PID with FTOF detector

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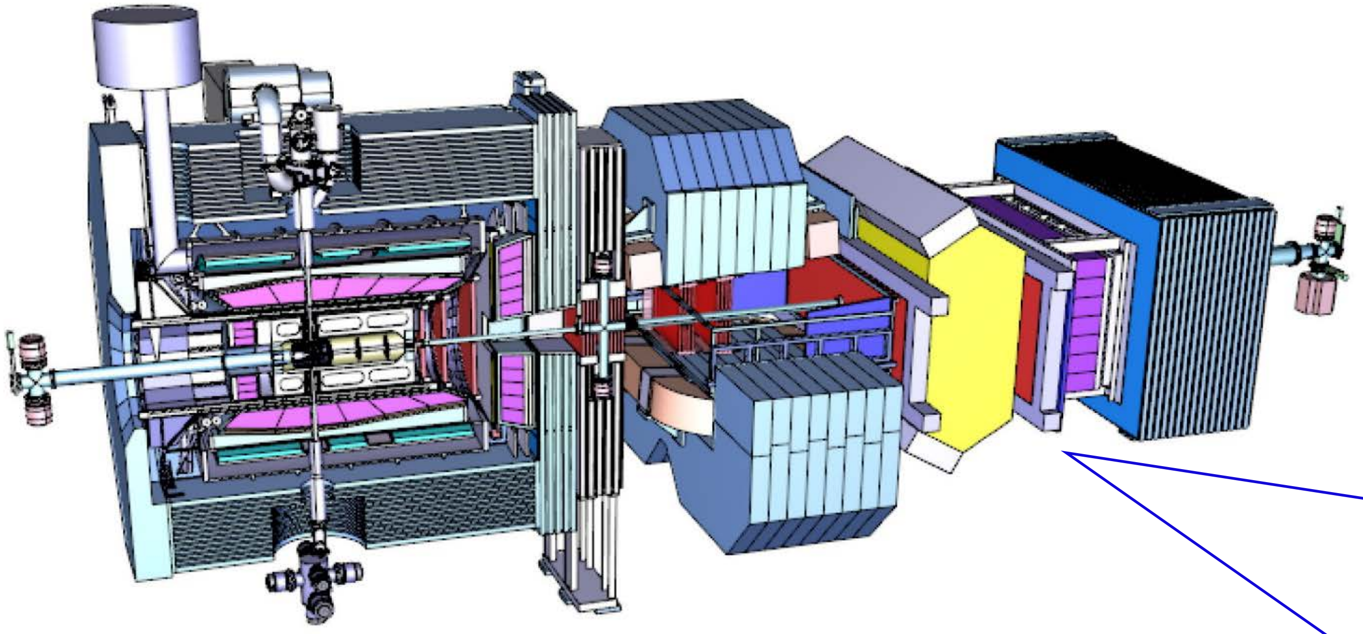
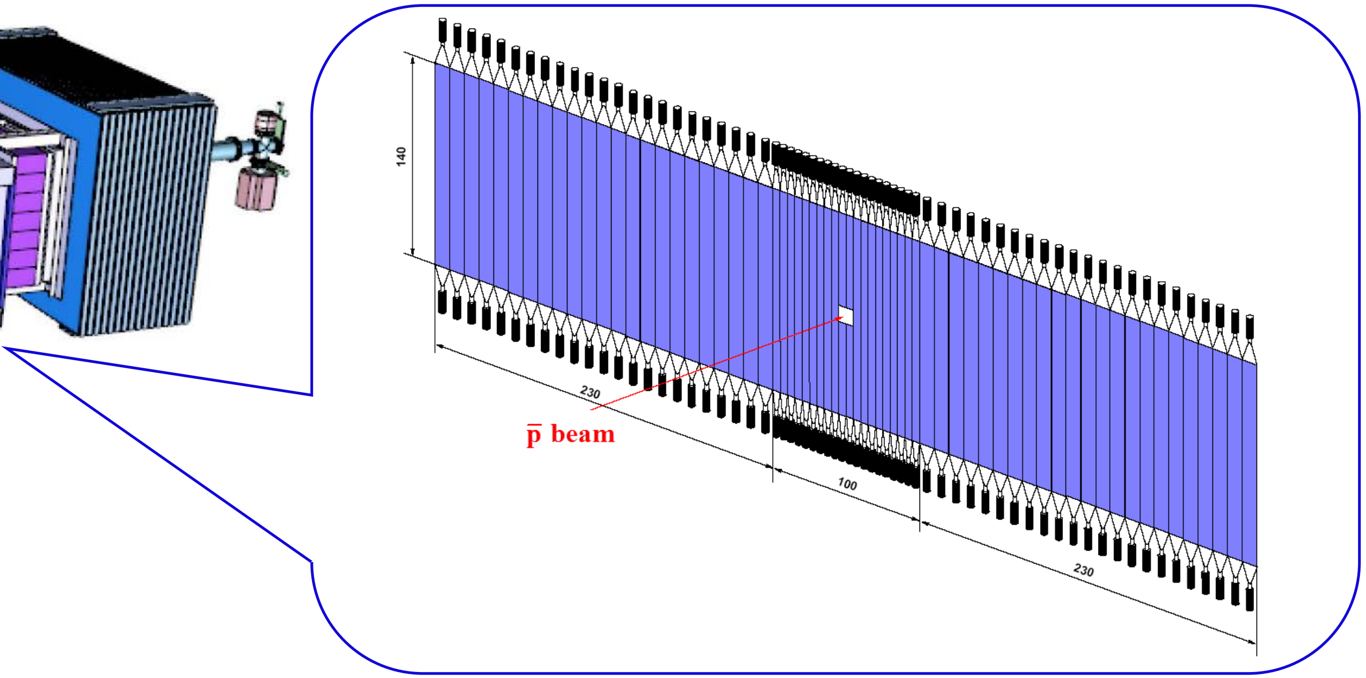
Overview of FTOF detector





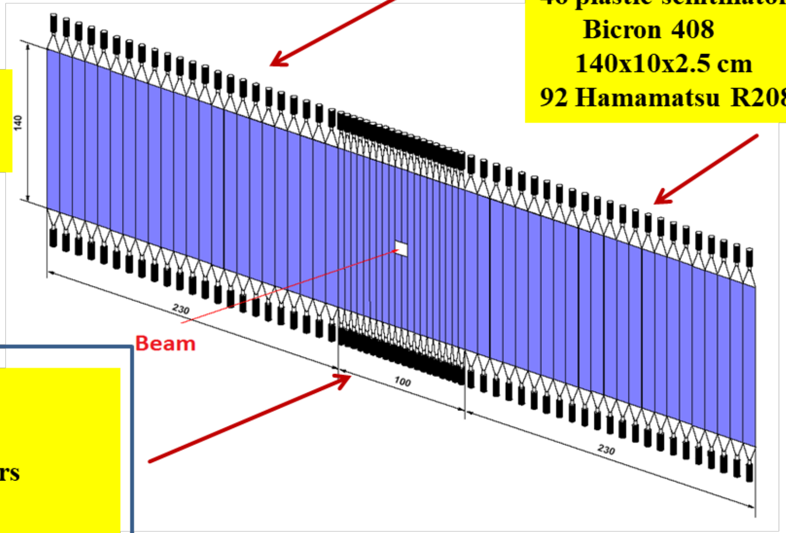
66 scintillation counters
20 counters in the central part
46 counters in the side parts (23 counters in each side part)
Each scintillator equipped with two PMTs (top and bottom)

Overview of FTOF detector

- The time resolution must be better than 100 ps
- No start counter, relative time-of-flight PID
- Triggerless system
- Use track length and momentum from tracking
- Separate particles for momentum below 4 GeV/c

positioned at 7.5 m from IP

Side parts
2x23 counters
46 plastic scintillators
Bicron 408
140x10x2.5 cm
92 Hamamatsu R2083 (2")



Central part
20 counters
20 plastic scintillators
Bicron 408
140x5x2.5 cm
40 Hamamatsu R4998 (1")

Sensitive area
width = 5600 cm
height= 1400 cm

Bicron 408 (recommended for large TOF counters)		***Fast PMTs** (hamamtsu)* R4998 1" (R9800), R2083 2" (R9779)	
Rise time	0.9 ns	Anode pulse rise time	0.7-1.8ns
Decay time	2.1 ns	TTS	160-370ps
1/e light attenuation length	210cm	Gain	$1.1\text{-}5.7\times10^{6}$

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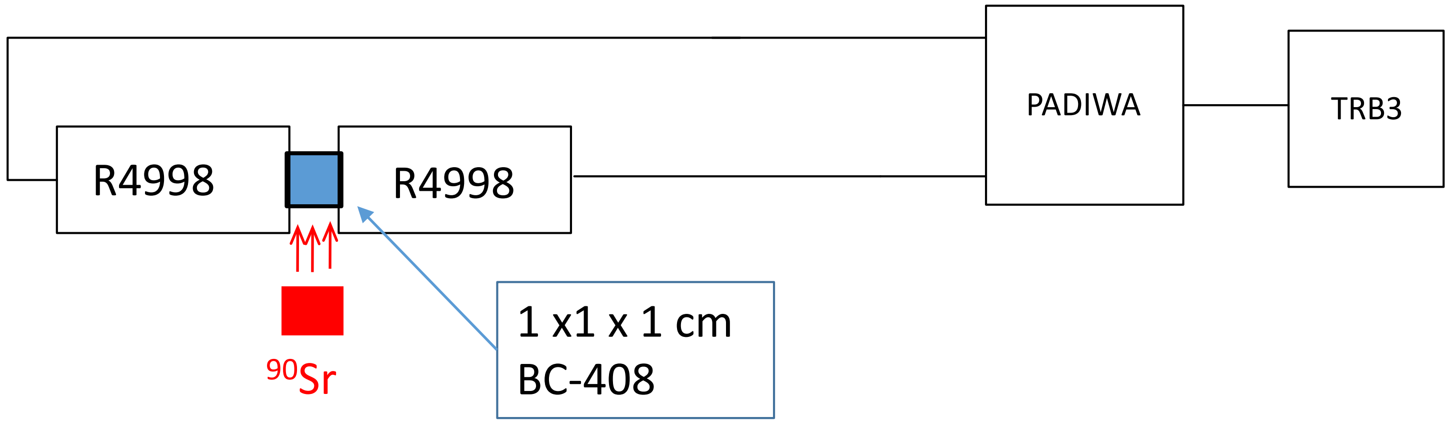
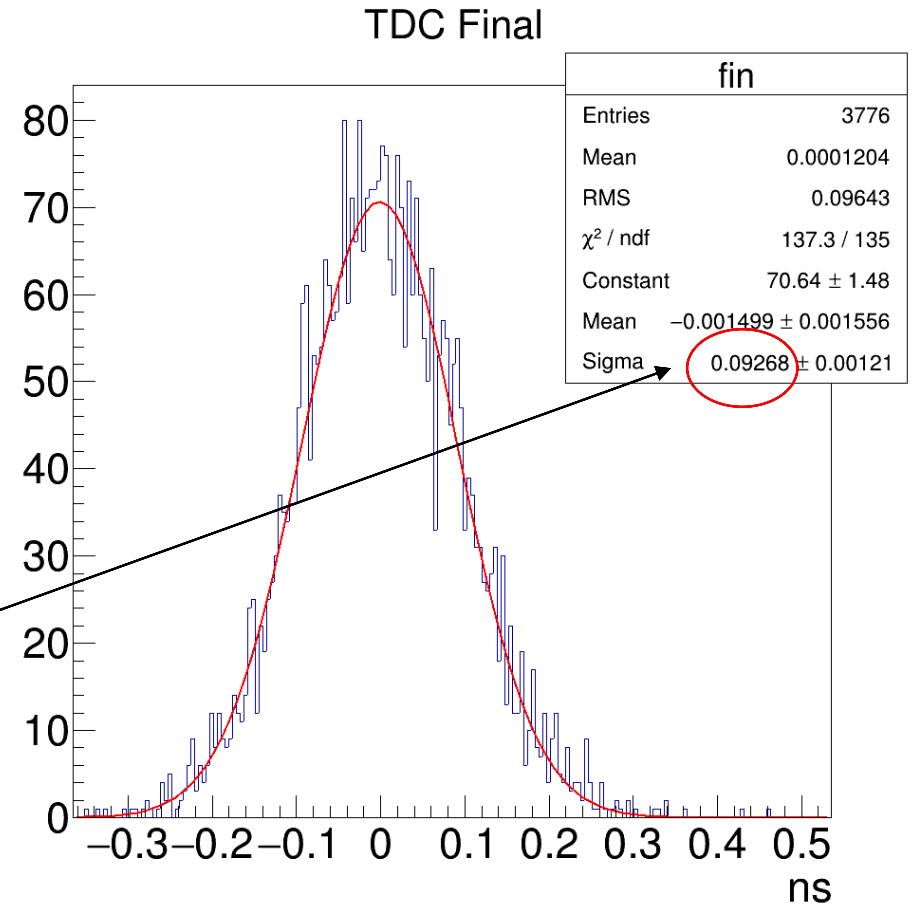
PADIWA+TRB3 test using radioactive source



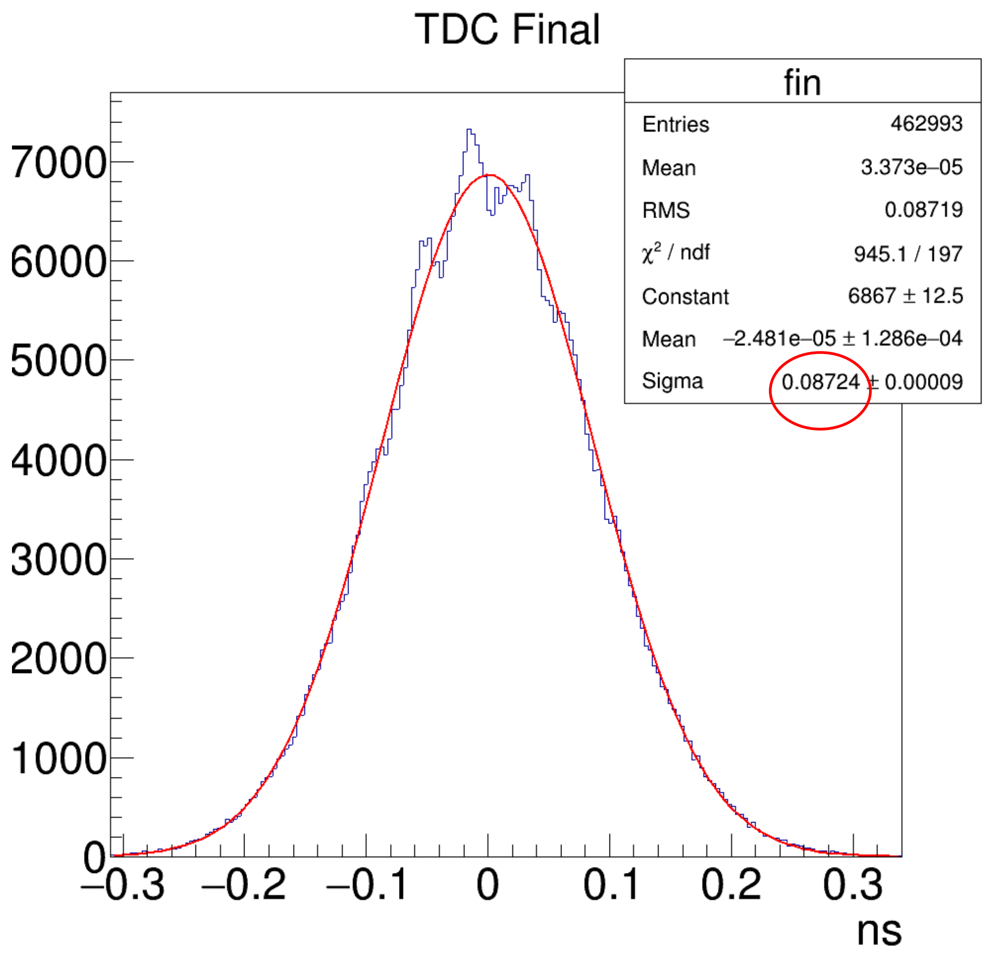


- PMT signal ~ 700-800 mV
- HV for PMT was optimized to stay in linear mode
- Measuring time difference between PMT1 and PMT2
- Measured time resolution σ = 130 ps and after time-over-threshold correction σ = 92 ps without correction for time walk of electrons in the scintillator and electronic resolution
- Time resolution of single PMT (after subtraction of time walk) σ = 60 ps

Tests of scintillator prototypes with laser

Laser driver: PicoQuant PDL 800-B
Laser head LDH-P-C-375B

Wavelengths 371 - 372 nm
Minimum pulse width - 48 ps (FWHM)
Time stamp at 3 ps precision
Peak power up to 1 W
Repetition rate from Hz to 40 MHz
Collimator optics



- Time resolution with laser on the same size prototype give about the same time resolution 92 ps (source) and 87 ps (laser)
- Laser gives monochromatic photons so no need to correct time signals to amplitude, no correlation between TDC signal and amplitude. Easy to test.

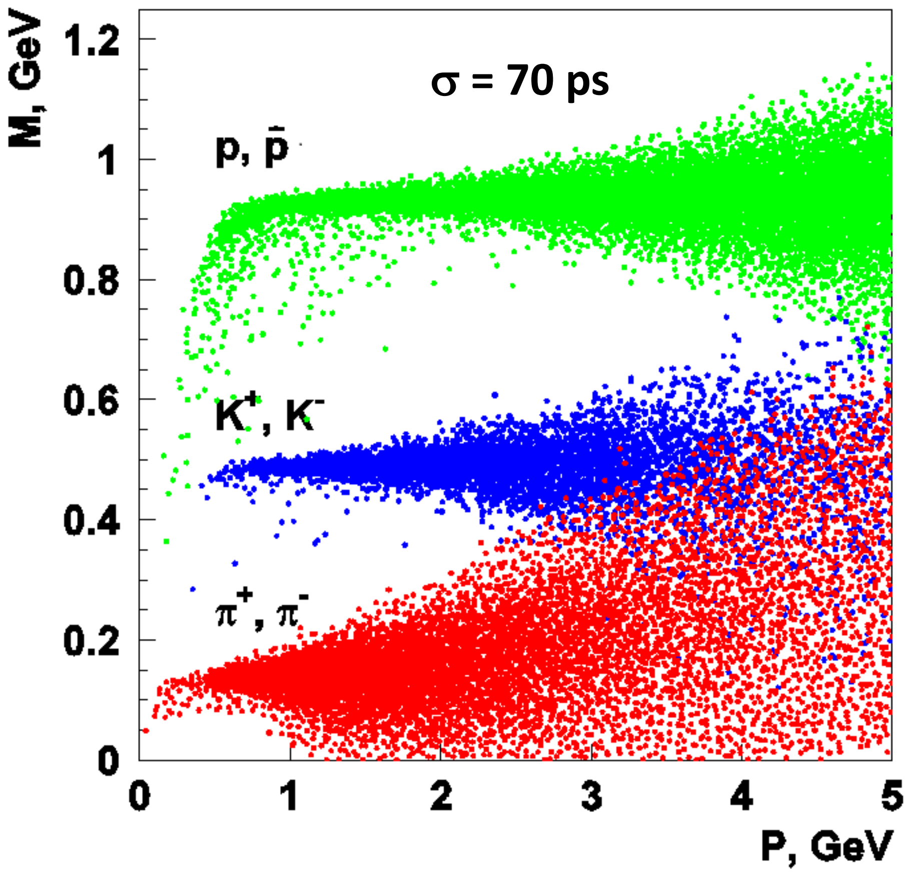
PID with time of flight

$$m = \frac{p}{c}\sqrt{\frac{t^2c^2}{L^2} - 1}$$

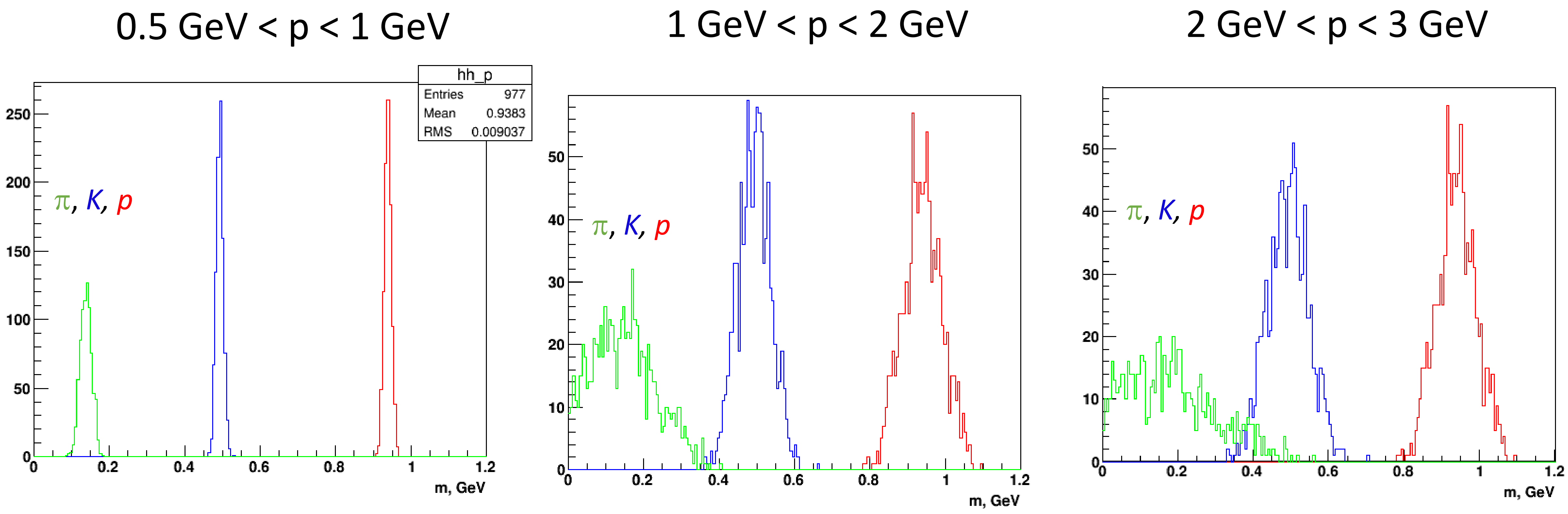
L - track length

t – TOF time

$$\frac{\delta m}{m} = \sqrt{\left(\frac{\delta p}{p}\right)^2 + \gamma^4\left(\frac{\sigma_{TOF}}{t}\right)^2}$$



Reconstructed mass

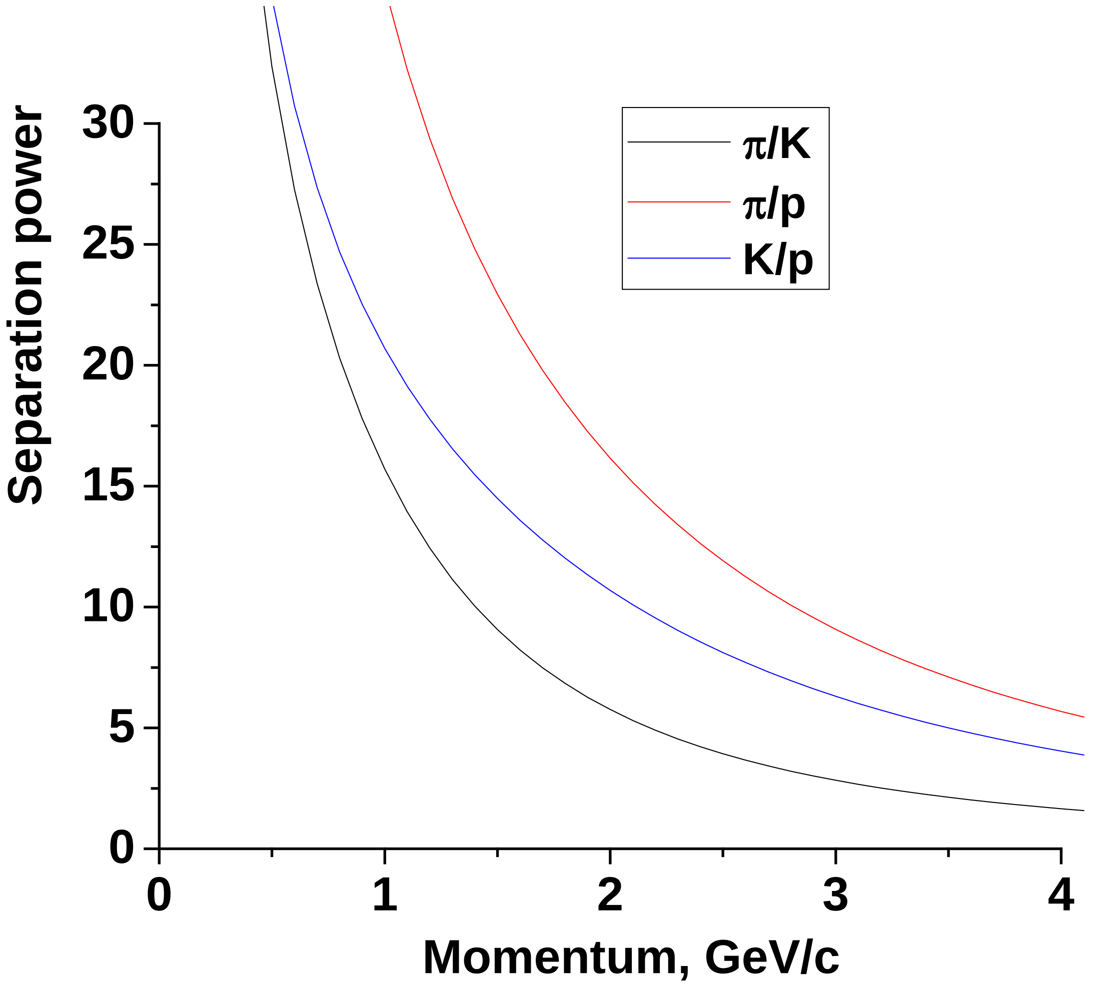


Separation power

How many sigmas (in Gaussian approx. between two peaks)

$$n_{i,j} = \frac{|m_i - m_j|}{(\sigma_i - \sigma_j)/2}$$

- $n_{\pi,K} > 2$ @ 3 GeV/c
- $n_{K,p} > 4$ and $n_{\pi,p} > 4$ @ 4 GeV/c



PID with CAtracking

- Box generator
- 1° < theta < 5°, 0° < phi < 360°
- Momentum 0.5 < p < 4 GeV/c

- 3000 events
- 3 particle per events (π, *K*, *p*)

- Eventbase simulation

- Track length taken from FTSIdealTrack

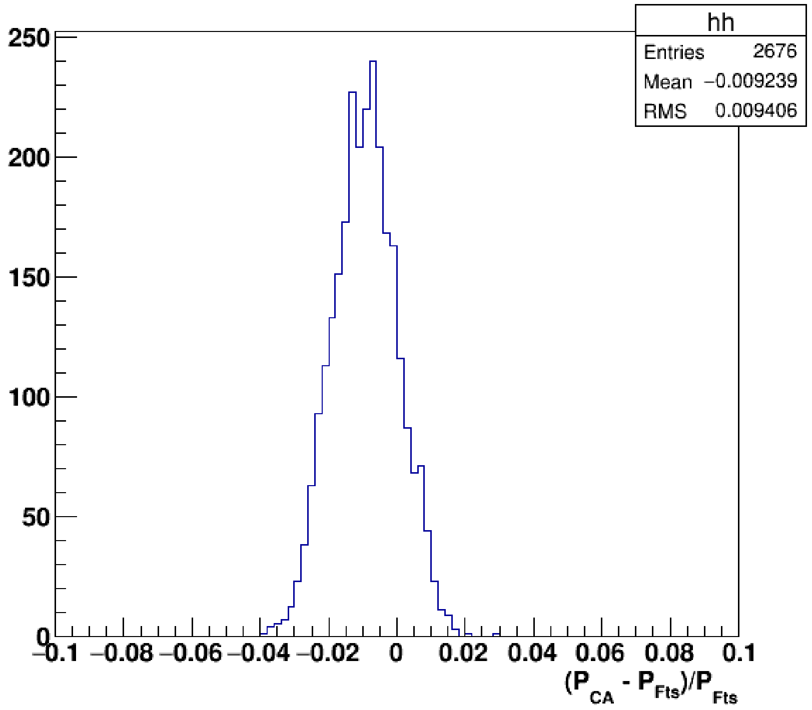
- Momentum taken from CATrack

CATrack efficiency in compare with FtsIdealTrack 97.1%

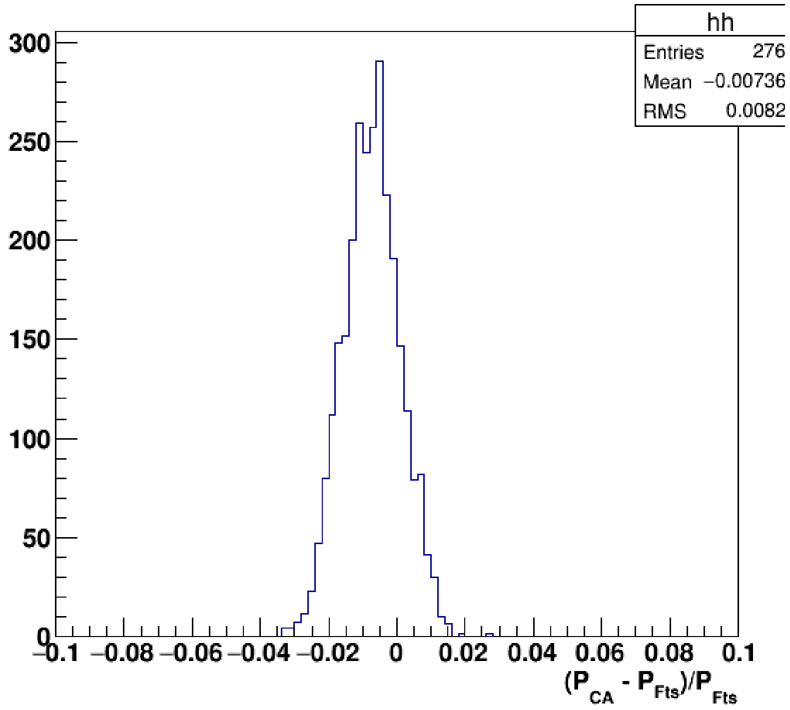
Momentum residuals

Mean value shifted from 0 (need to apply Kalman filter after)

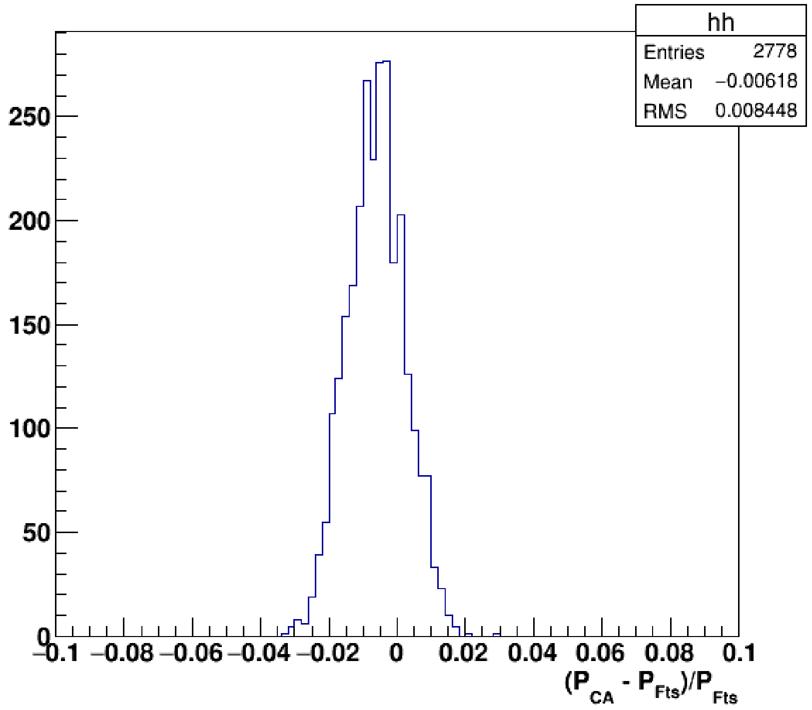
Pion



Kaon

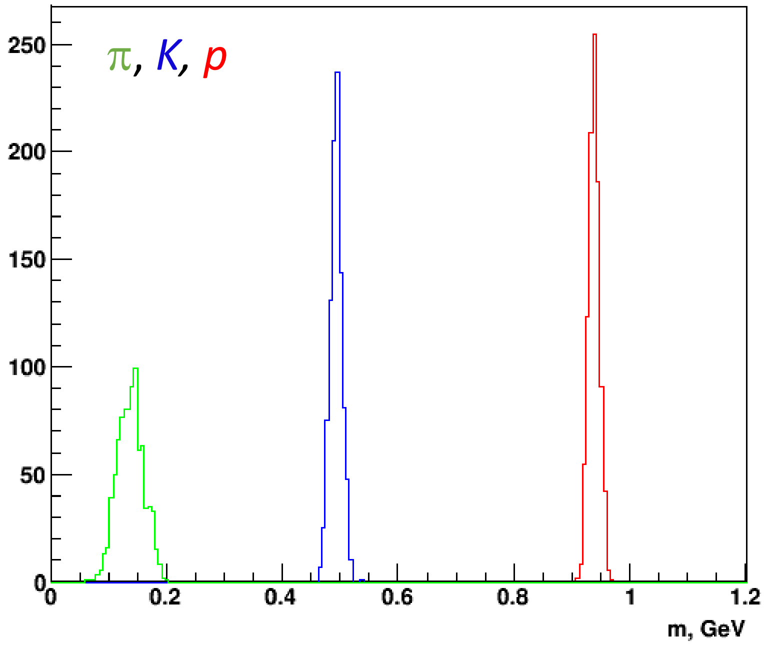


Proton

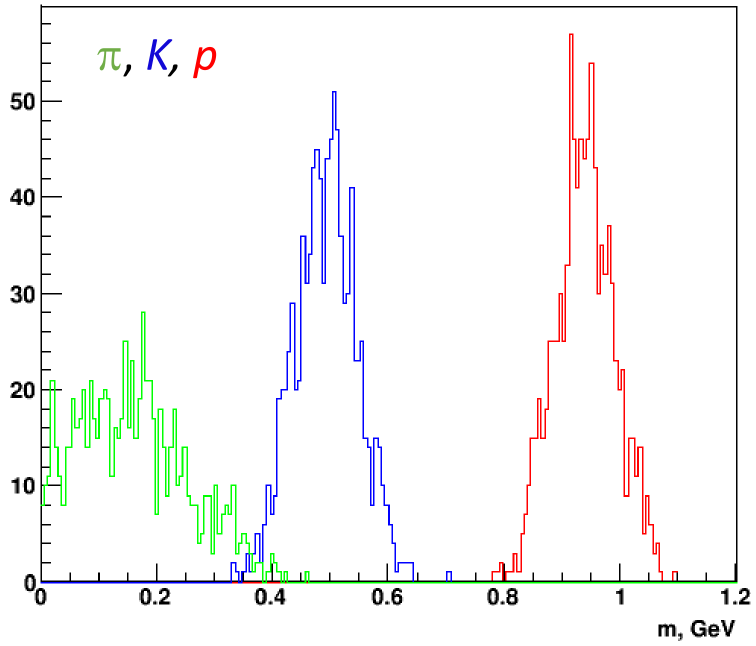


Reconstructed mass

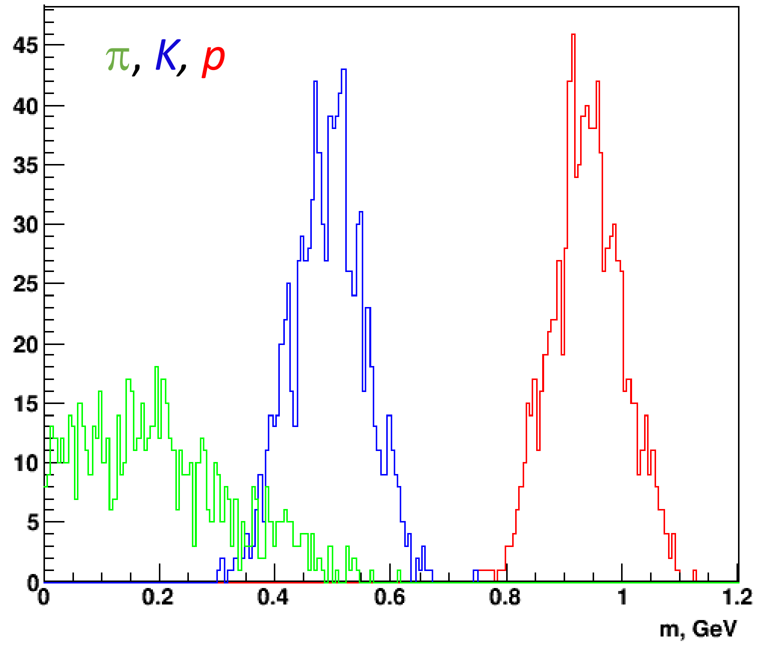
0.5 GeV < p < 1 GeV



1 GeV < p < 2 GeV

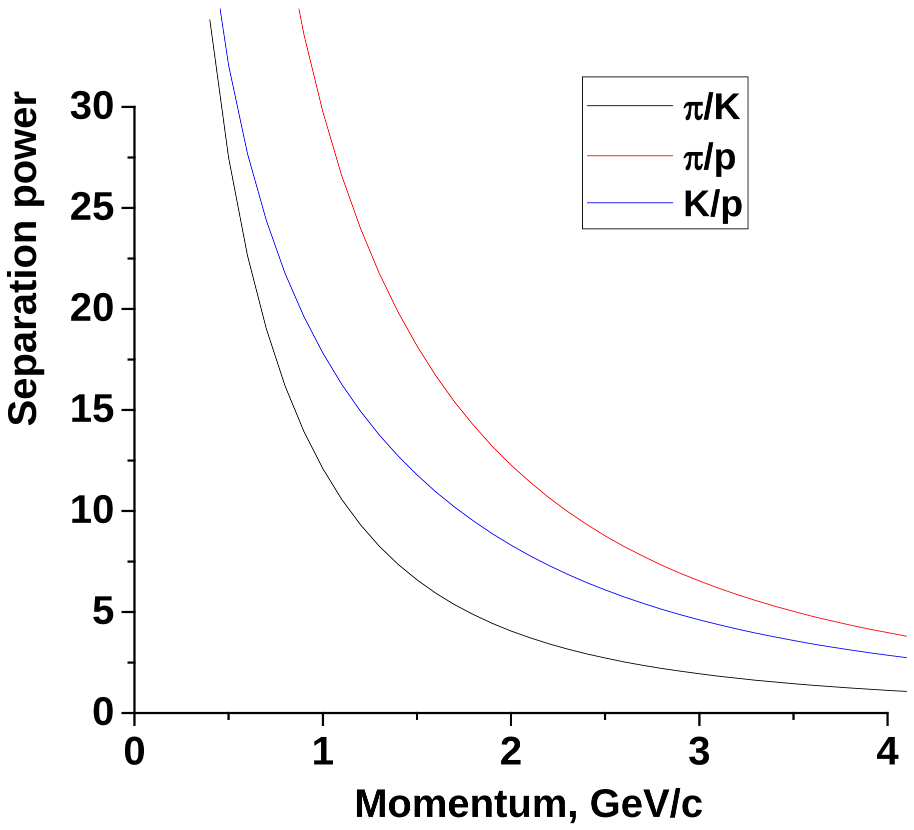


2 GeV < p < 3 GeV

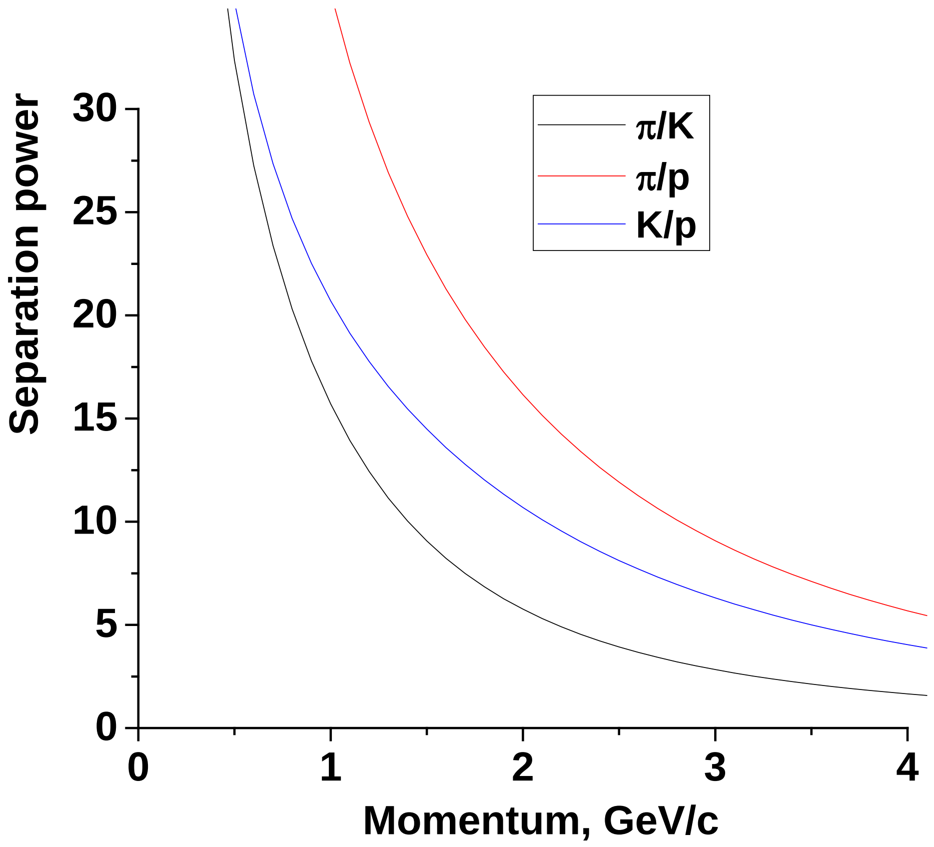


Separation power

CATrack



FtsIdealTrack



T0 and PID determination

$$t_1^{TOF} = t_0 + \frac{L_1}{c\beta_1} = t_0 + \frac{L_1}{c}\frac{\sqrt{p_1^2 + m_1^2}}{p_1}$$

$$t_2^{TOF} = t_0 + \frac{L_2}{c\beta_2} = t_0 + \frac{L_2}{c}\frac{\sqrt{p_2^2 + m_2^2}}{p_2}$$

………

$$t_n^{TOF} = t_0 + \frac{L_n}{c\beta_n} = t_0 + \frac{L_n}{c}\frac{\sqrt{p_n^2 + m_n^2}}{p_n}$$

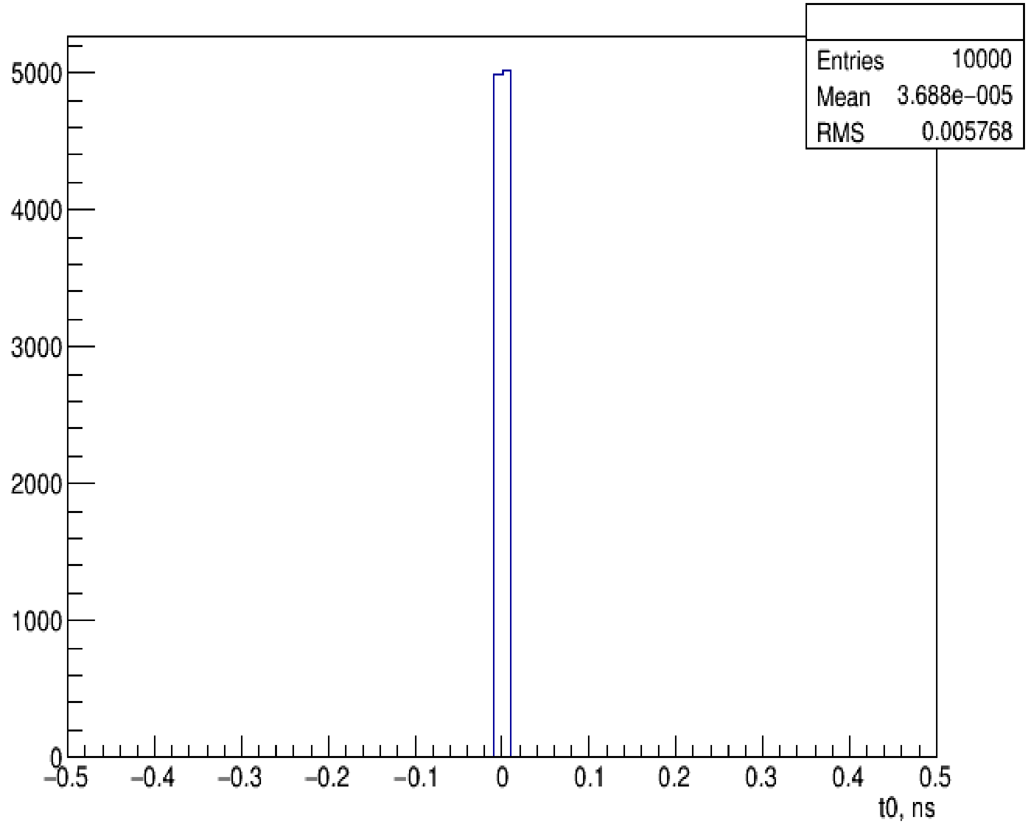
TOF hits

- n equations and n+1 unknown variables $t_0, m_1, \ldots, m_n$
- m can be only m_p, m_K, m_π, m_μ or m_e
- L and p provided by tracking
- Loop over all possible combination and find right one

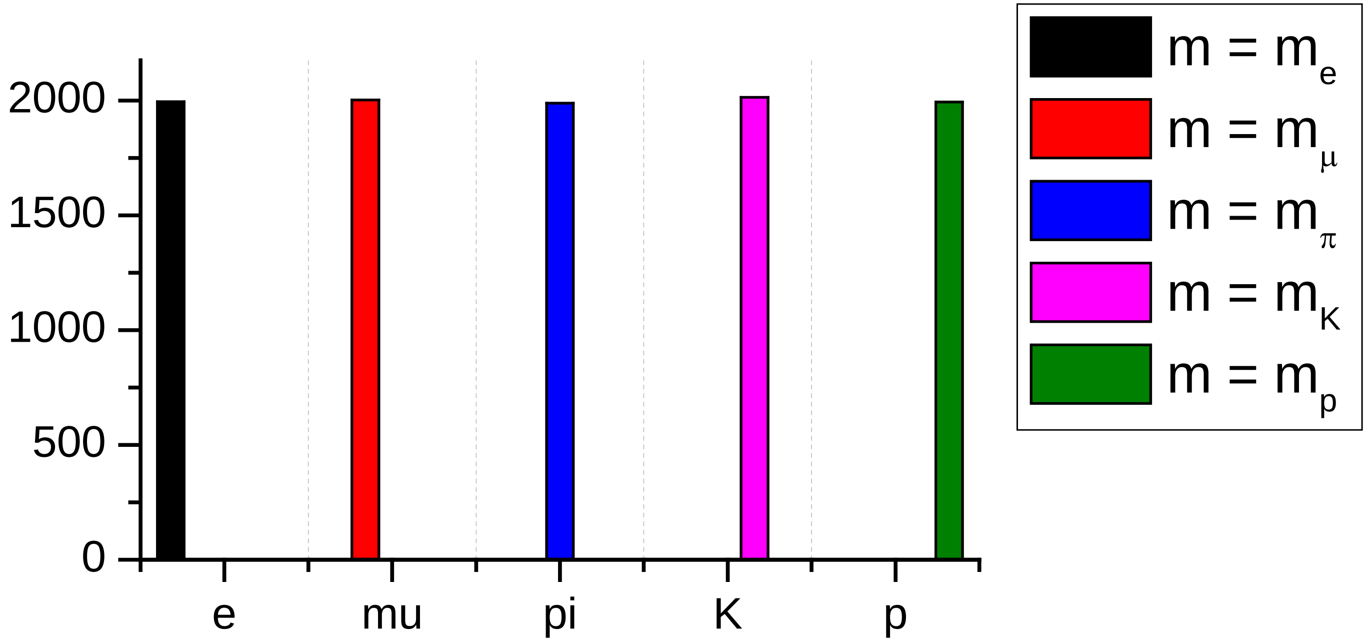
- All hits should belong to one events, so need event building before
- Need tracking info
- No quality parameter, hard to estimate precision

T0 and PID algorithm check with ToyMC

PID and t0 without TOF smearing and 2 particle in events

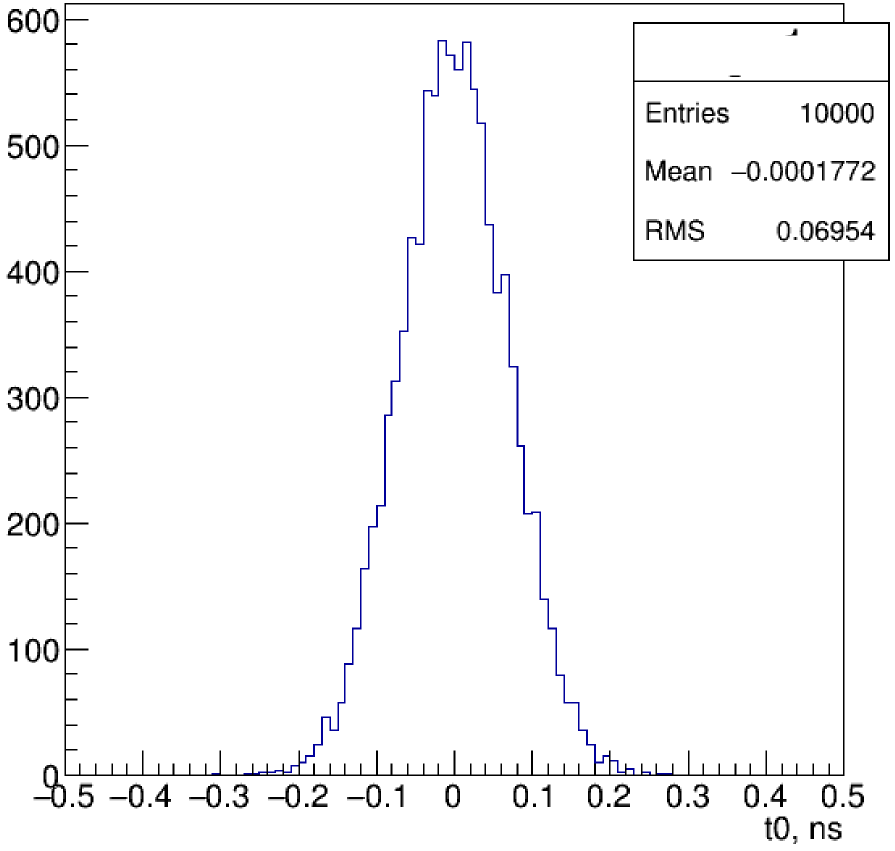


Number of particle detected as e, mu, pi, K or p

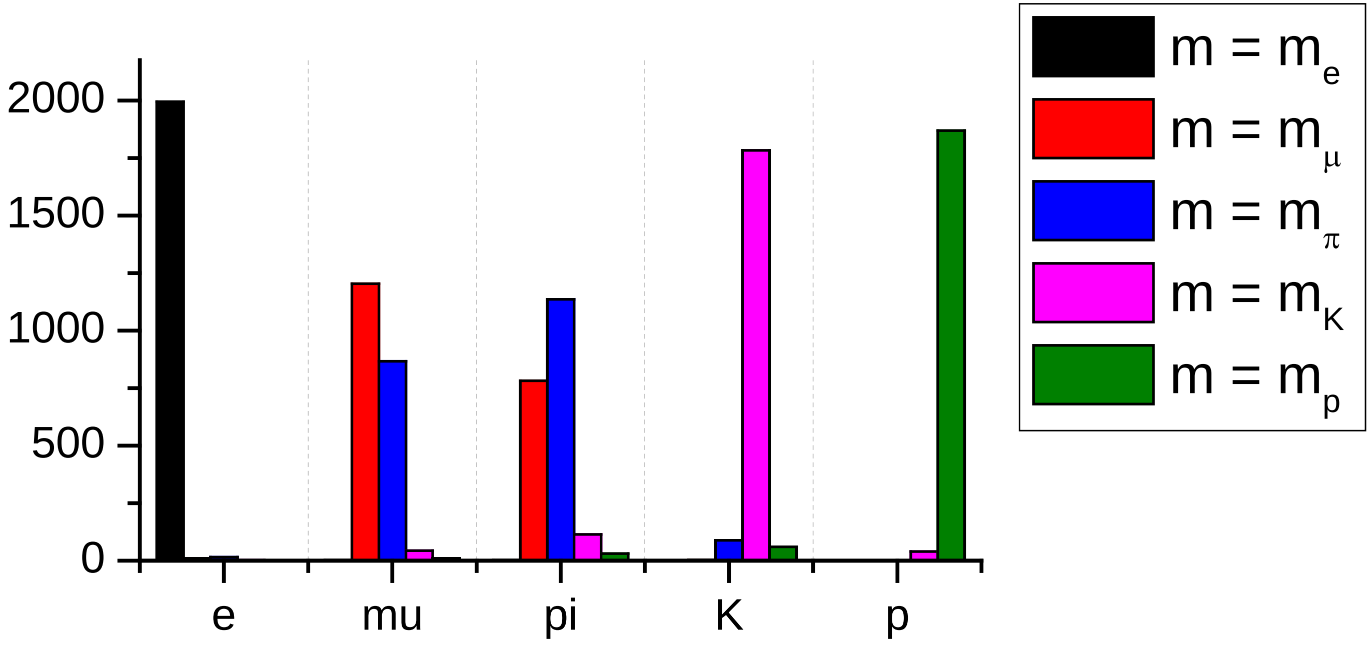


T0 and PID algorithm check with ToyMC

PID and t0 with TOF smearing and 2 particle in events



Number of particle detected as e, mu, pi, K or p

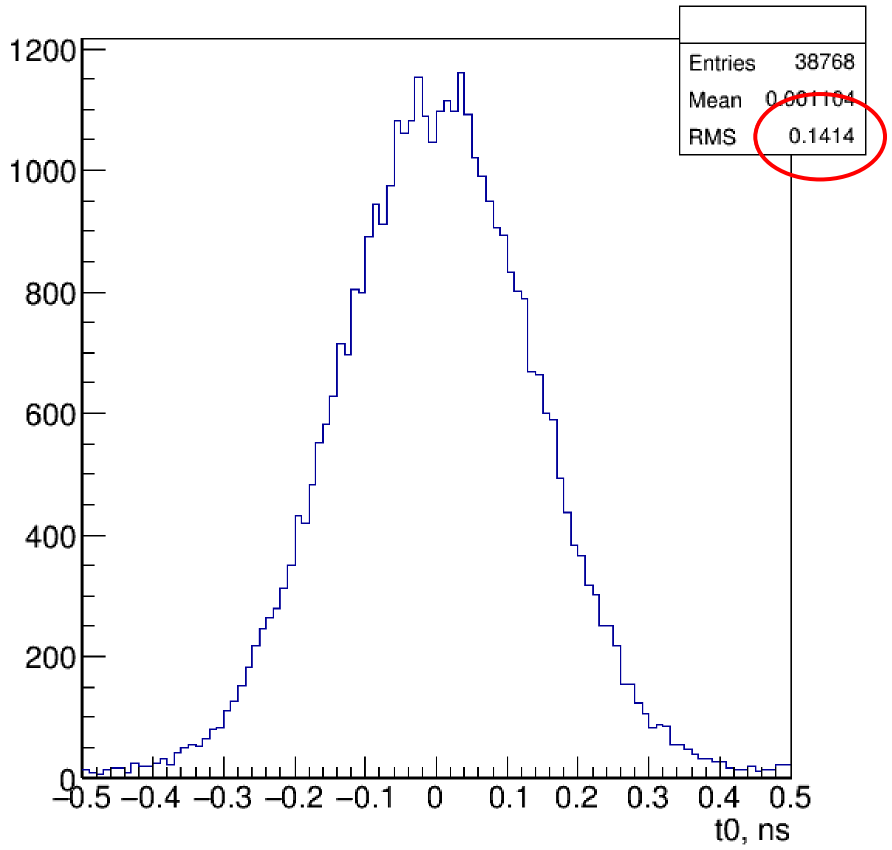


T0 and PID with PandaROOT

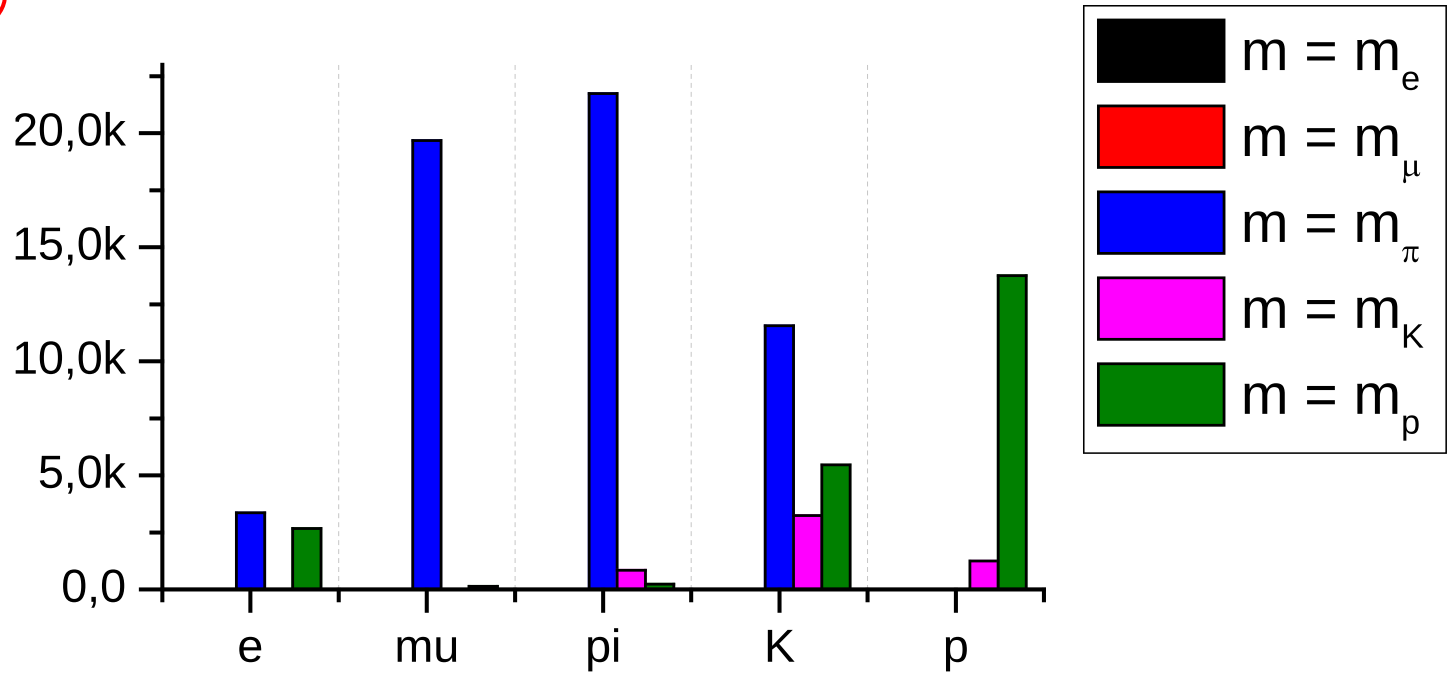
- Generate 1M DPM events
- FTOF time resolution set to 70 ps
- FtsIdealTrack reconstruction
- Use tracking info for momentum, t_{TOF} and track length
- Event base simulation -> T0 should be 0
- Cut on momentum p < 4 GeV
- Events with only 2 FTOF hits
- Events with 3 and more FTOF hits

T0 and PID with PandaROOT

PID and t0 for events with only 2 FTOF hits

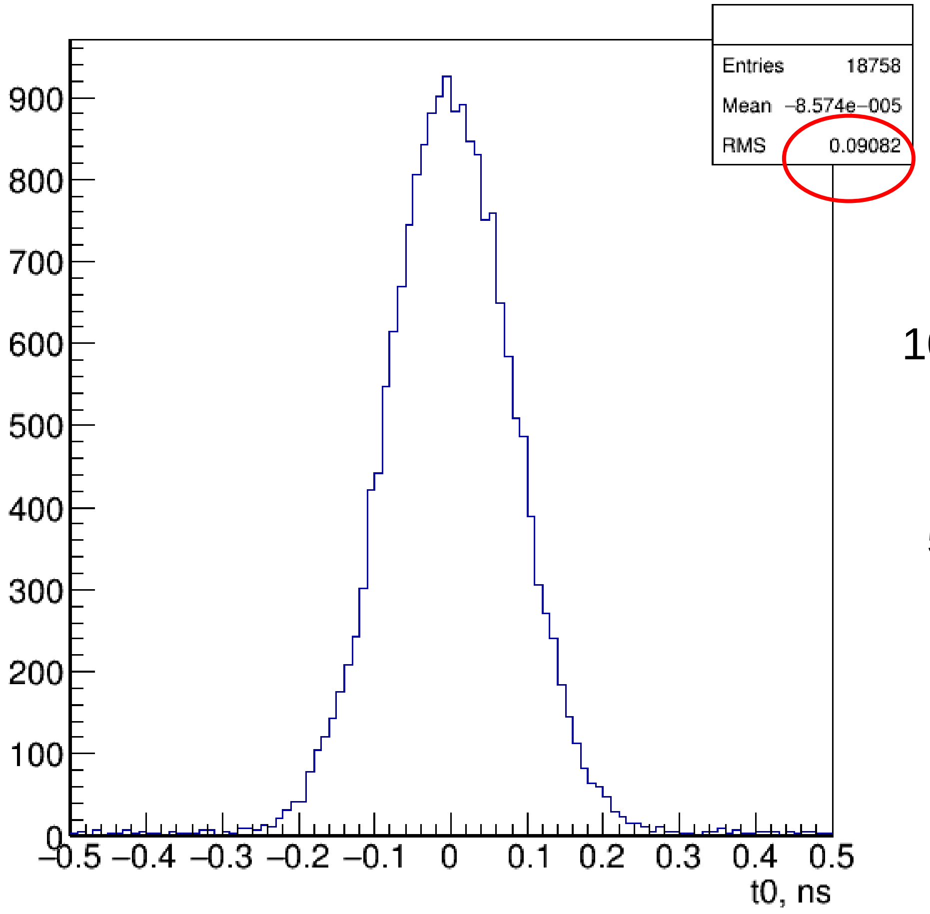


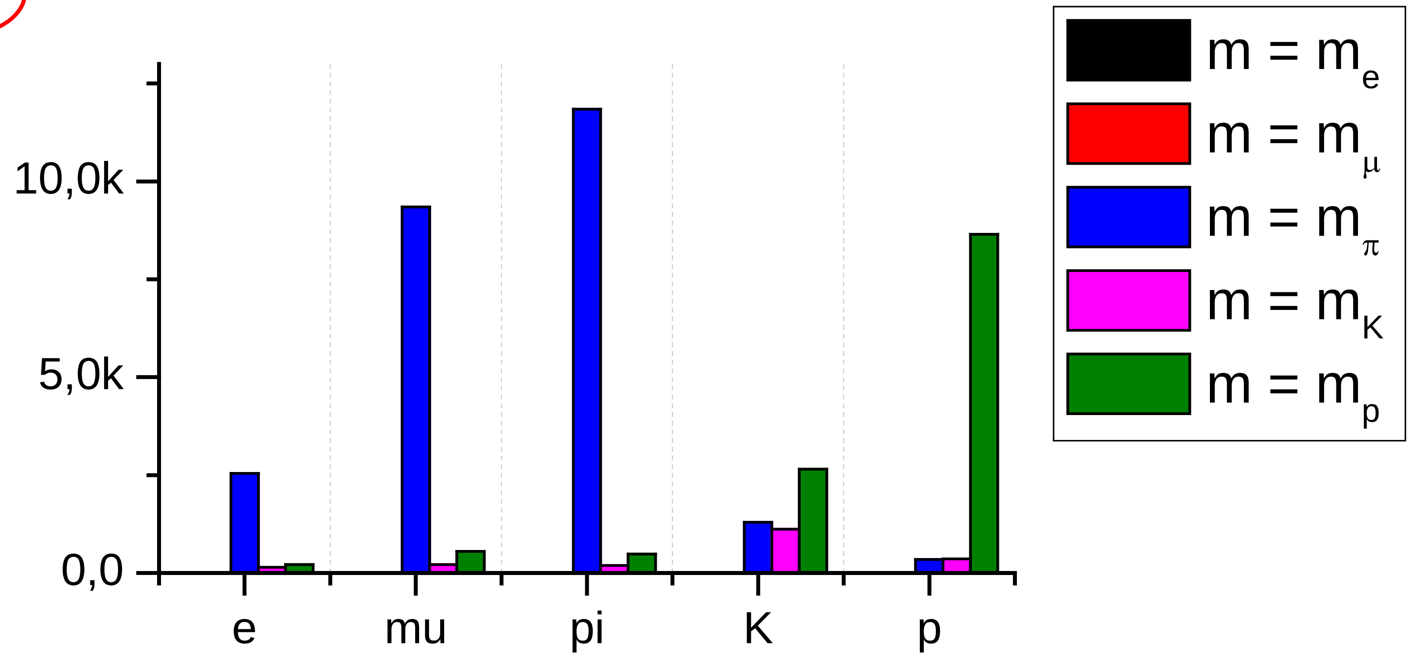
~20% protons as kaons and ~13% pions as kaons



T0 and PID with PandaROOT

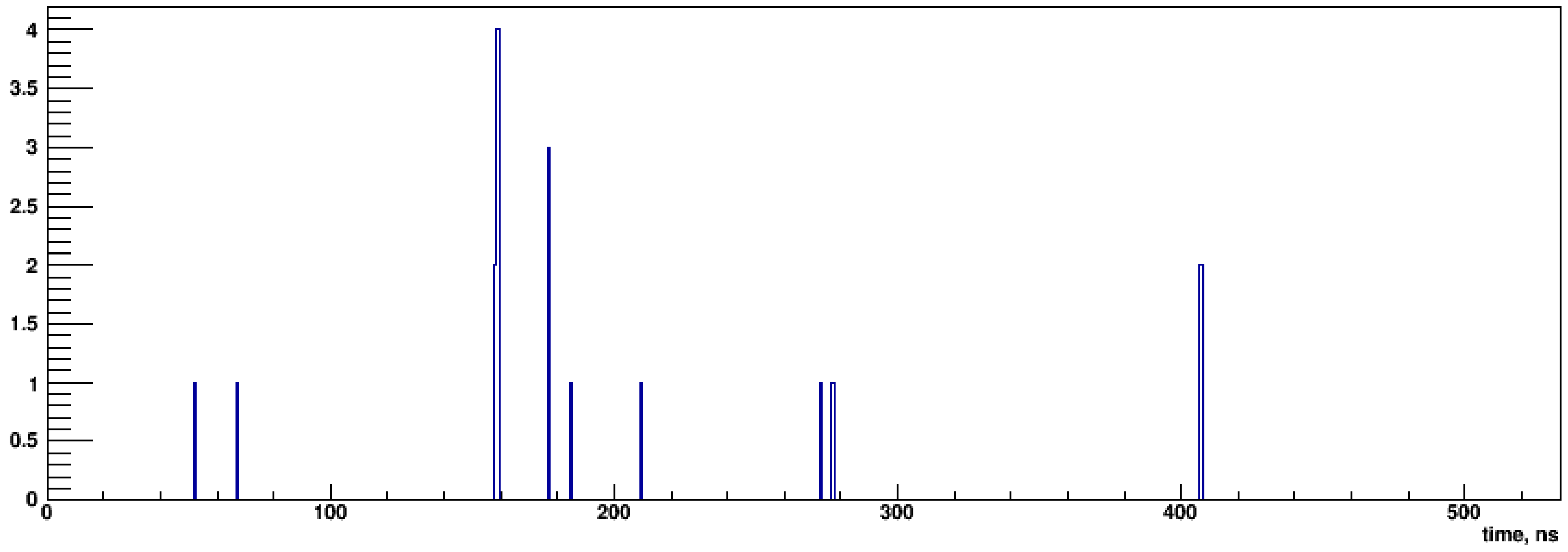
PID and t0 for events with only 3 FTOF hits

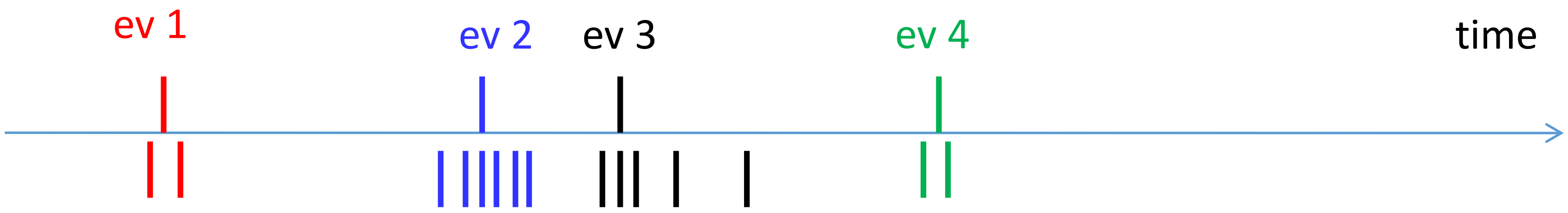




Timebase simulation

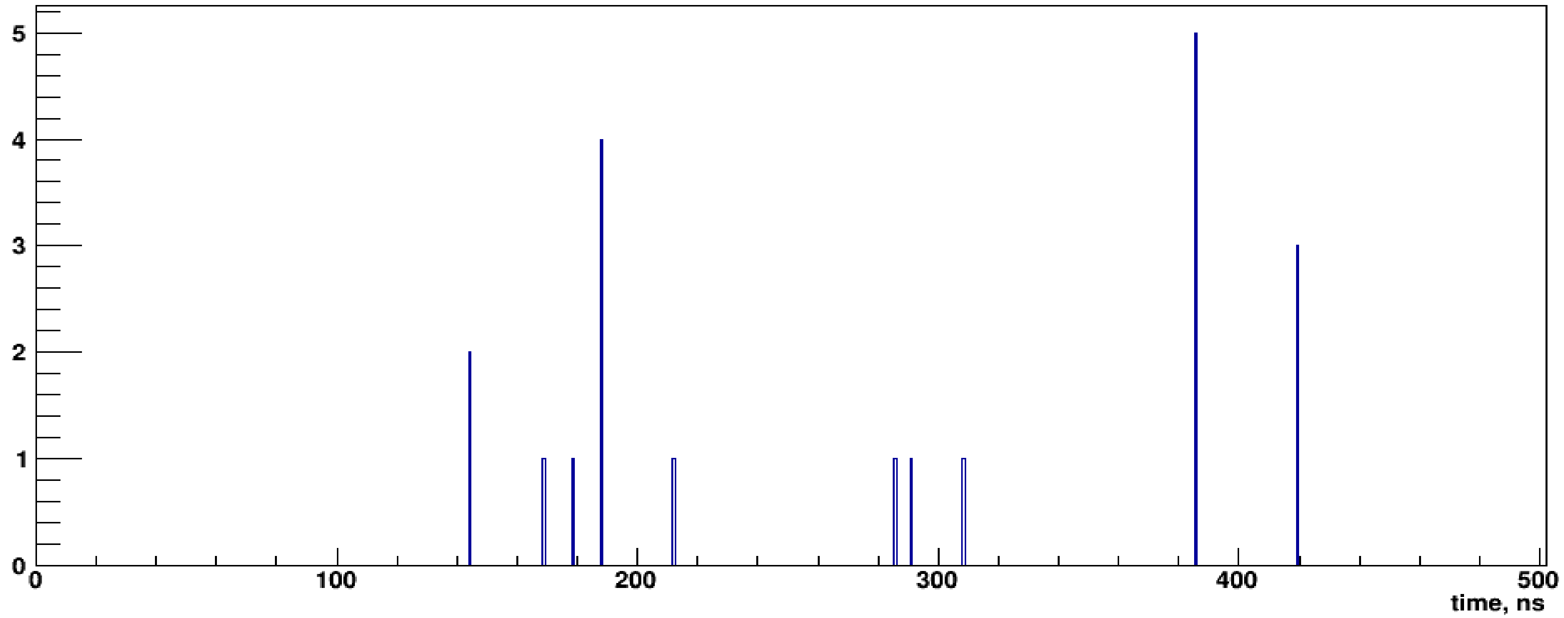
- DPM generator
- High lumi mode
- P_{beam}= 5 GeV

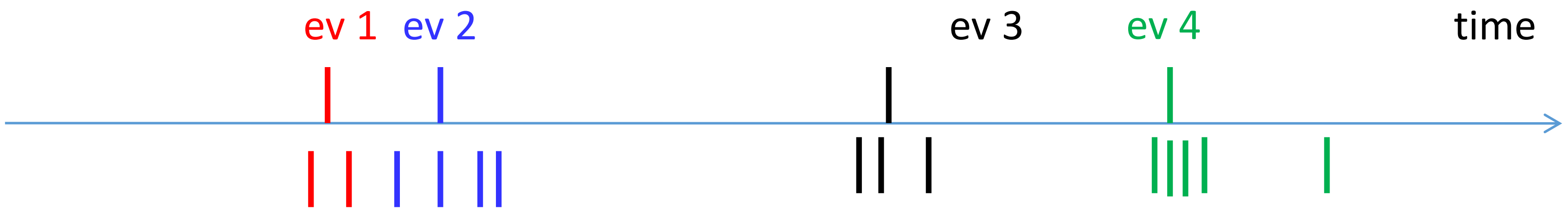




Timebase simulation

- DPM generator
- High lumi mode
- P_{beam}= 15 GeV





Open points and outlook

- Event sorting
- Quality of PID (separation power) in relative TOF
- Track length

- Standalone FTOF can separate particle with efficiency ~85% and determine T0 with resolution ~90 ps (ideal tracking)
- Way to improve, combine SciTil and FTOF hits