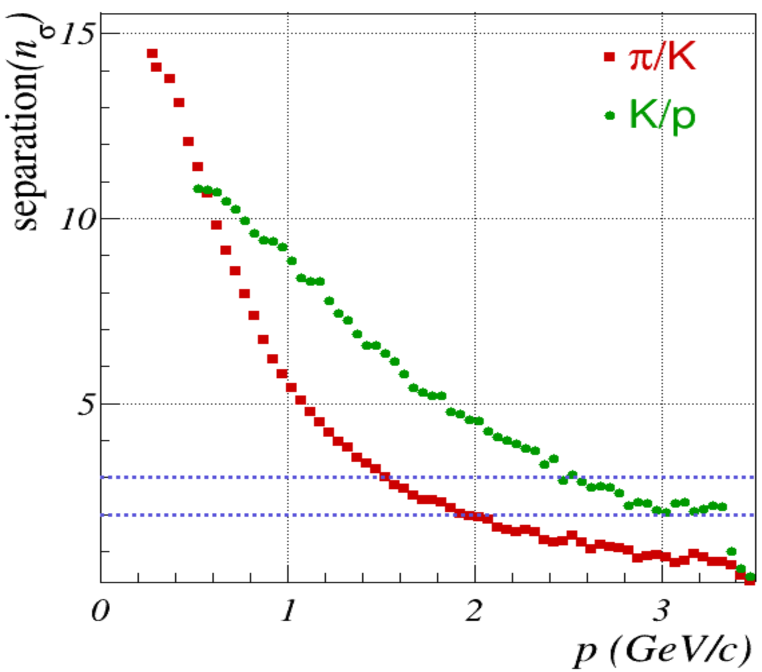
VD



Straw

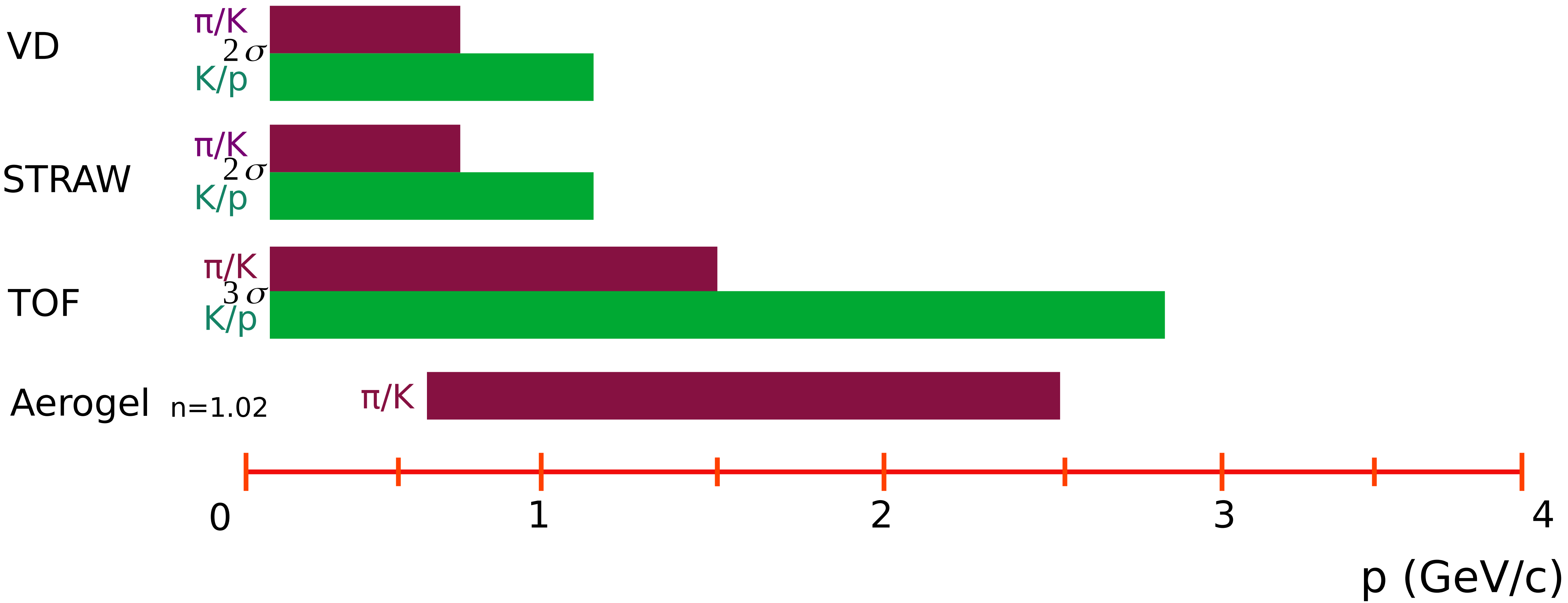


TOF

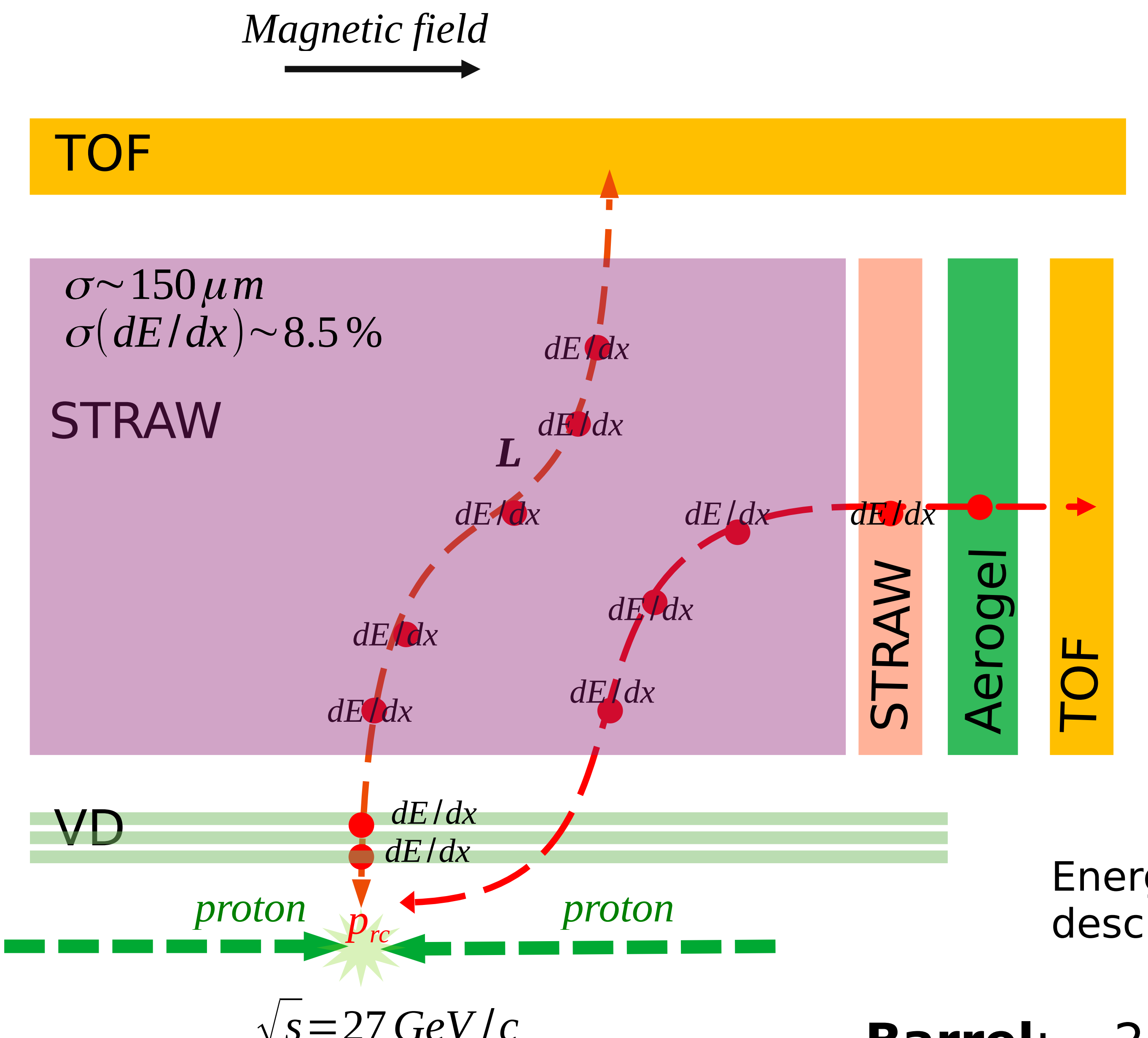


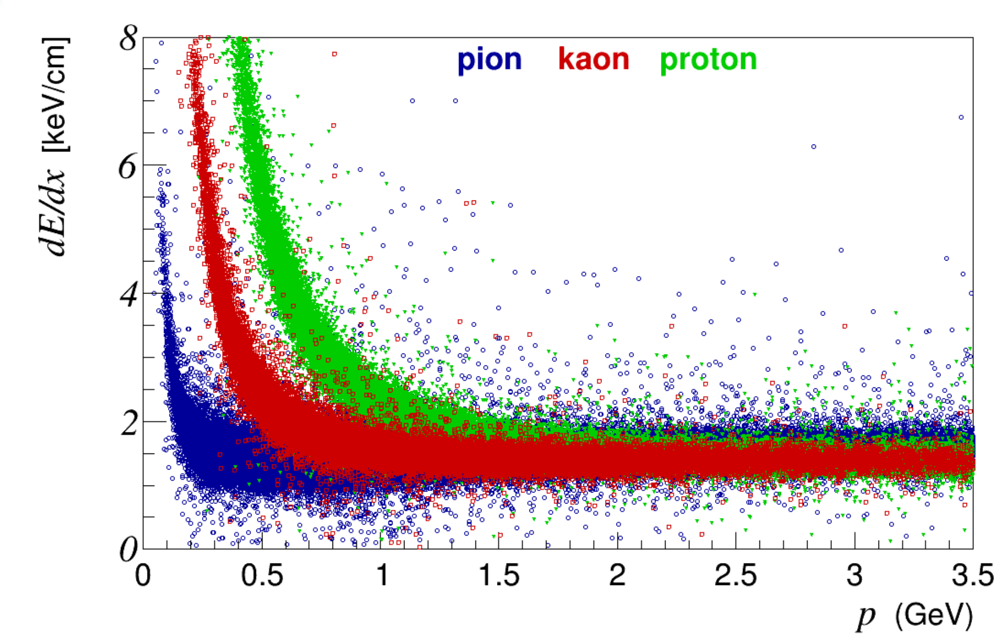
$$separation = \frac{\mu_i - \mu_j}{\sqrt{\sigma_i^2 + \sigma_j^2}}$$

Particle identification in SPD



Straw Tracker





Each track crosses several straw tubes.

In simplest case, we calculate mean value of dE/dx for each track

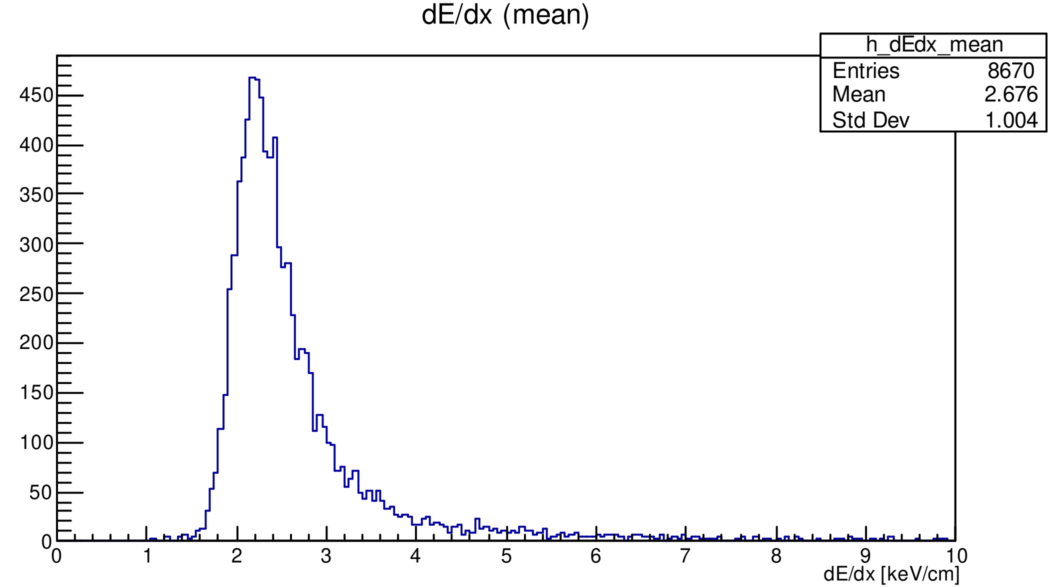
Energy loss per unit path length (dE/dx) is described by the Bethe-Bloch formula

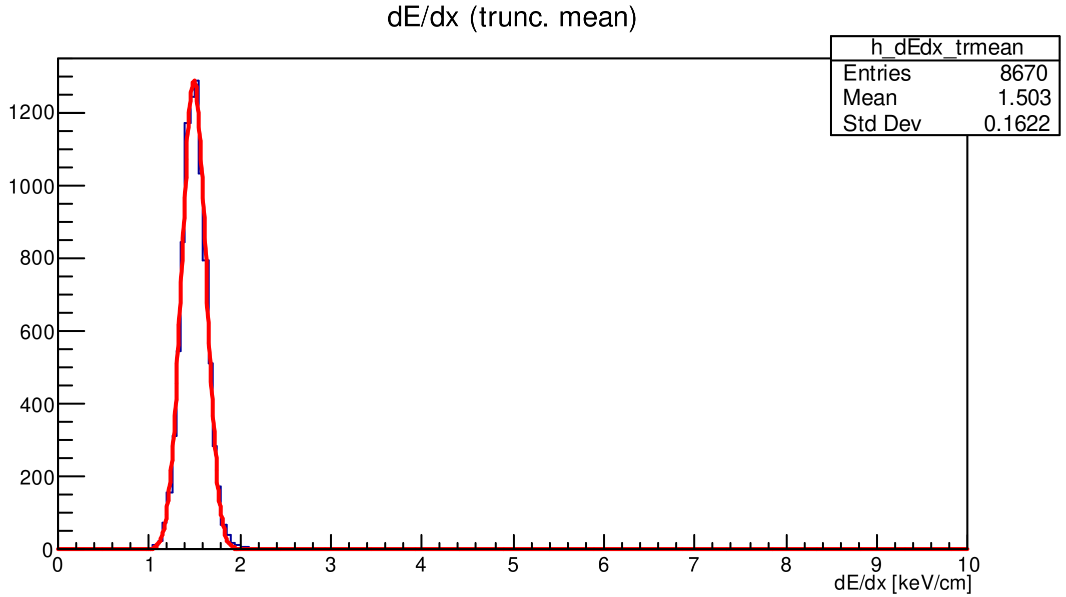
Barrel: 29 double layers
End-Cap: 8 double layers

Analysis for VD is similar

Truncated mean method for STRAW

Truncated mean is used to remove fluctuations due to the tail towards higher deposits ("Landau-like")

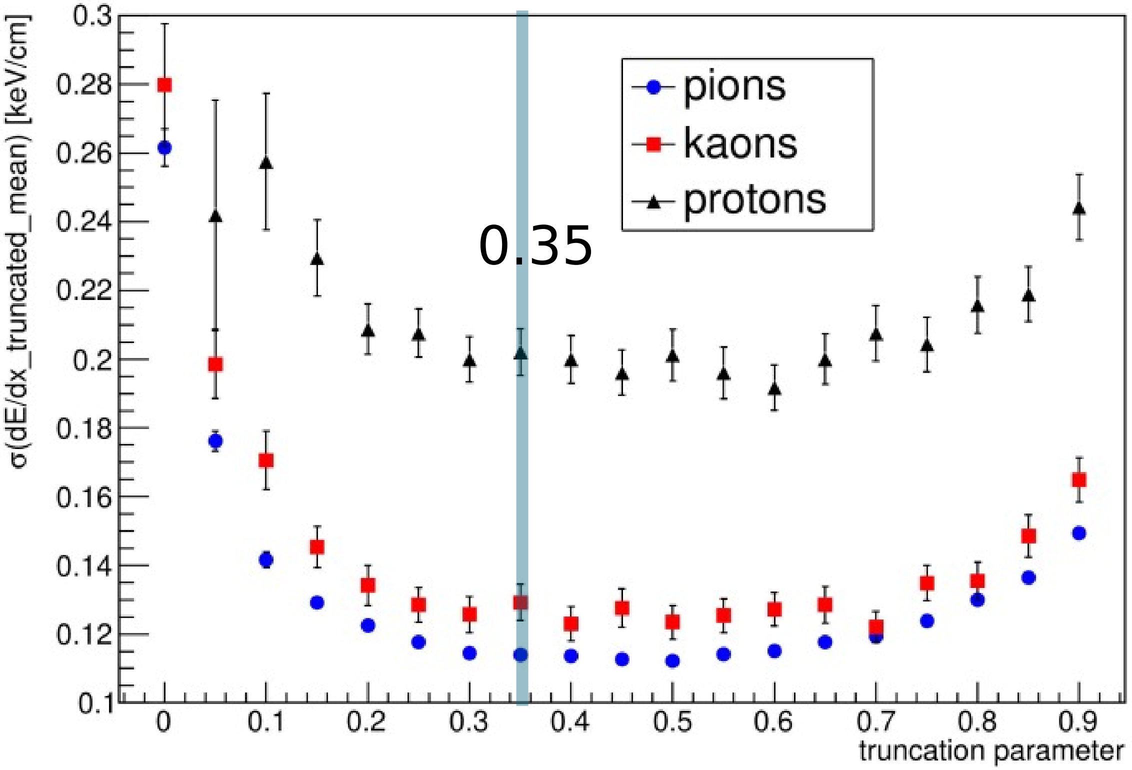




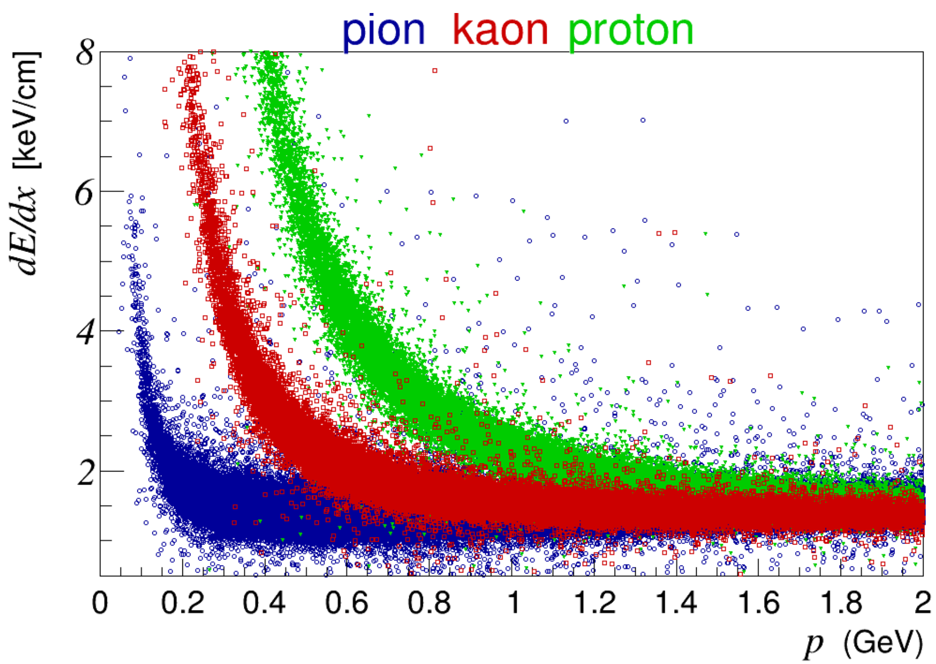
Example shown here for pions:

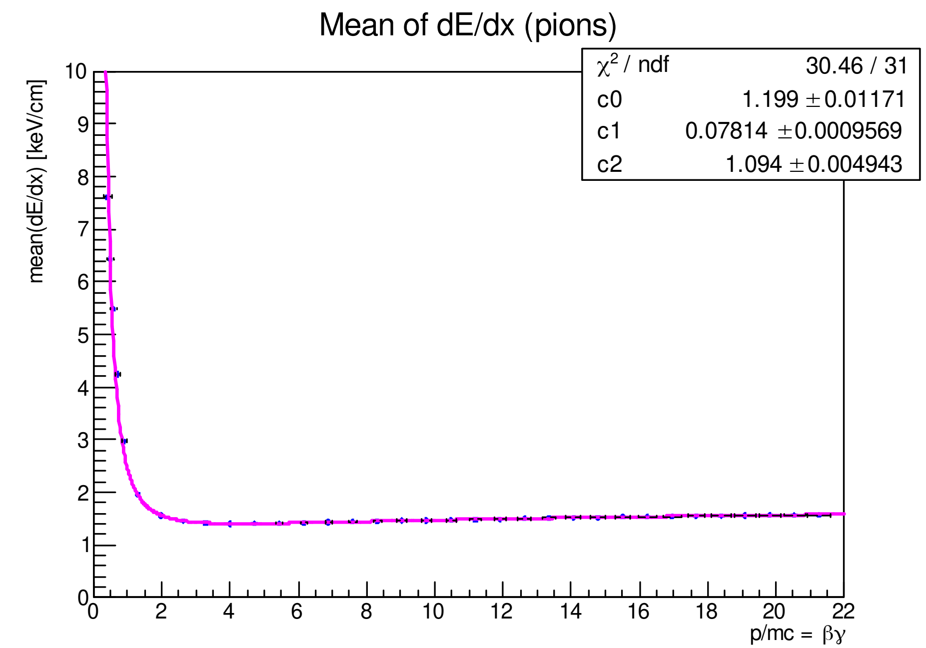
- p_0 = 0.312 GeV/c
- truncation parameter 0.35.

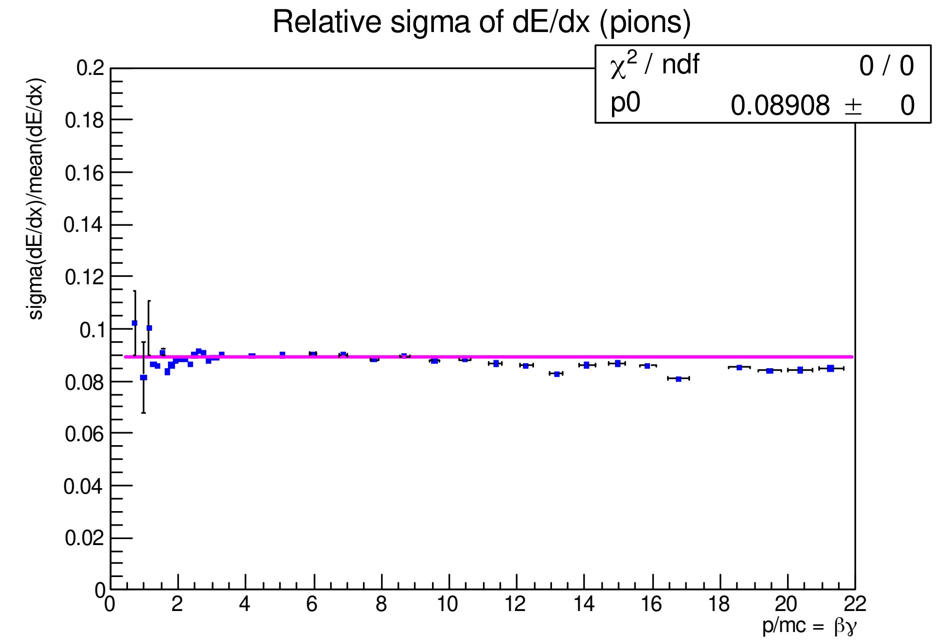
Truncated mean dE/dx distribution sigma



How to parametrize pions in STRAW







Parameterization of truncated mean dE/dx distribution

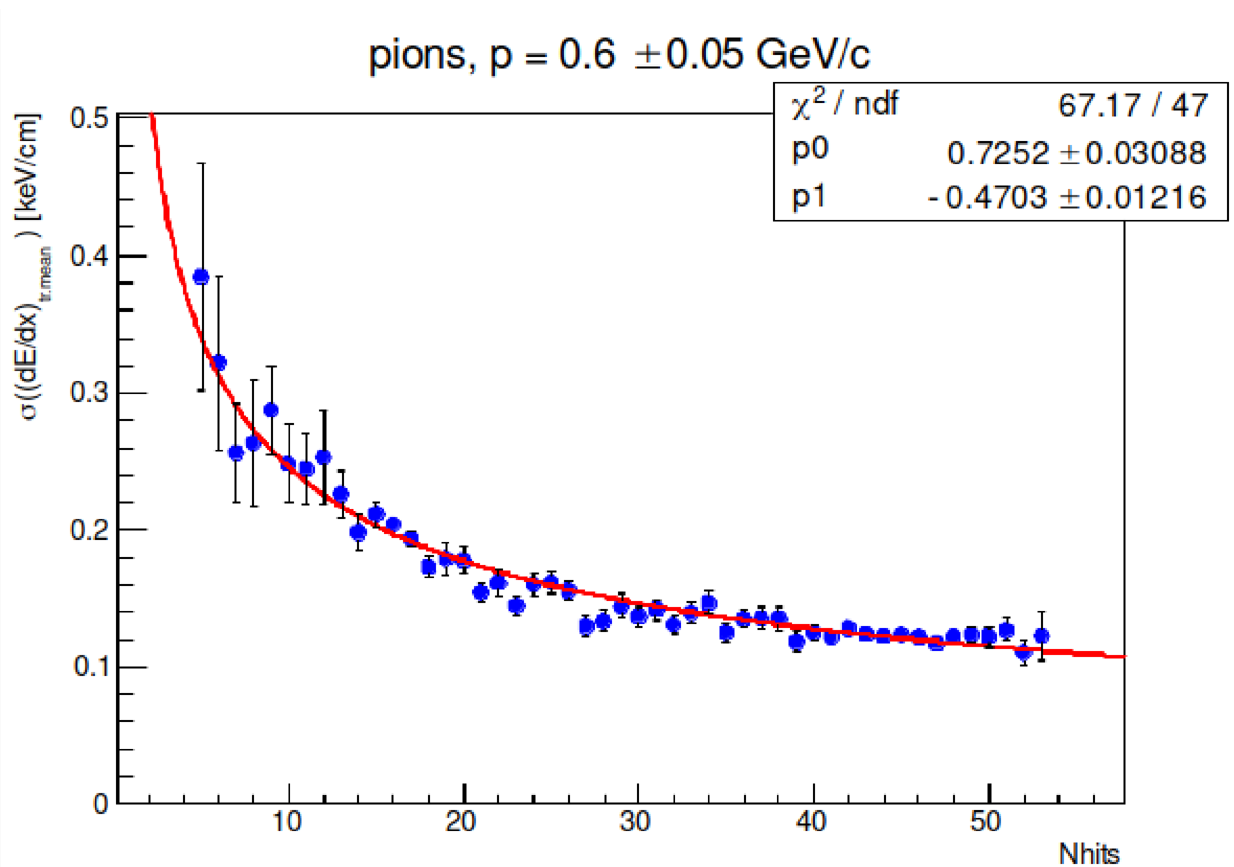
$$\text{mean} = \frac{c_0}{\beta^2} + \frac{c_1}{\beta^2}\ln(\beta\gamma) - (c_0 - c_2)\left(1 + \frac{\ln(\beta^2)}{\beta^2}\right)$$

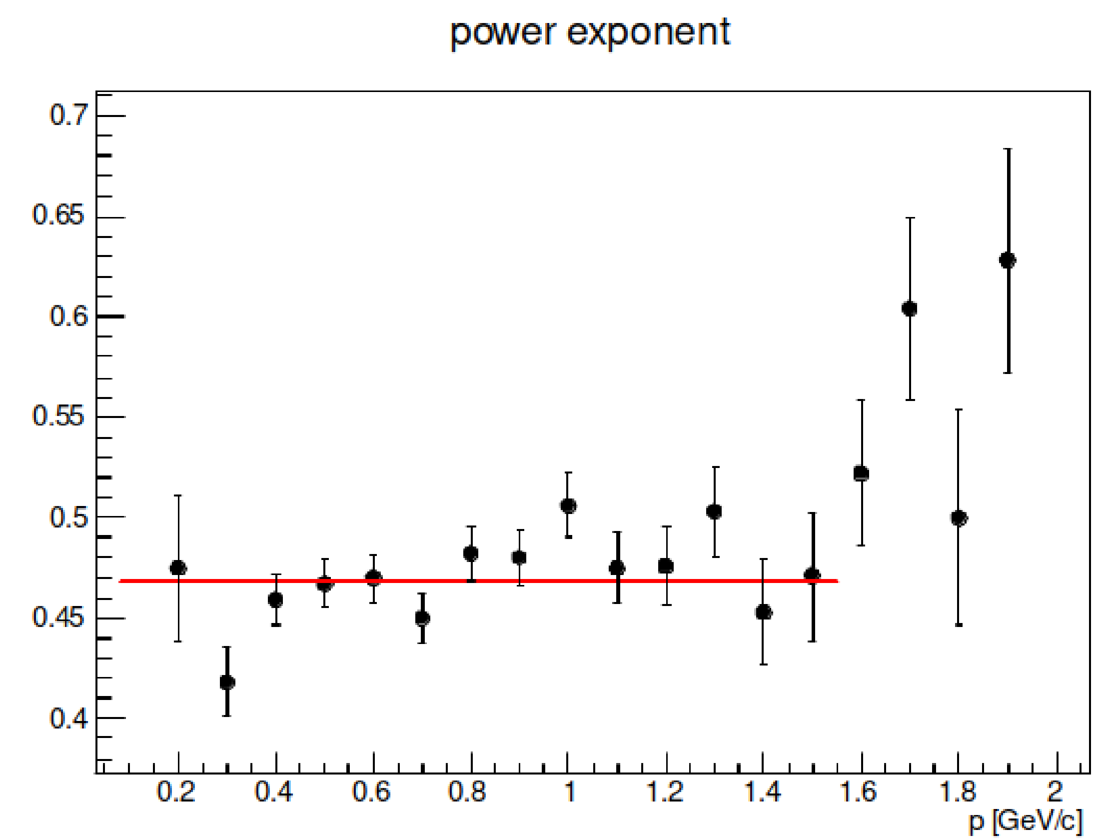
$$\beta\gamma = p/m, \quad \beta^2 = \frac{(p/m)^2}{(p/m)^2 + 1}$$

$$\sigma = R \cdot \text{mean}$$

Dependence of $\sigma((dE/dx)_{trunc.mean})$ on number of hits

- Naive expectation: $\sigma \sim 1/\sqrt{N_{hits}}$

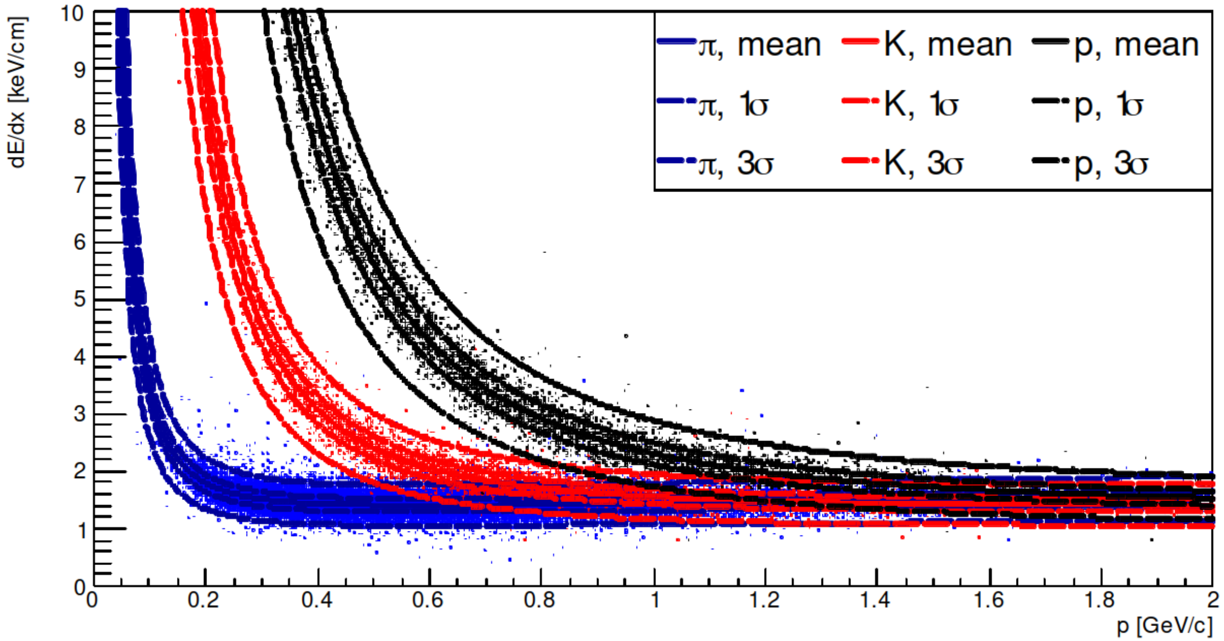




Parametrization dEdx vs p for STRAW

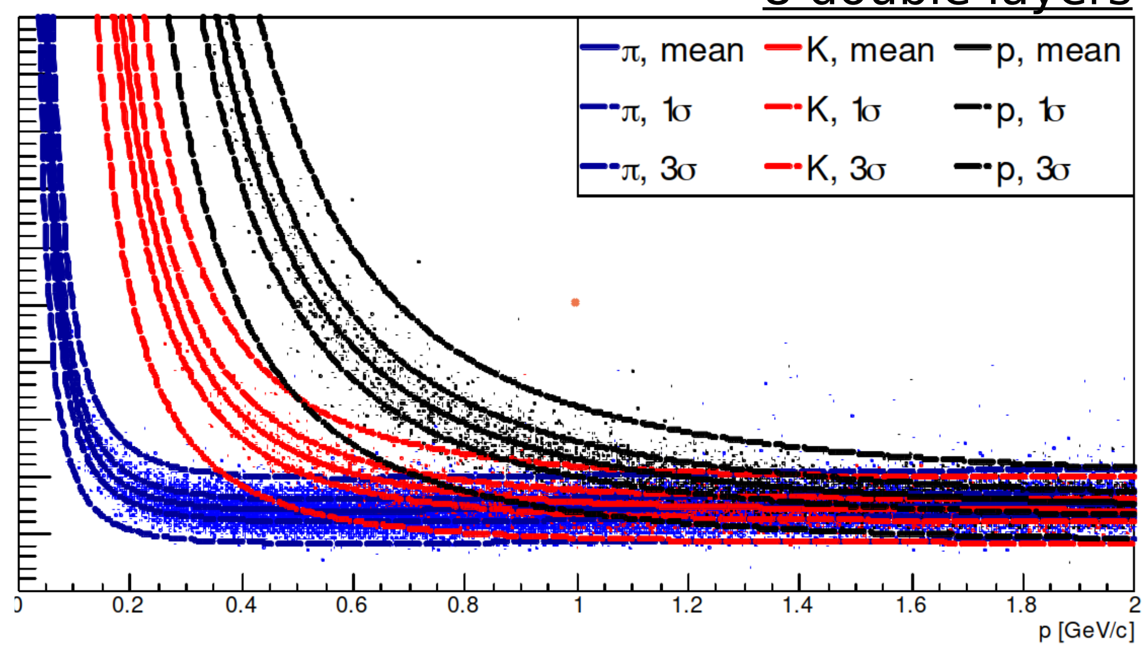
Barrel

29 double layers



End-Cap

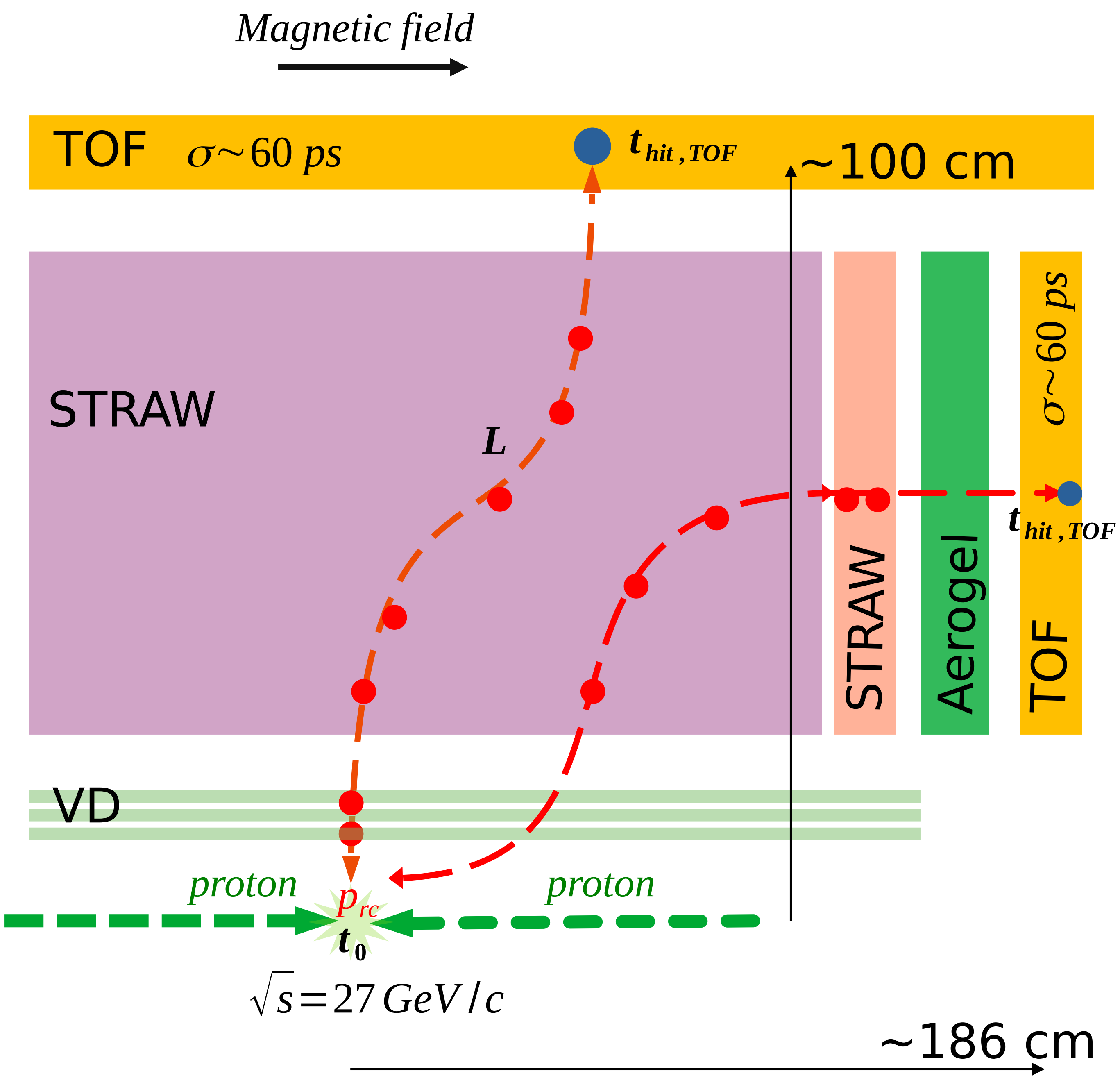
8 double layers

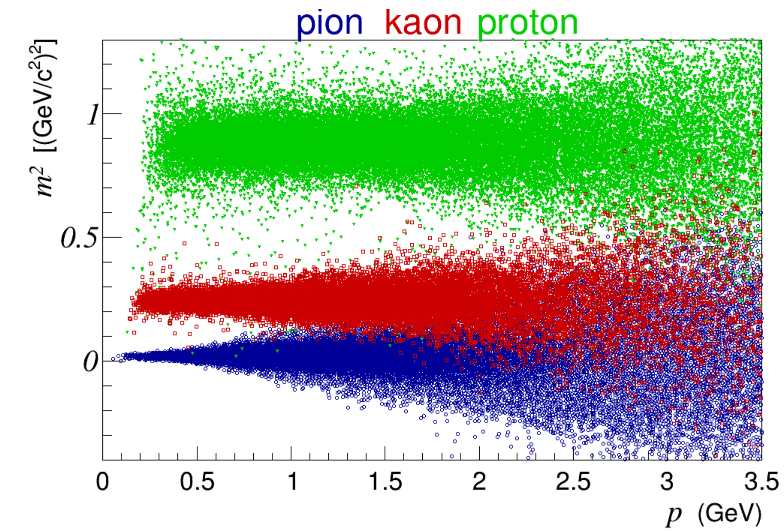


End-Cap: pions separable from kaons up to ~0.45 GeV/c, from protons up to ~0.85 GeV/c

Barrel: pions separable from kaons up to ~0.6 GeV/c, from protons up to ~1.1 GeV/c

Time of Flight system





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

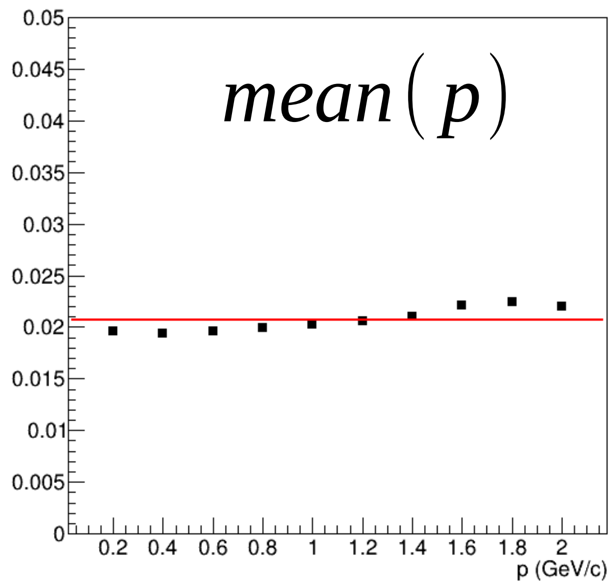
$$\sigma_{m^2}^2 = 4m^4\left(\frac{\sigma_p}{p}\right)^2 + 4E^4\left(\frac{\sigma_t}{t}\right)^2 + 4E^4\left(\frac{\sigma_L}{L}\right)^2$$

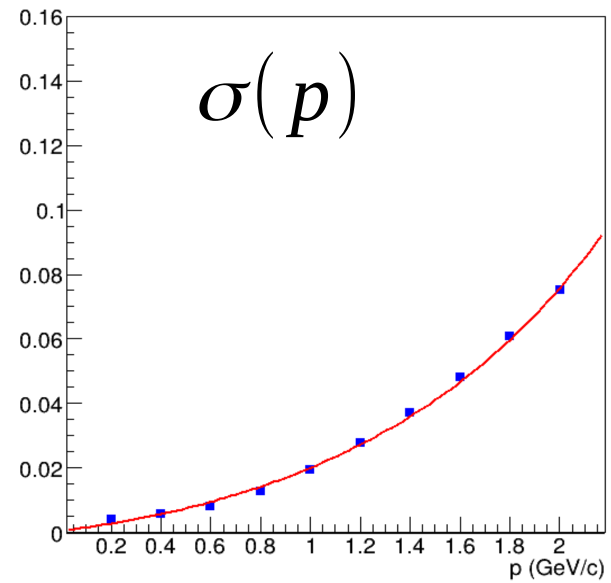
from reconstruction $\sigma \sim 150\ \mu m$

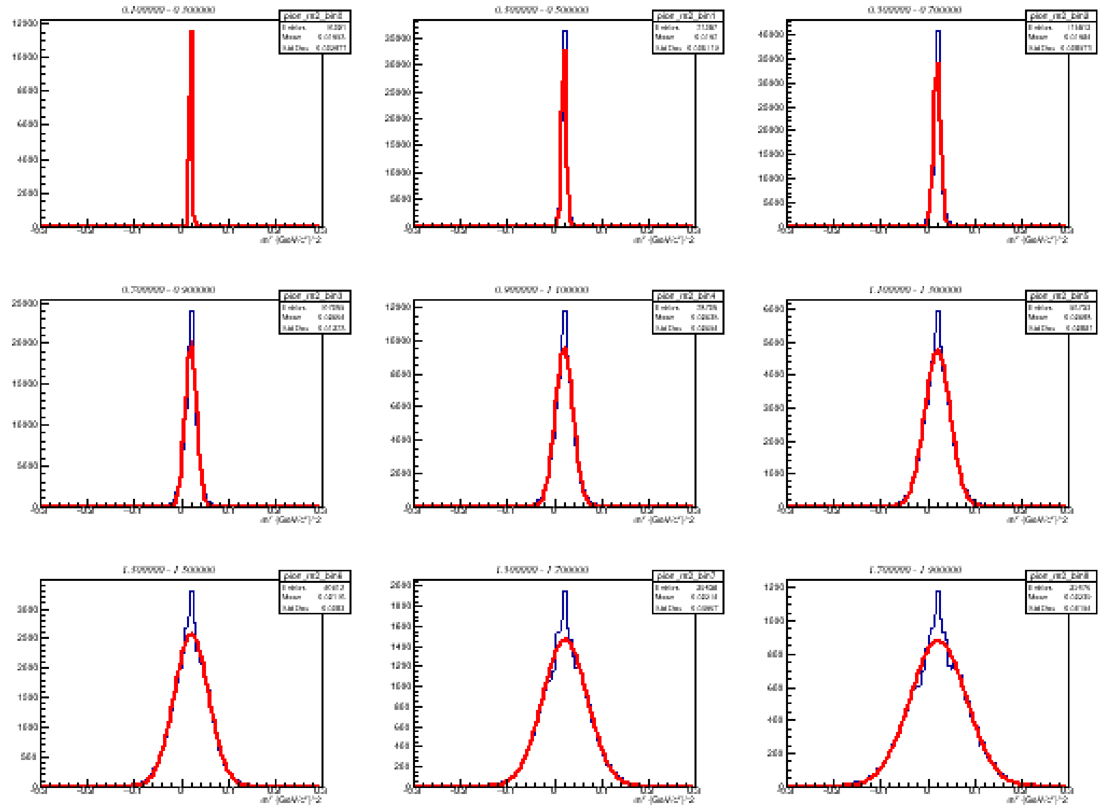
$\sigma_{TOF} = 60\ ps$

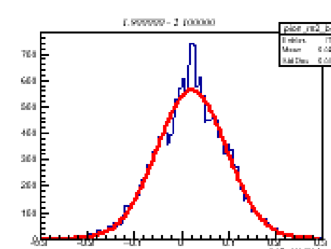
at the moment fixed

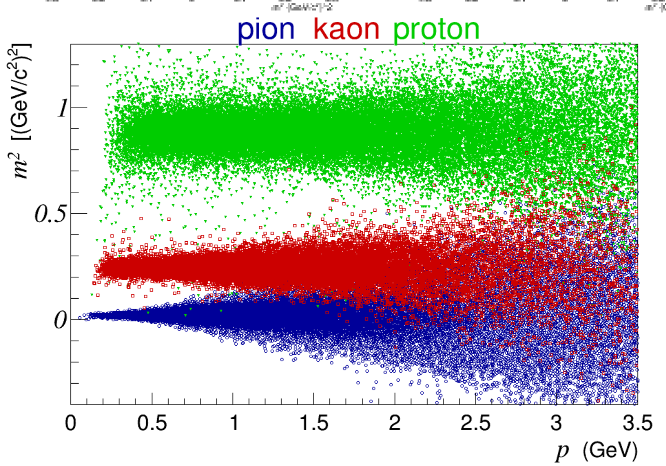
How to parametrize pions in TOF



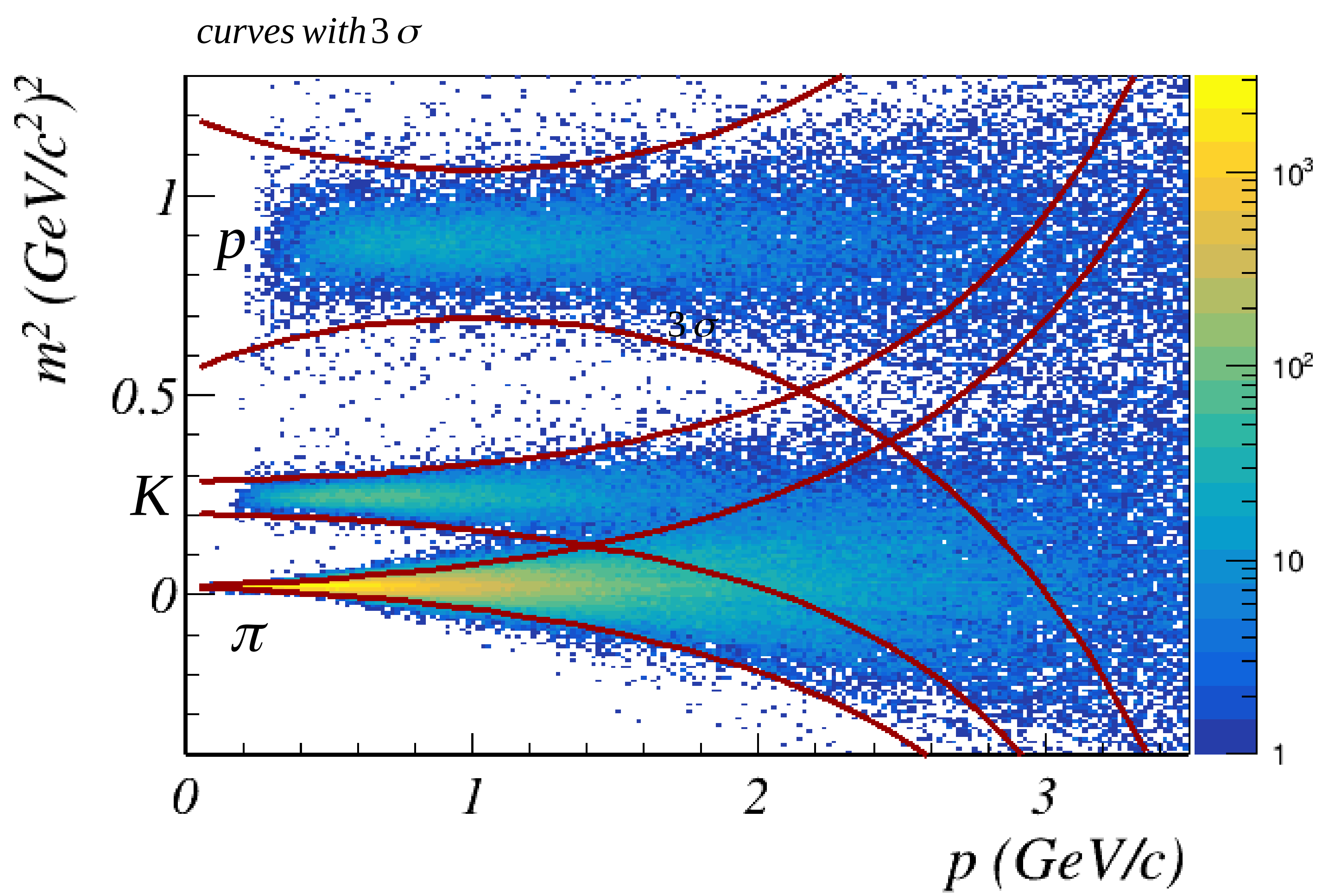




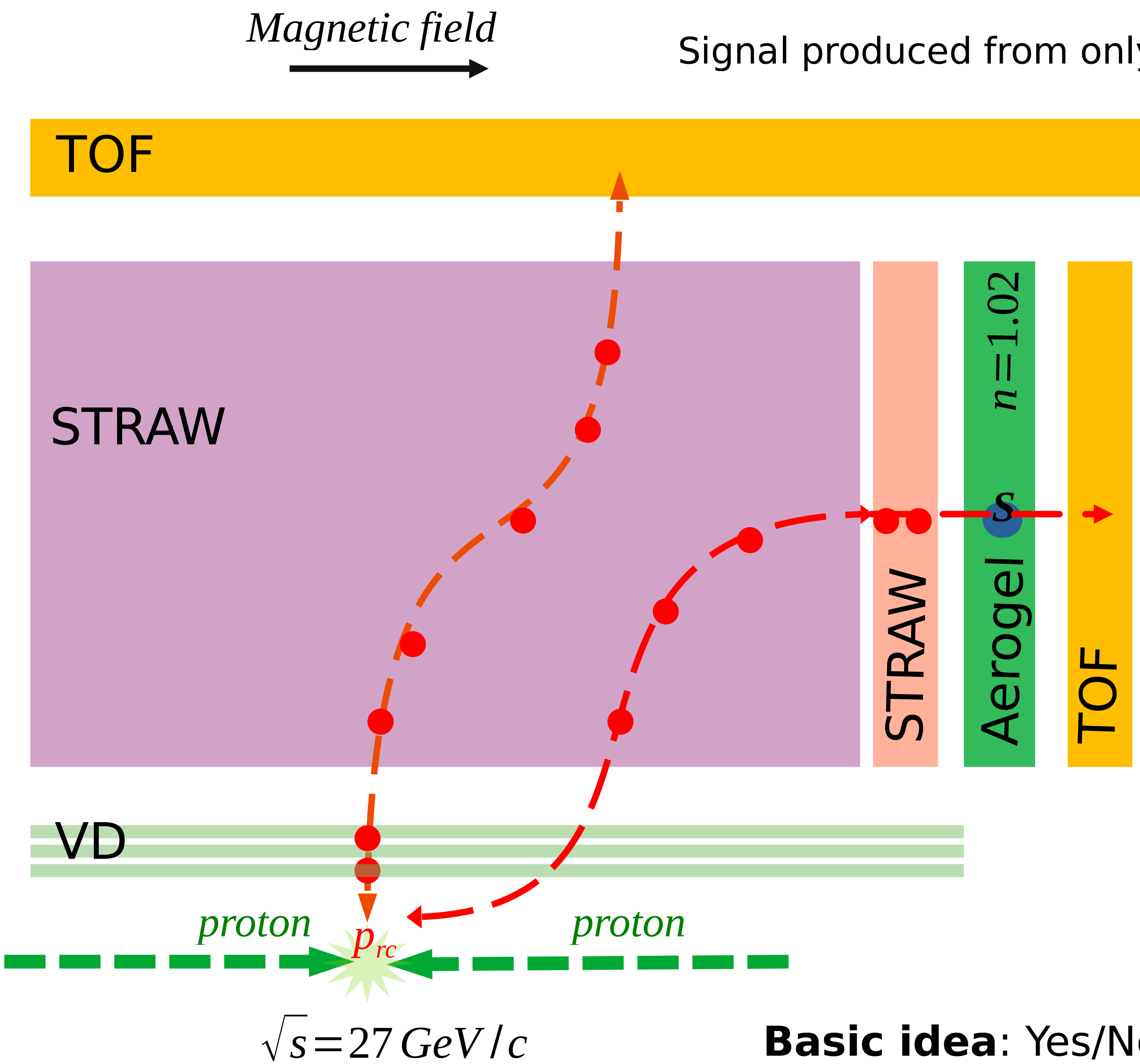




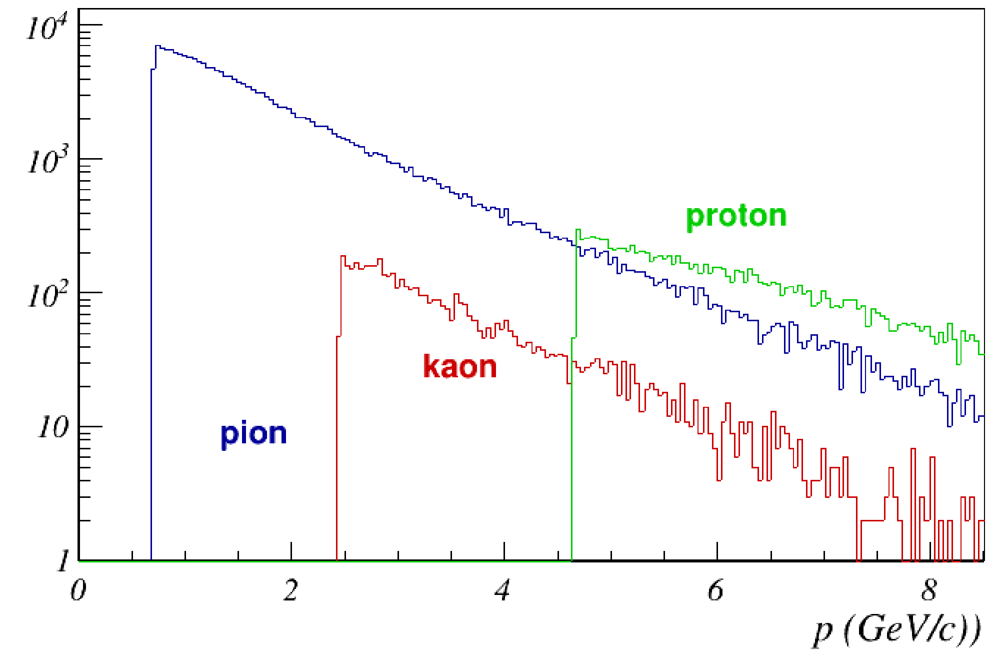
Parametrization m² vs p for TOF



Threshold Aerogel counters



Signal produced from only those particles which are above Cherenkov threshold.

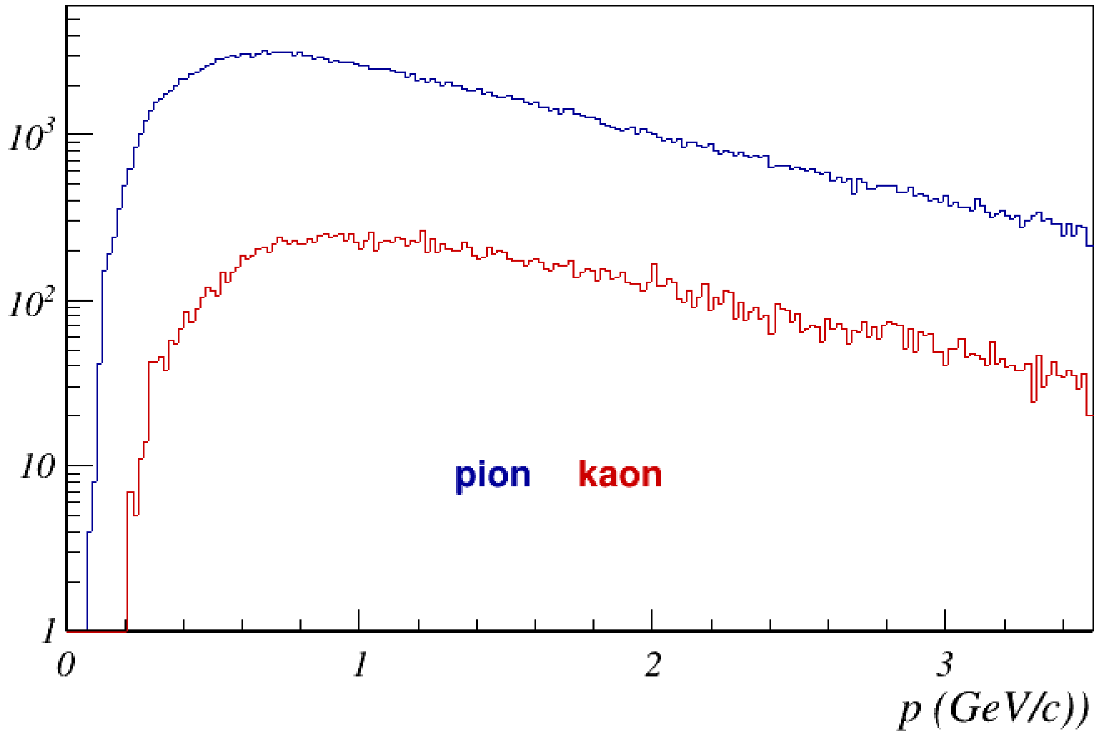


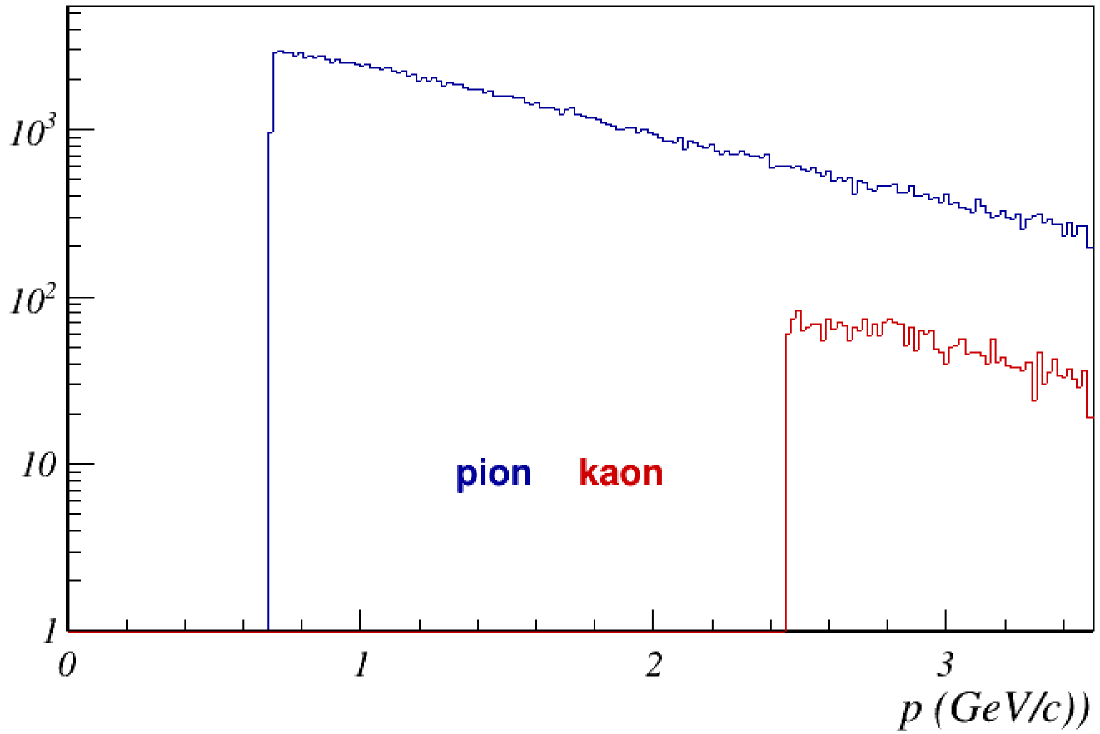
$$p_{th}=\frac{m}{\sqrt{n^2-1}}$$

Basic idea: Yes/No decision, on the existence of the particle type.
For this, count the number of photoelectrons detected

Threshold Aerogel counters

pion/kaon separation





n=1.02					
	electron	muon	pion	kaon	proton
P_{th} (GeV/c)	0.0025	0.52	0.69	2.45	4.66

$$p_{th} = \frac{m}{\sqrt{n^2 - 1}}$$

PID methods

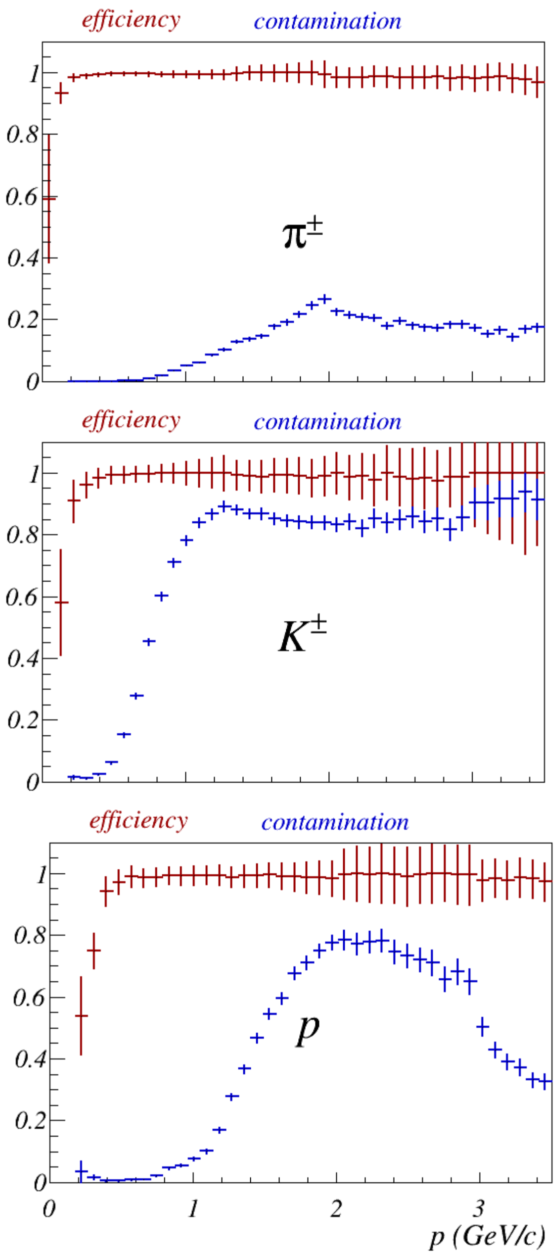
1. Define a cut on $n\sigma<k$, k=1,2,3 in single detector analysis
2. Define a multiple-cuts on nσ for several detectors
3. Define a cut on a combined-nσ variable

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

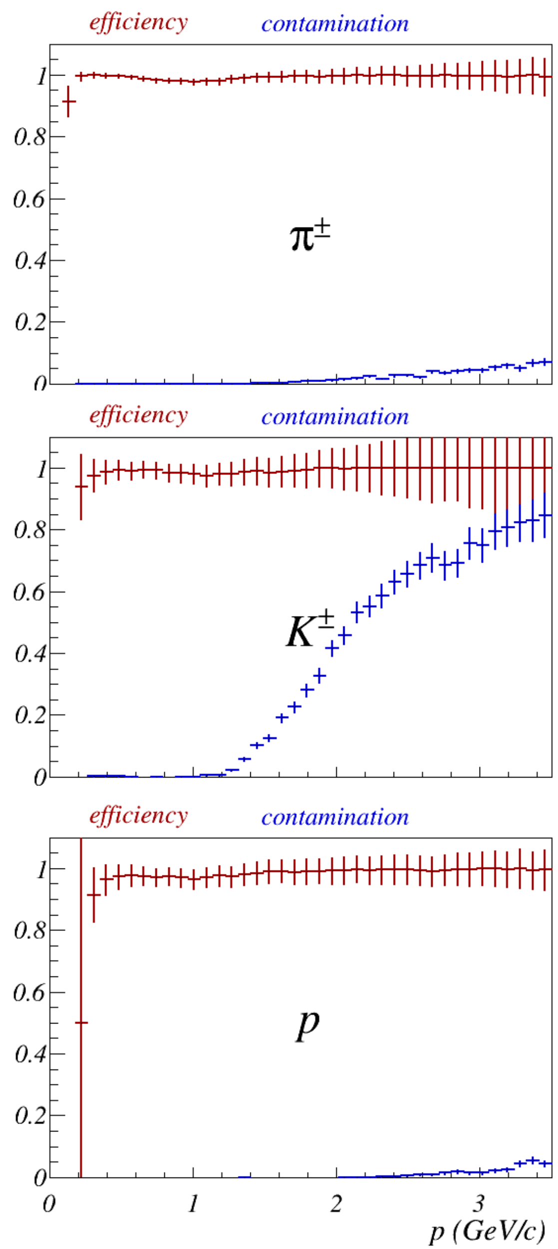
4. The Bayesian approach:
   combine information from different PID detectors,
   with and without Gaussian responses

Particle identification for STRAW/TOF/Aerogel

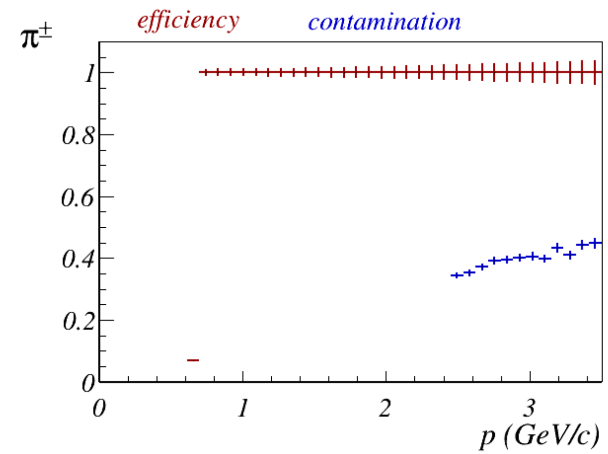
STRAW ($n\sigma<2$)



TOF ($n\sigma<3$)



Aerogel (yes/no)



$$efficiency=\frac{N_{corr}}{N_{true}}$$

$$contamination=\frac{N_{incorr}}{(N_{incorr}+N_{corr})}$$

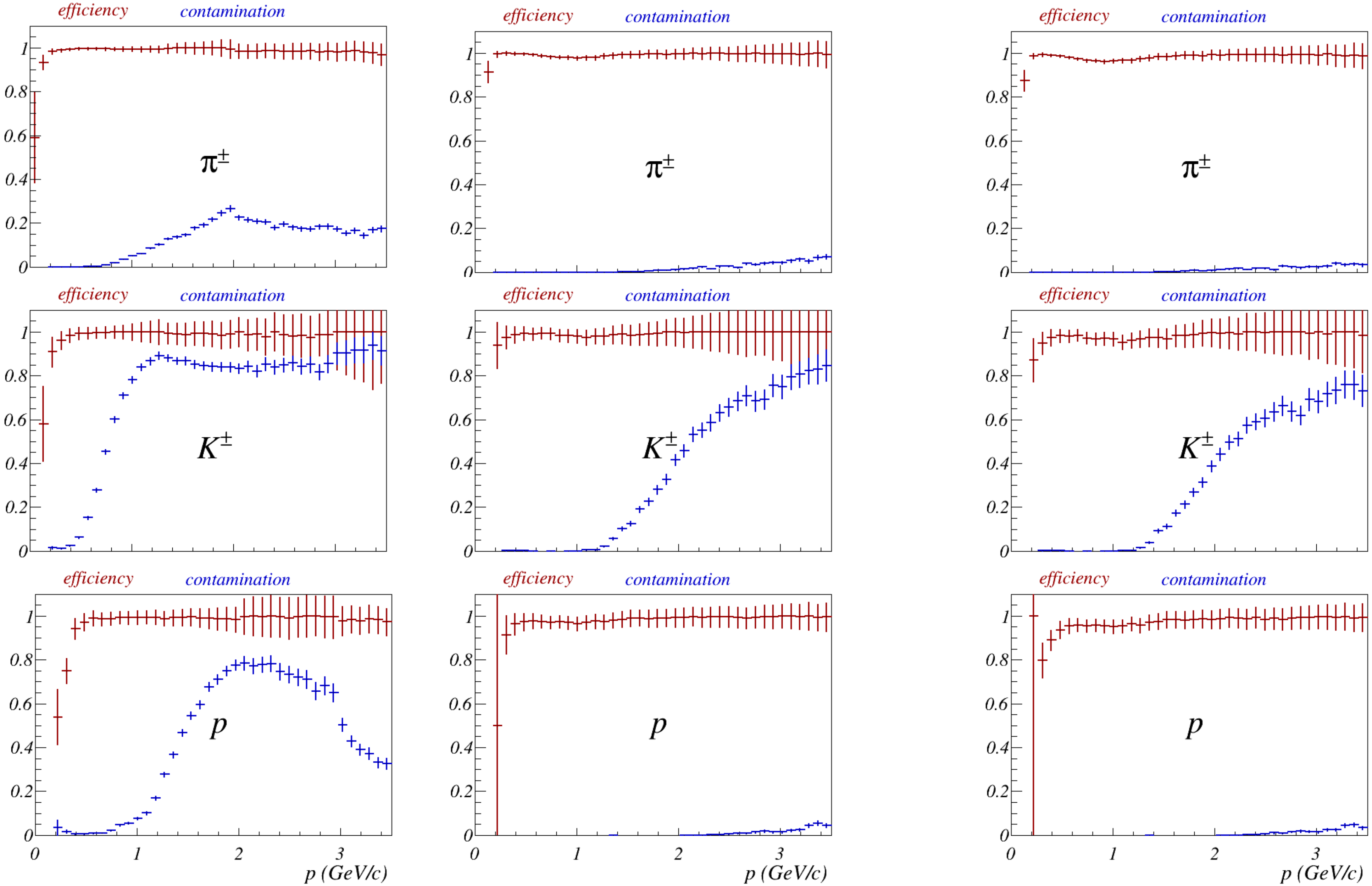
N_{corr} – the number of correctly identified particles of a certain type

N_{incorr} – number of misidentified particles a certain type

N_{true} – the true number of particles of a certain type.

Particle identification for STRAW and TOF

STRAW (nσ<2) | TOF (nσ<3) | TOF+STRAW (nσ<3)



Bayes approach

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

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)

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

Many detectors

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

What is priors

Strategy to calculate

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

Iterative procedure based on a set of unidentified tracks (raw yield $Y(p)$)

$$P(m^2) = \frac{1}{\sqrt{2\pi\sigma(p)}} e^{\frac{-(m_{TOF}^2 - m_{fit}^2)^2}{2\cdot\sigma(p)^2}}$$

1) Start with “flat” priors (i.e 1 for all species)

Priors obtained as a function of p

2) Bayesian posterior $P_n(H_i|S)$ at step n obtained from unidentified raw yield

$$Y_{n+1}(H_i, p) = \sum_S P_n(H_i|S)$$

3) Obtain identified raw yields at step $n+1$ using posteriors as weights

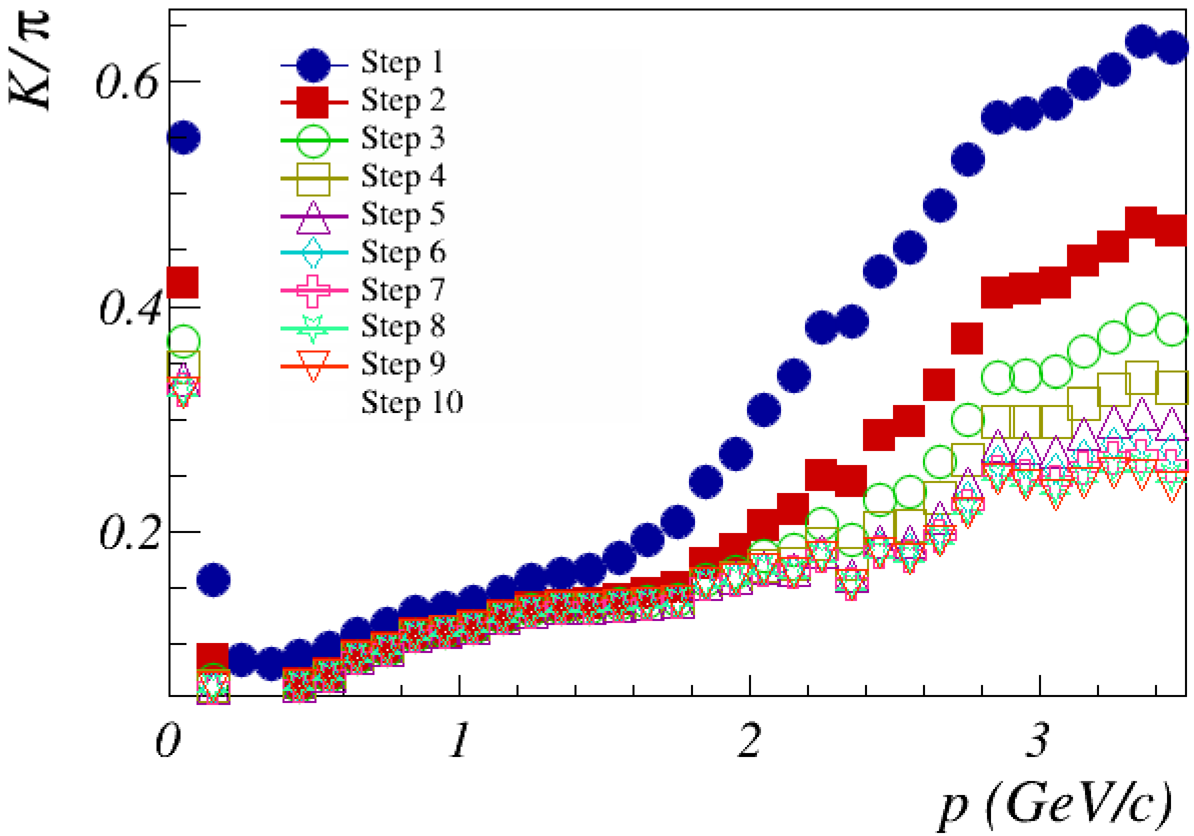
$$C_{n+1}(H_i, p) = \frac{Y_{n+1}(H_i, p)}{Y_{n+1}(H_\pi, p)}$$

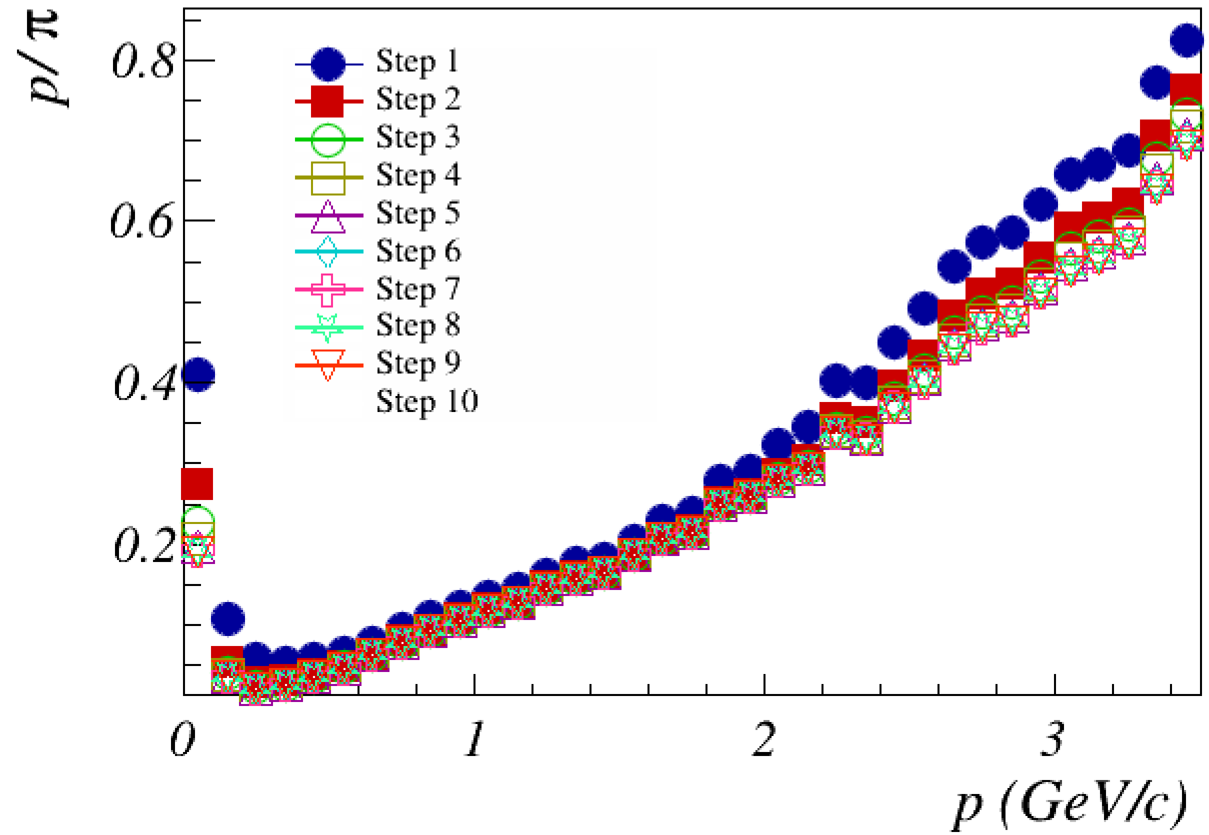
4) Obtain a new set of priors from the relative ratios of identified spectra

Separate sets of priors have to be evaluated for each collision system p-p, d-d, p-d and energies

Calculation priors: TOF+STRAW

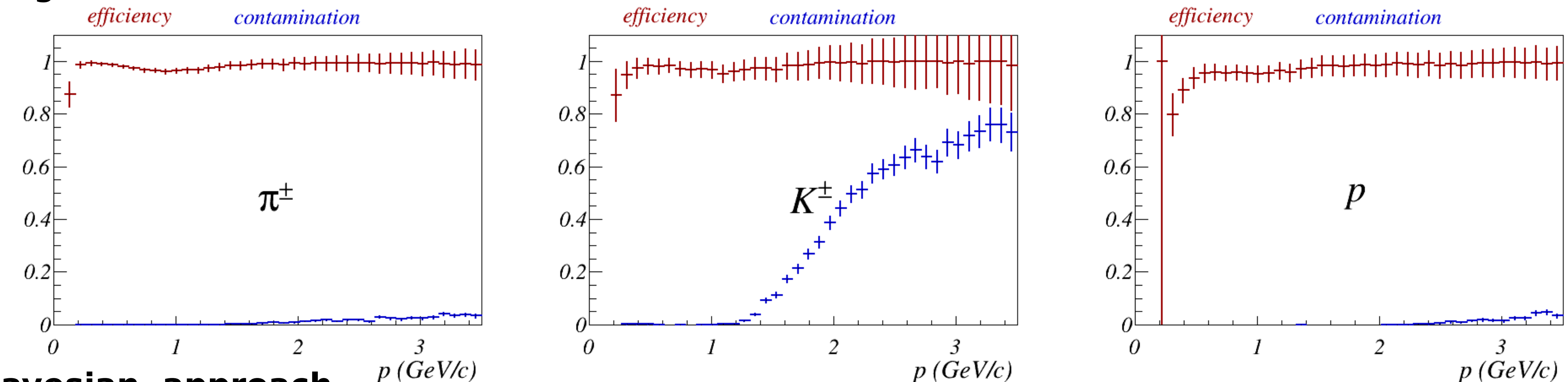
The extracted K/π and p/π ratio of the priors is shown as a function of *p* at each step of the iteration.



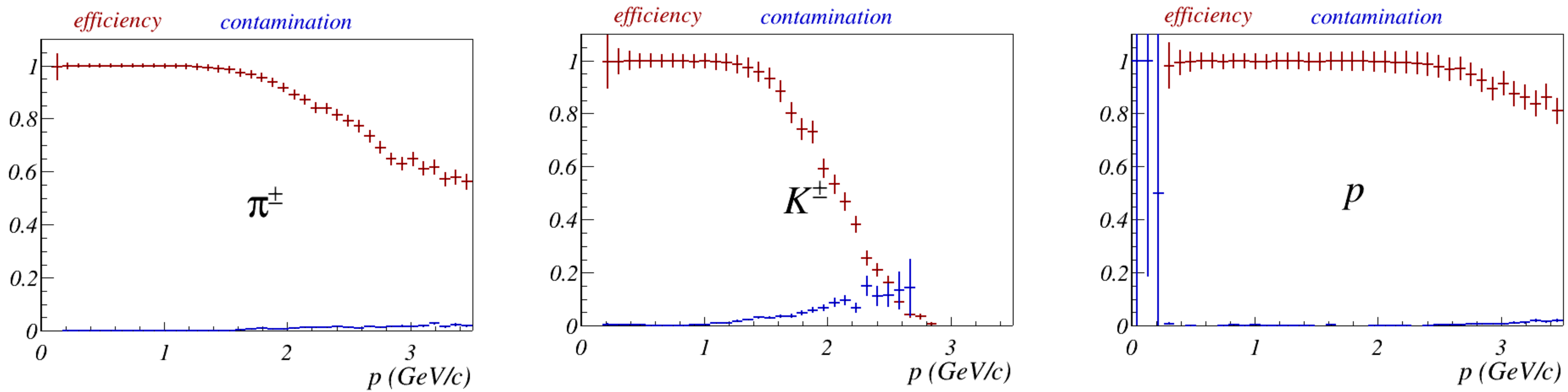


n-sigma and Bayesian approach for STRAW and TOF

n-sigma



Bayesian approach

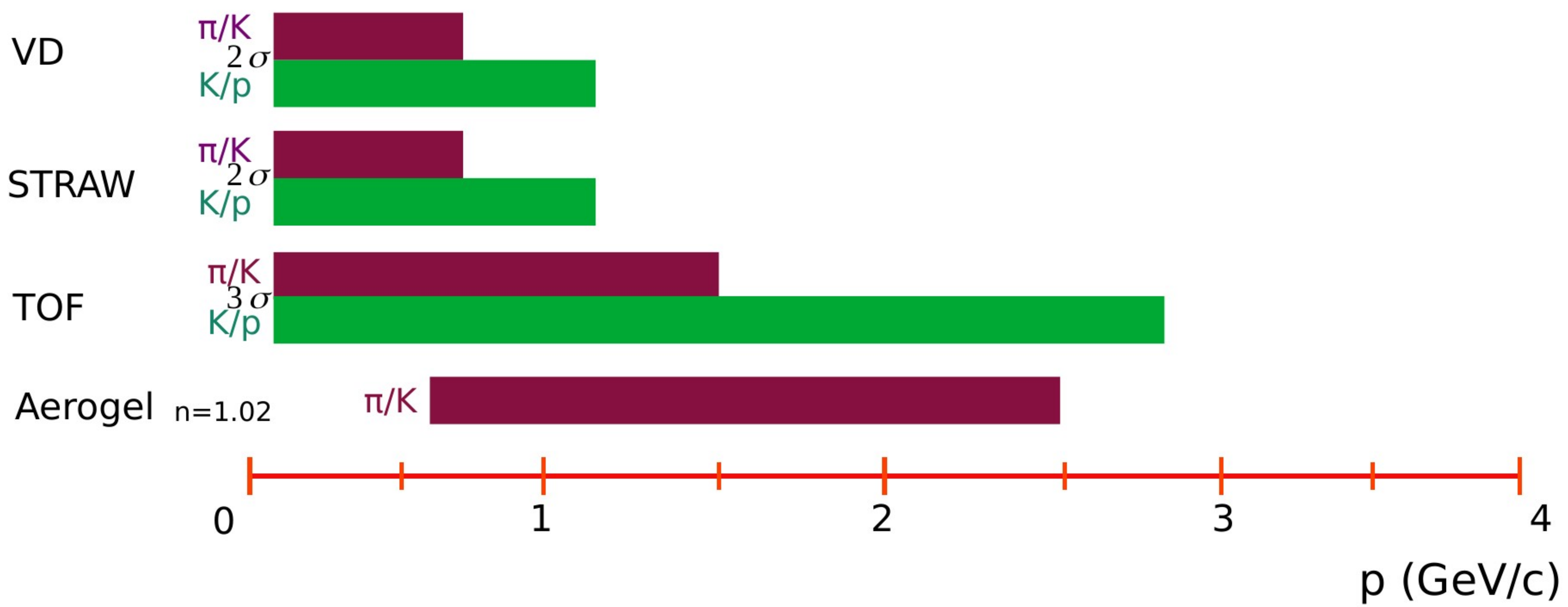


n-sigma: fixed cut

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

Conclusion

- Methodology for particle identification in SPD for STRAW and TOF was developed, and the code is implemented in SpdRoot.



Thank you for your attention