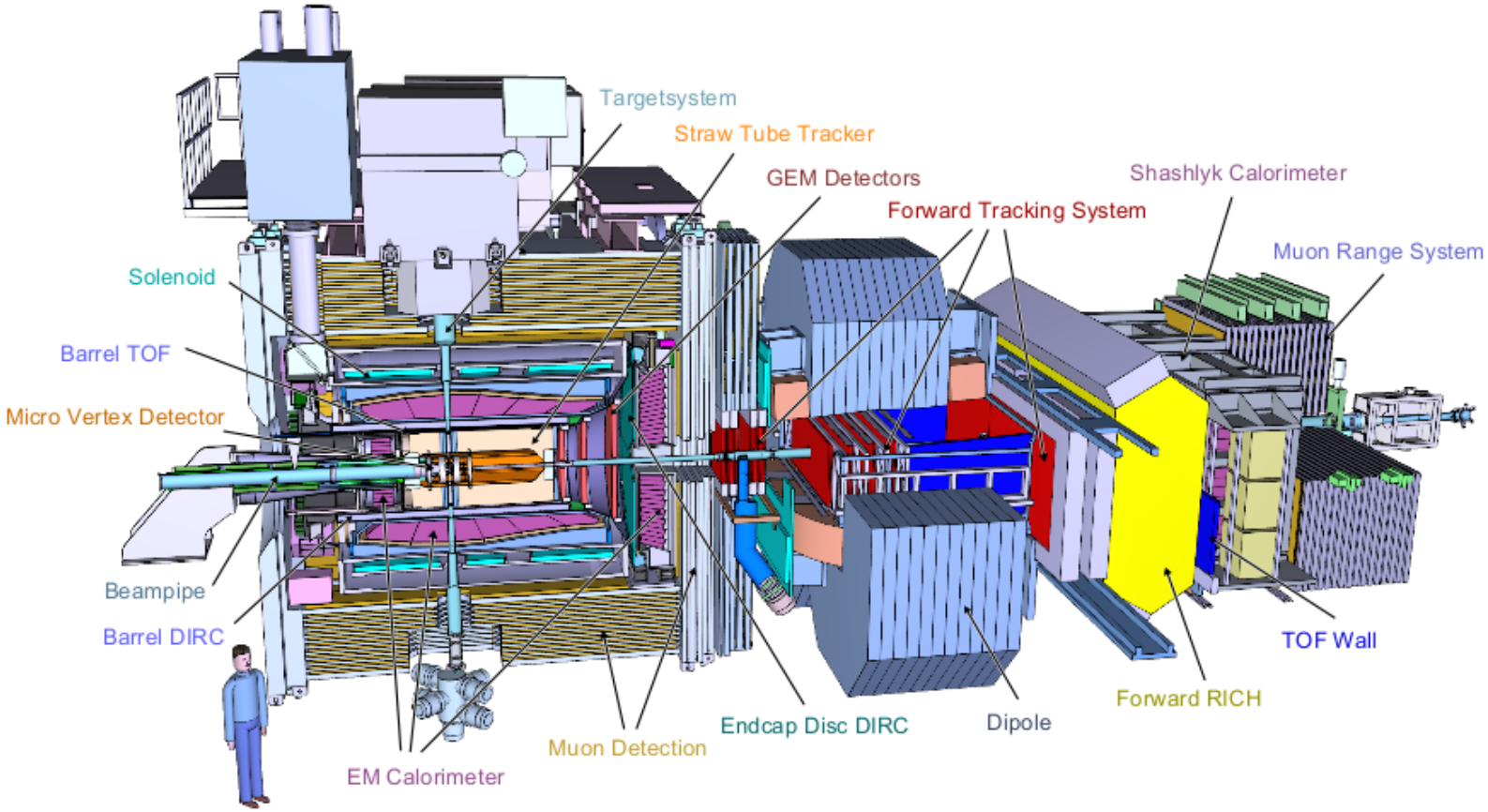
Particle Identification
with the
Barrel TOF

Dominik Steinschaden

Content

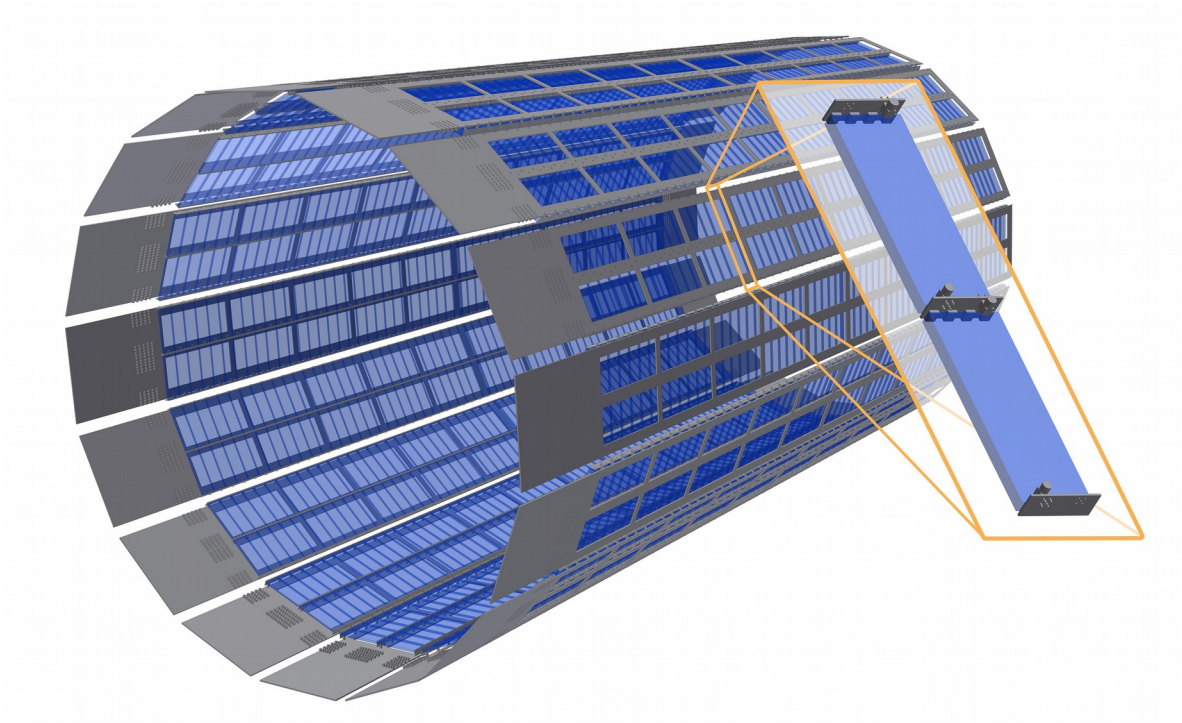
- Introduction to the Barrel TOF
  - Motivation
  - Requirements
  - Design
- Specifications and PandaRoot implementation
- Relative Time - of – Flight based PID
- Standard Time of Flight PID
- Open issues

Introduction



Barrel TOF

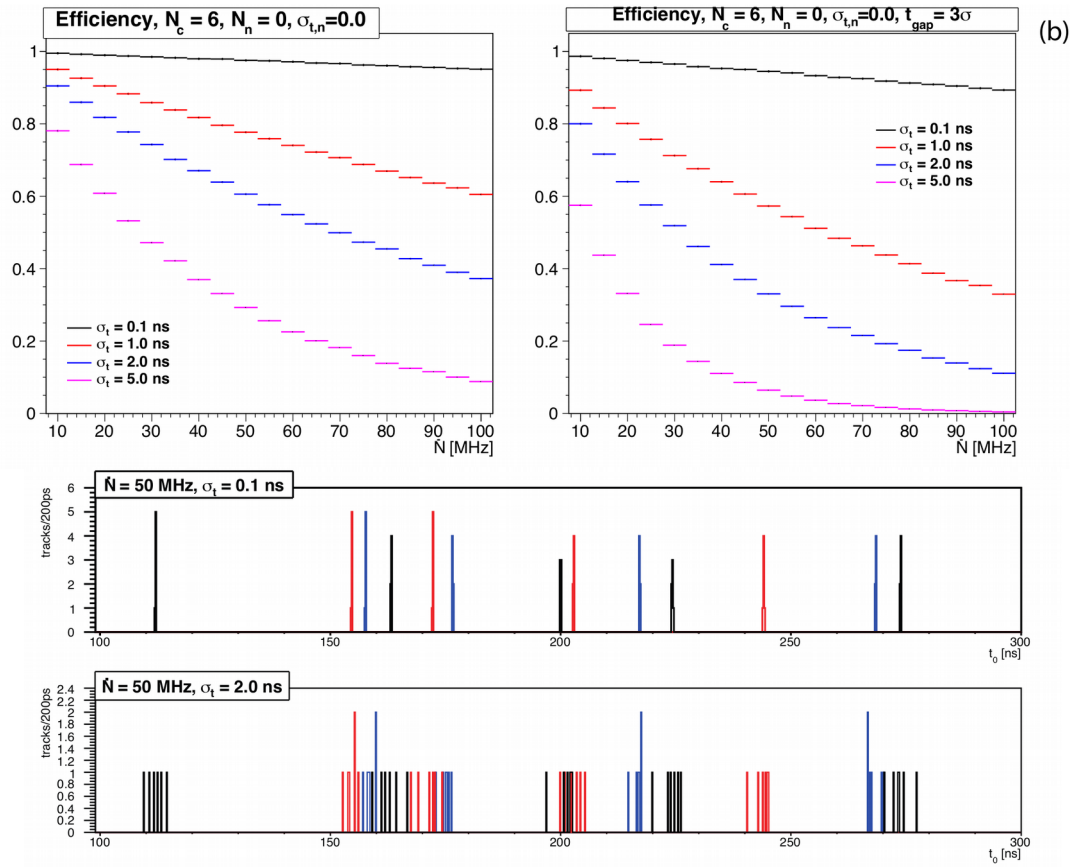
- Barrel-shaped scintillator tile hodoscope
- Timing counter for charged particles



Motivation and Requirements

Motivation

- Trigger-less, continuous read out at high collision rates (20 MHz)
  - Separation of single events at high collision rates
  - Event/ T0 determination
  - Intelligent online software trigger by event topology to reduce the data



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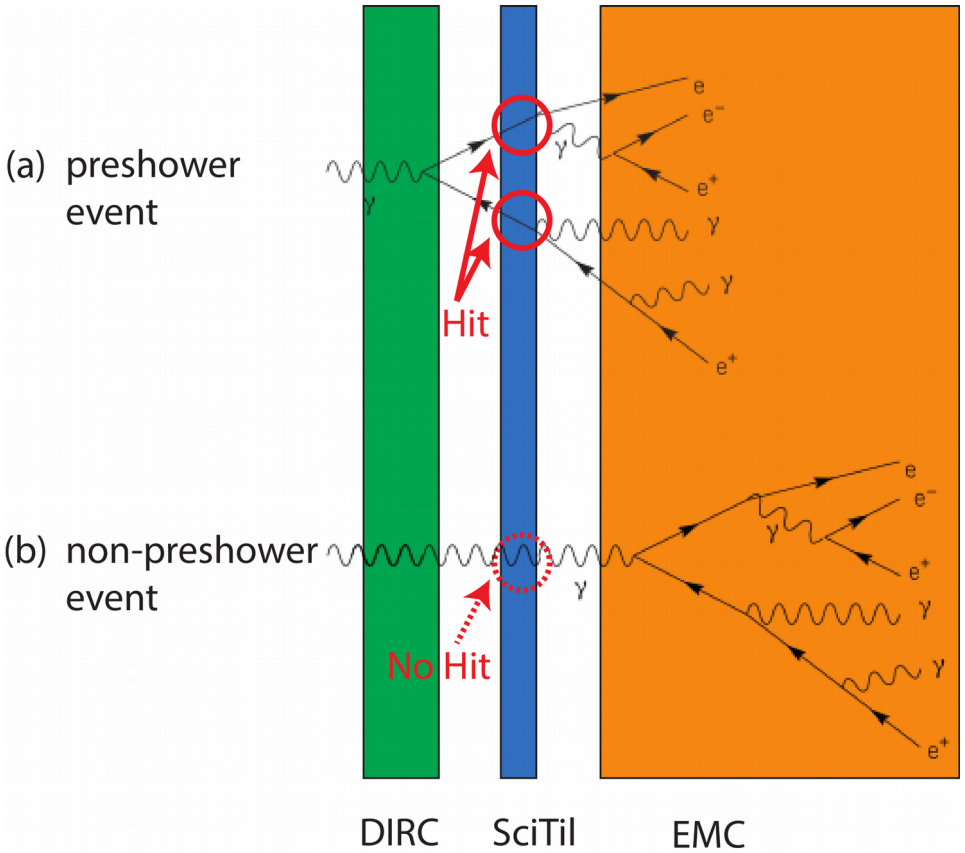
  - Charge discrimination and gamma conversion detection in front of the EMC
  - Ghost track reduction
  - Relative time-of-flight together with FTOF (t0 determination)



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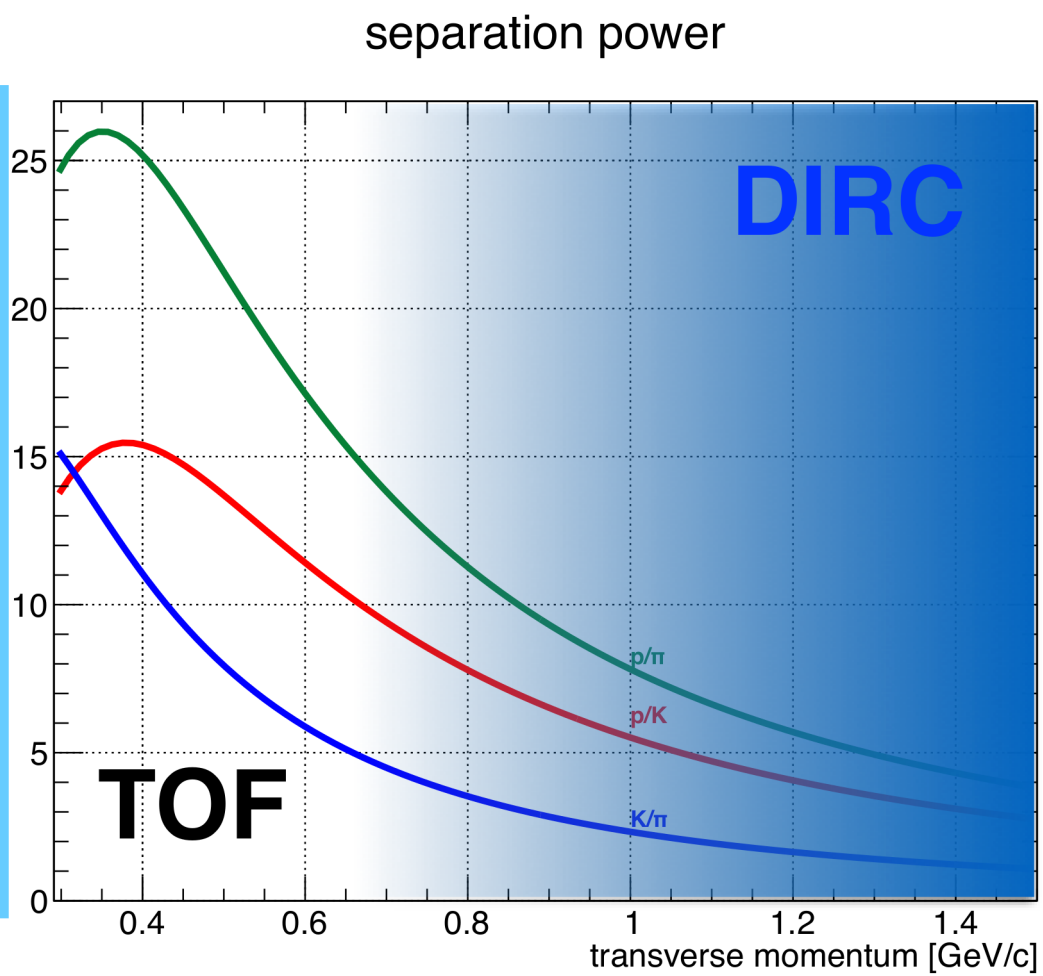
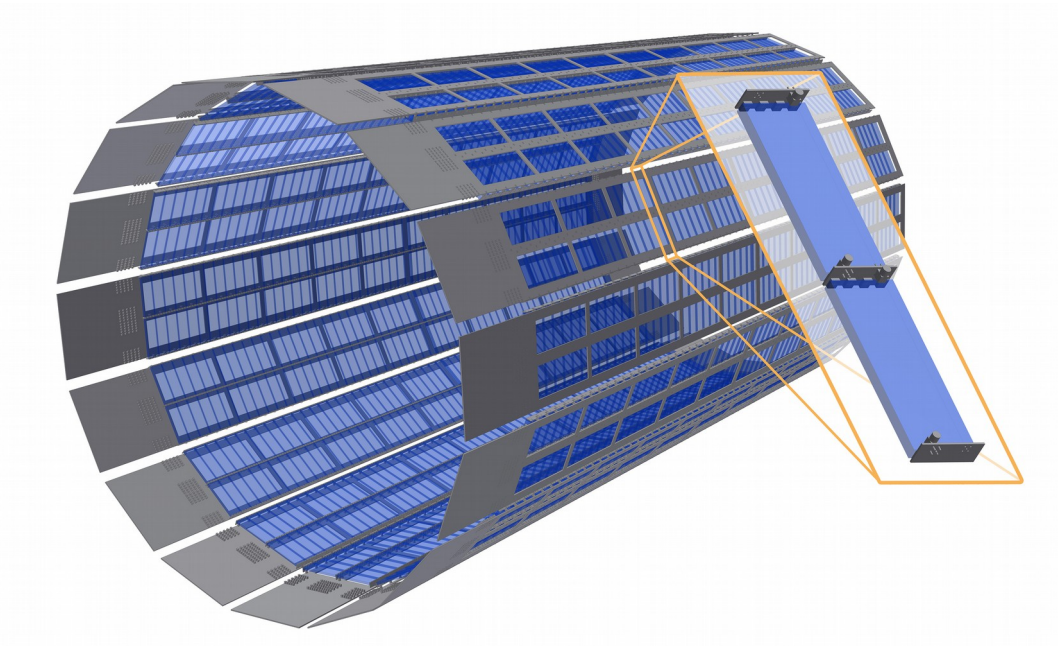
  - Relative time-of-flight together with FTOF (t0 determination)
- Particle identification below the Cherenkov detector (DIRC) momentum threshold



Requirements

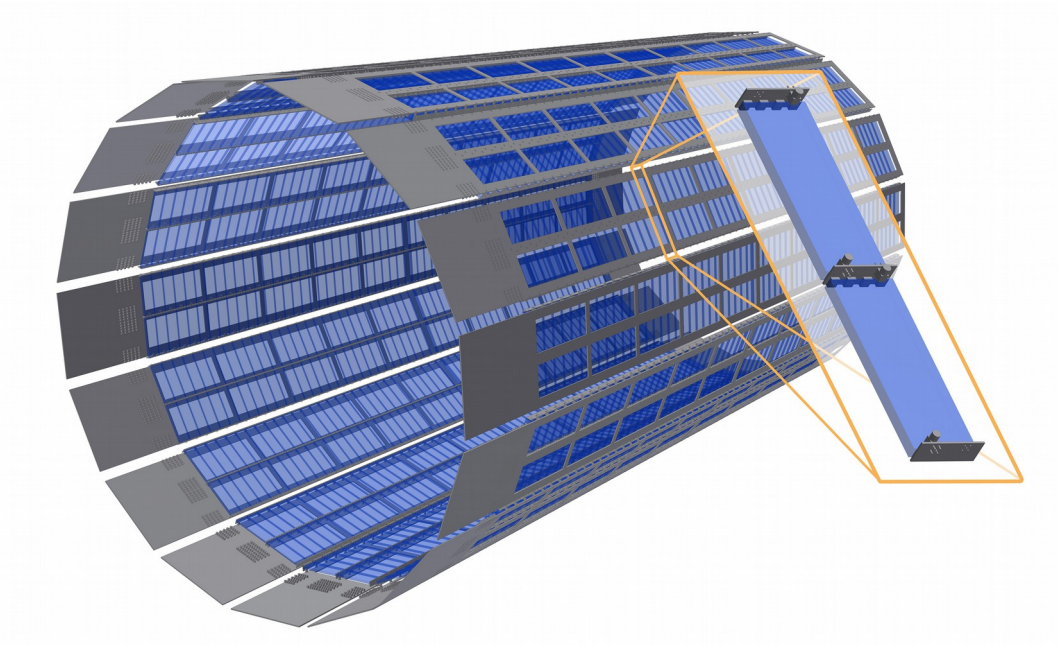
- Good time resolution
  - $\sigma < 100$ ps
- Fast readout and signal processing
- Robust and reliable for commissioning
- Minimum material budget
  - 2% of a radiation length
  - 2 cm radial thickness
- Large angular acceptance
  - $(22° \leq \theta \leq 140°)$
- Radiation hard



Design

Barrel TOF

- Barrel-shaped scintillator tile hodoscope
  - 16 super-modules
  - 48 signal railboards
  - 1920 scintillator modules
  - 3840 signal channels
  - 15360 SiPMs



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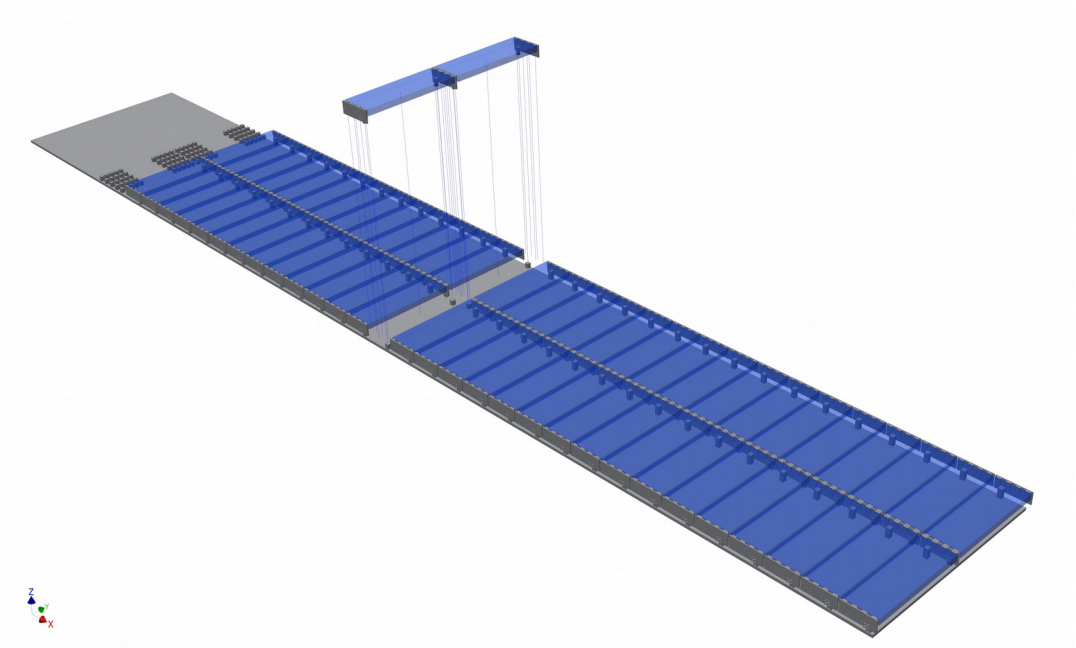

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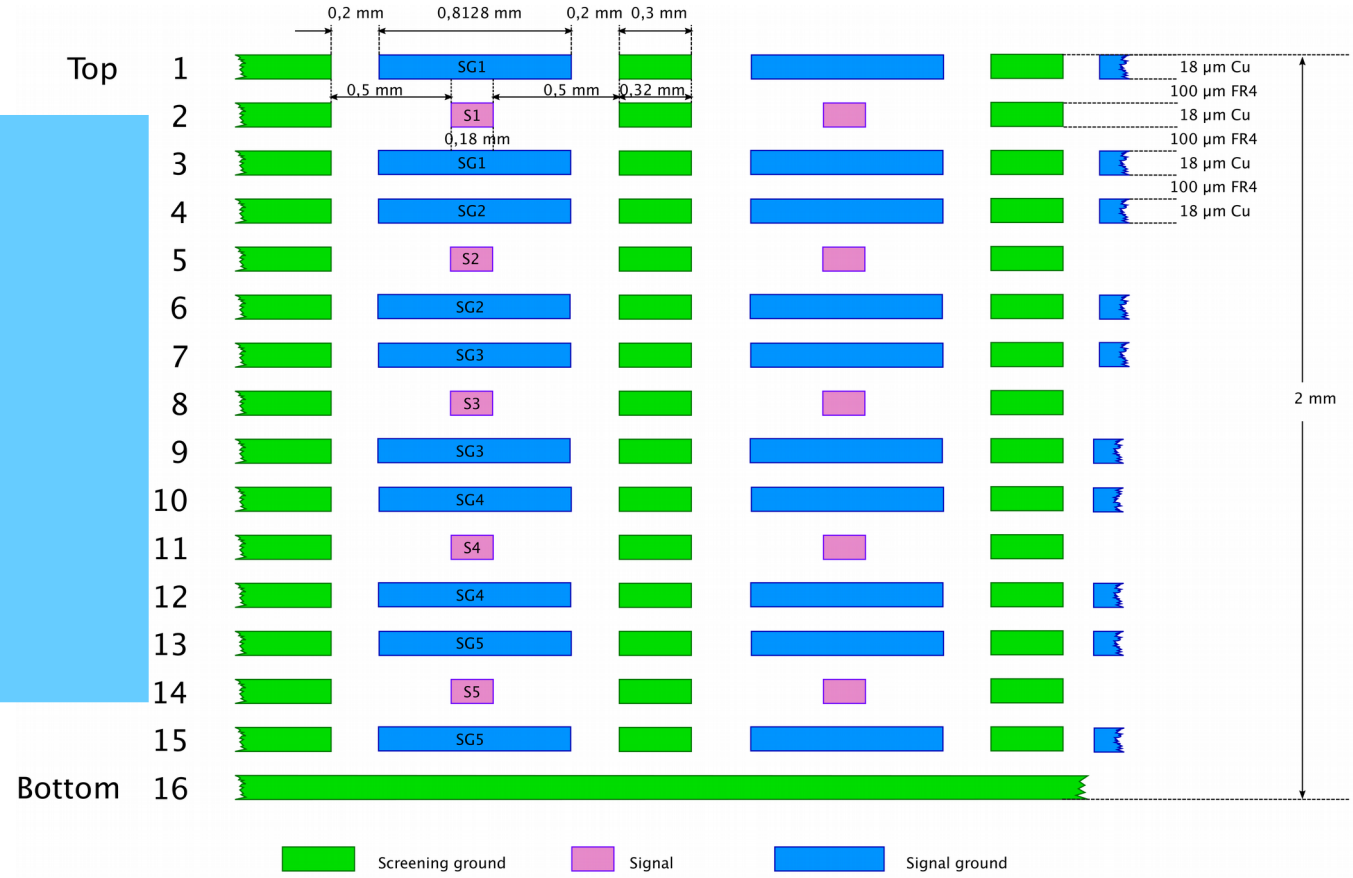

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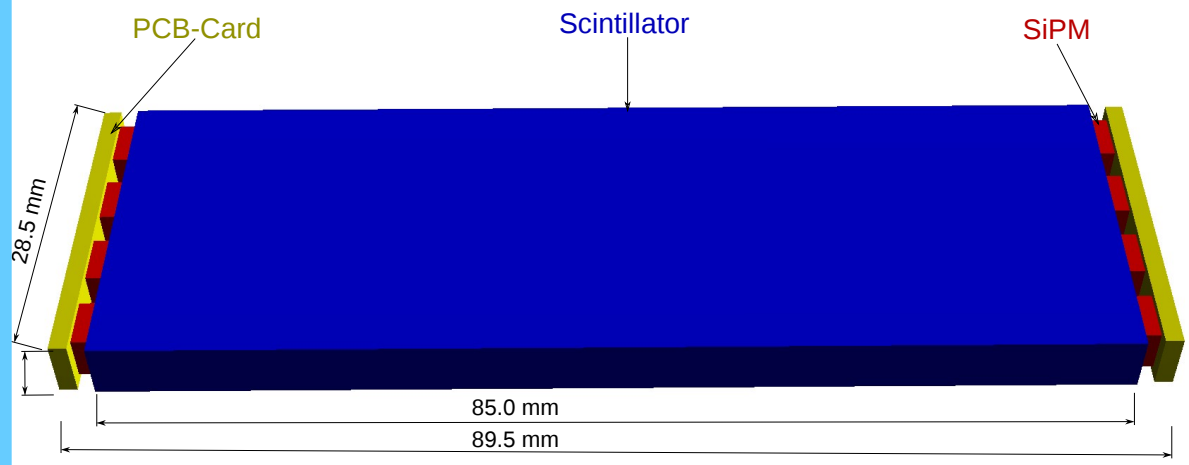
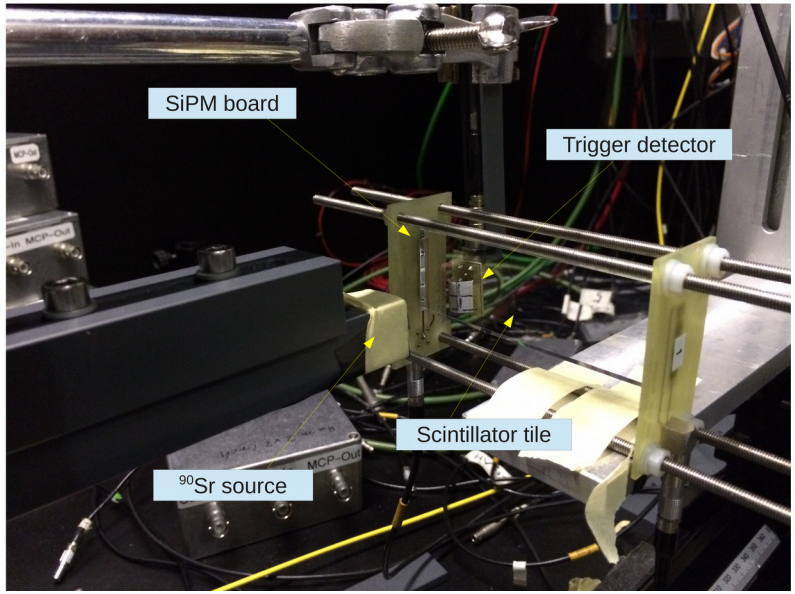


A detector module consists of a scintillator tile (blue), read out by 4 SiPMs (red) on both sides. The PCB cards (yellow) connect the SiPM and the signal railboards.

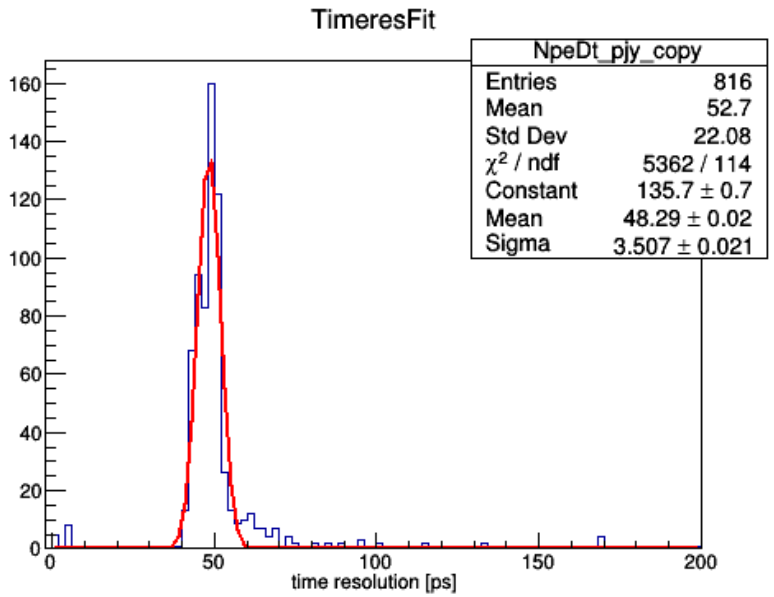
Time and Position Resolution

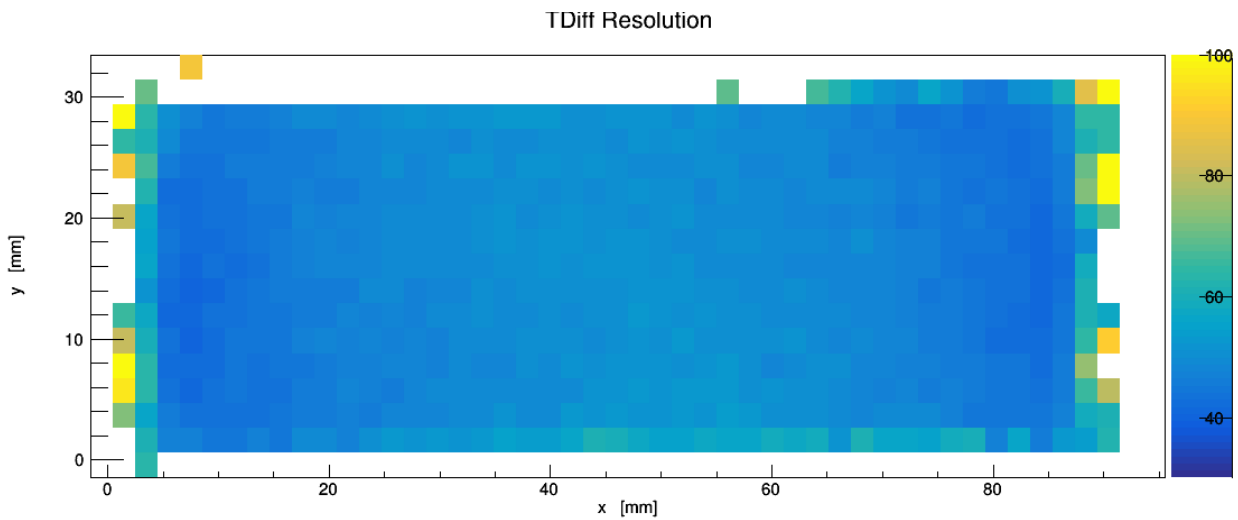
Erlangen 2017



Erlangen 2017

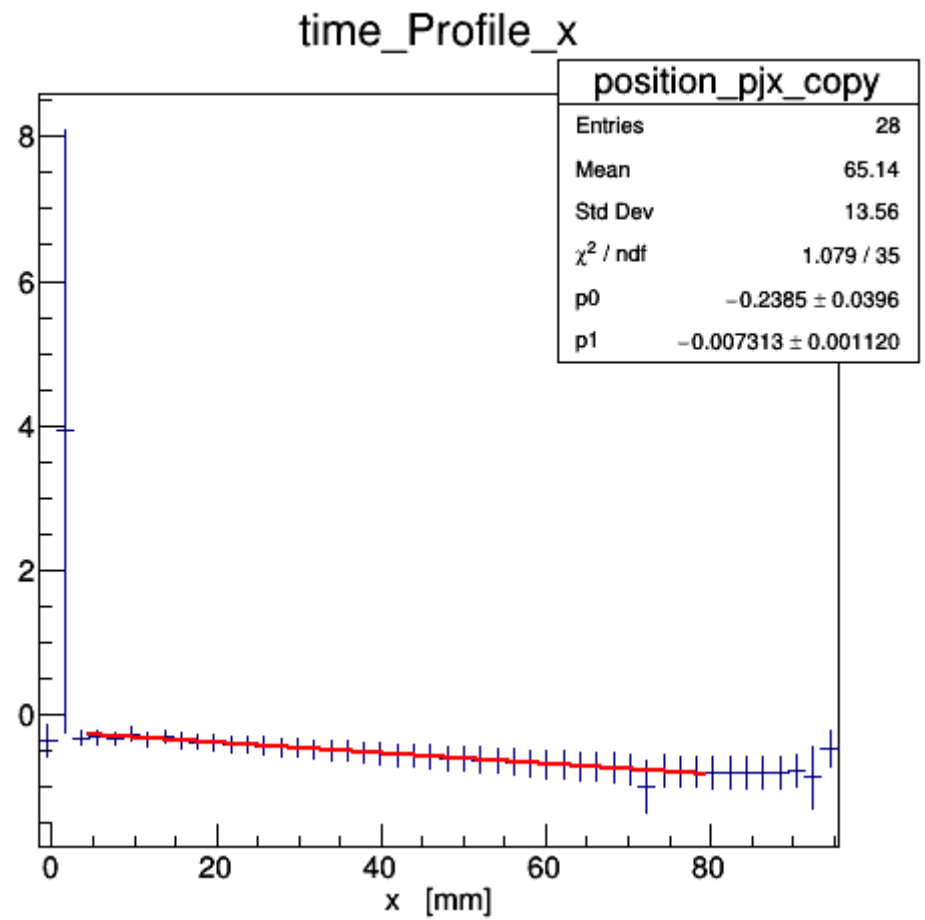
- Time resolution σ < 50 ps





Erlangen 2017

- Time resolution
  - σ < 50 ps
- Position resolution
  - σ~14mm

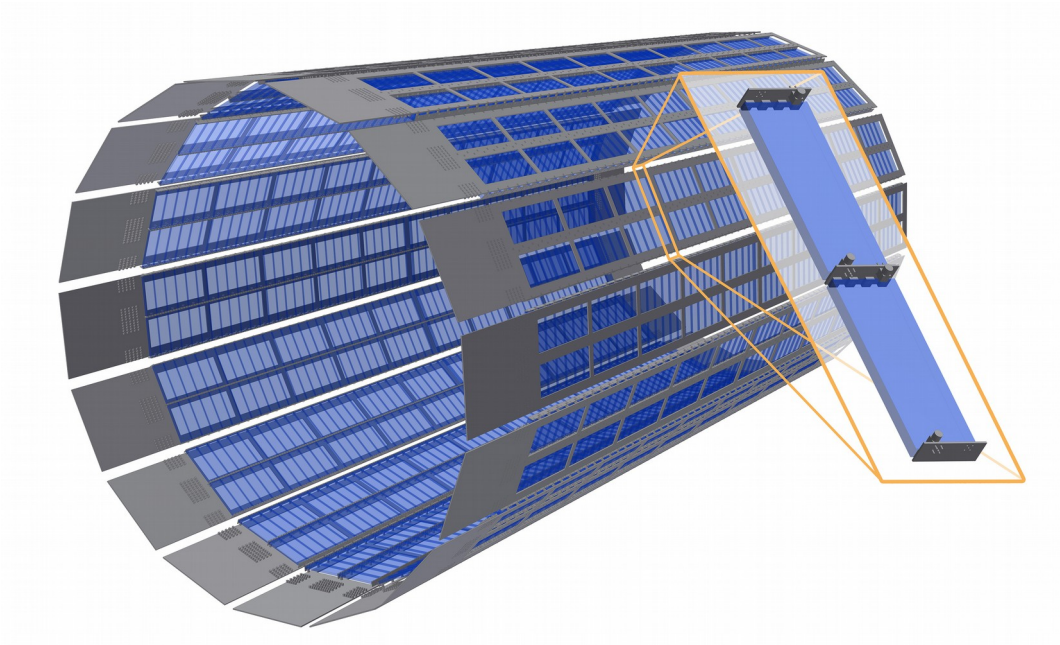


Implementation of the Barrel TOF in PandaRoot

- Fully implemented
  - Current design
    - Scintillator, SiPM, PCB boards
  - Time resolution : $\sigma = 75$ ps
  - Event and time based
    - Pile up
    - Event mixing
  - Access to
    - Time
    - Position
    - Errors
    - Charge deposit

Geometrical Acceptance and Efficiency

- Angular acceptance
  - 22° < θ < 140°
    - No forward end cap!
    - FTOF : 0° < θ < 5°
- Geometrical efficiency
  - Active area
    - 4.9 m²
    - ~ 86 %
    - Gap for support structure, target, wrapping



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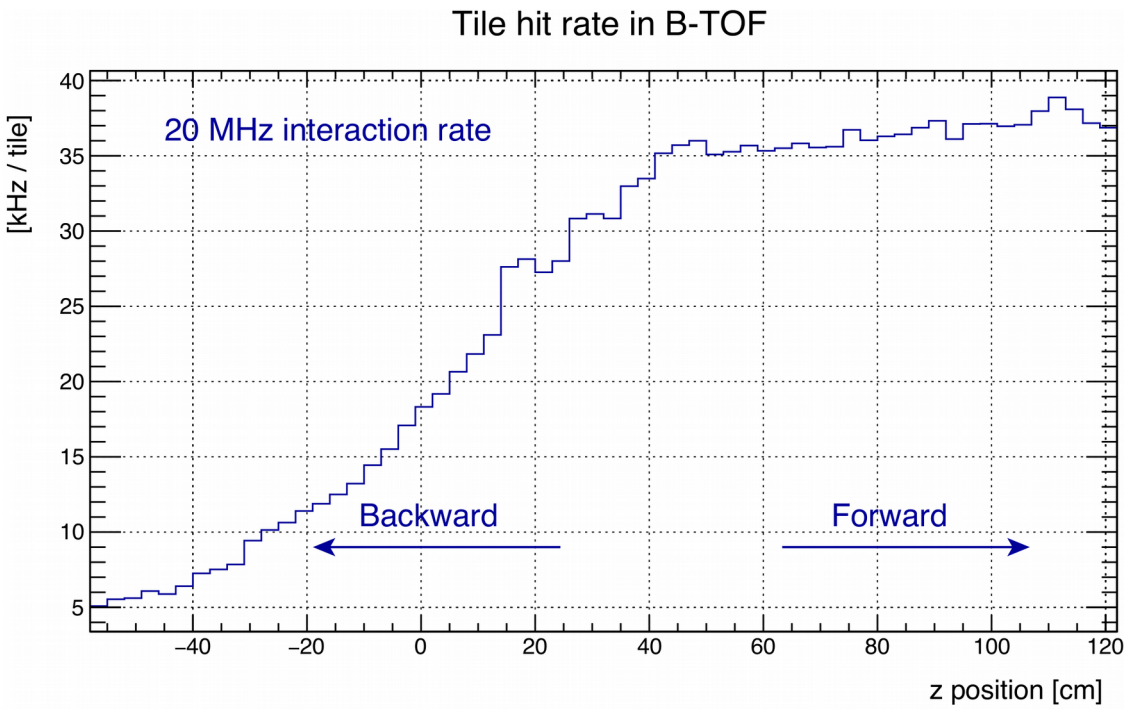
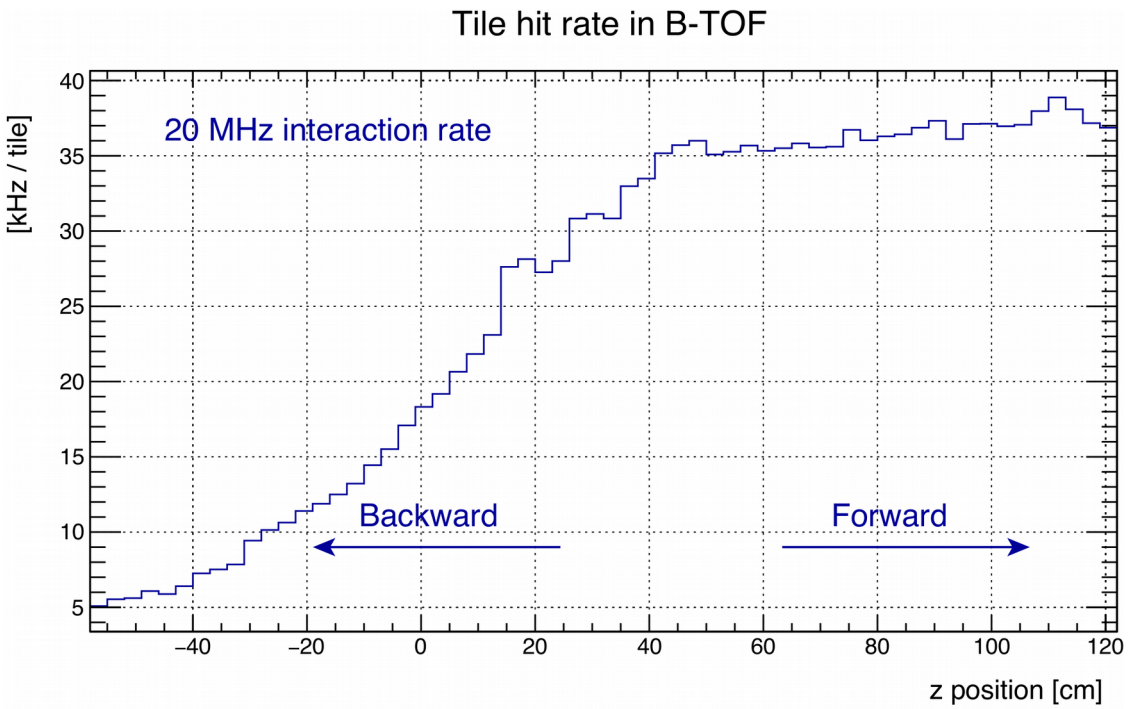
    - Gap for support structure, target, wrapping
  - Geometrical efficiency > 91 %
    - Forward peaking distribution, emission angles



- Angular acceptance
  - 22° < θ < 140°
- Geometrical efficiency
  - Active area
    - 4.9 m²
    - ~ 86 %
    - Gap for support structure, target, wrapping
  - Geometrical efficiency > 91 %
    - Forward peaking distribution, emission angles
- DAQ efficiency > 99 %
    - PETsys TOFPET2 ASIC
    - Internal buffer for up to 4 hits



Relative TOF based PID

- No start time detector in PANDA
  - T_0 important for Event building, Tracking, TOF . . .
- Relative time of flight using TOF counters

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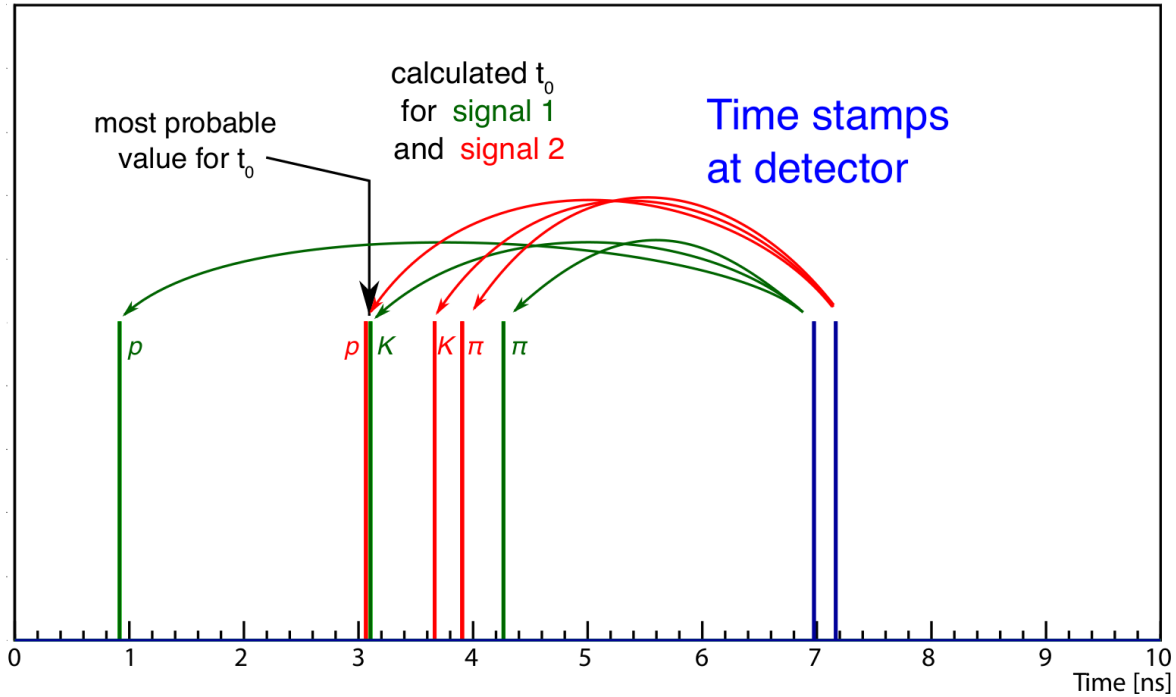
  - T_0 important for Event building, Tracking, TOF . . .
- Relative time of flight using TOF counters
  - Calculate possible t_s for all detected tracks
    - Using reconstructed track parameters
    - Mass assumption for p, K, π, μ, e
  - evaluate all 5^N mass configurations
    - Compare their X^2 weights
    - Select the most promising



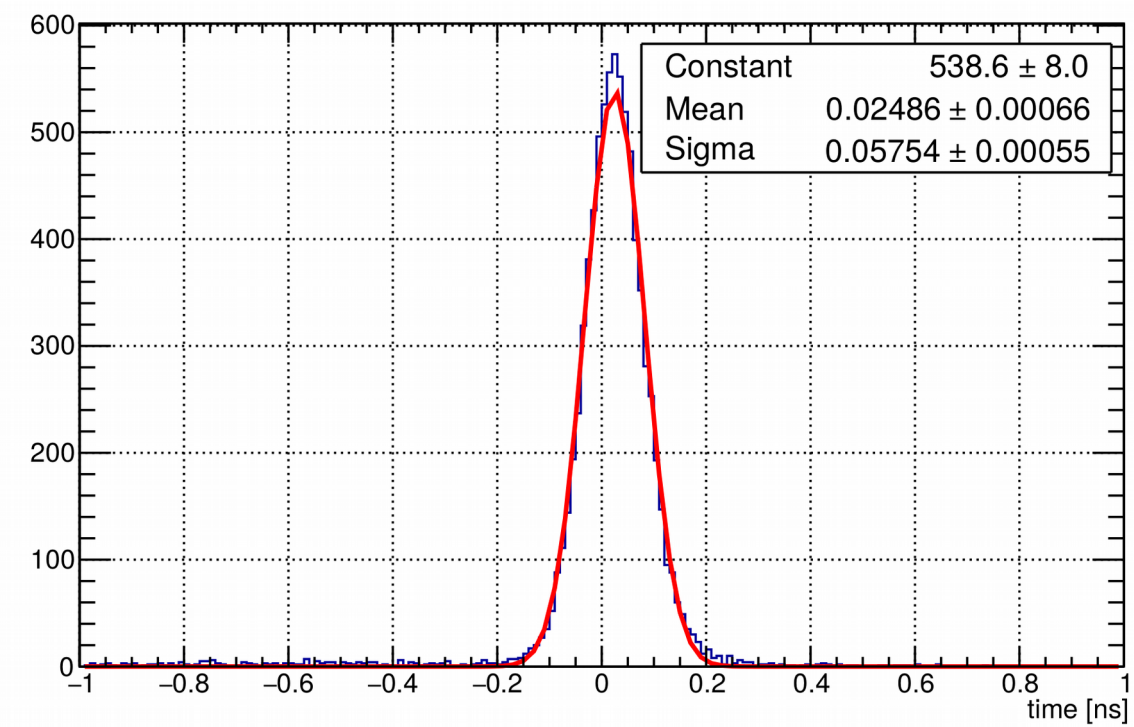
- For the detected signals in the Barrel TOF (blue) the corresponding possible track creation times according to a certain mass assumption are calculated (green and red). The combination providing the best conformity is equivalent to the most probable mass configuration.

- Evaluate all 5^N mass configurations
  - Minimization of the X^2

$$\Psi_{W_{(m_1,\ldots,m_N)}} = \frac{\sum_{i=1}^{N} (t_{i,0} - t_0)^2}{\sigma_{i,TOF}^2}$$

$$t_{i,0} = t_i - \frac{l_i}{c} \cdot \sqrt{\frac{m_i^2}{p^2} + 1}$$

- Either select most probable mass configuration
  - Lowest X^2 Value
- Or get a p.d.f for every track and mass hypothesis



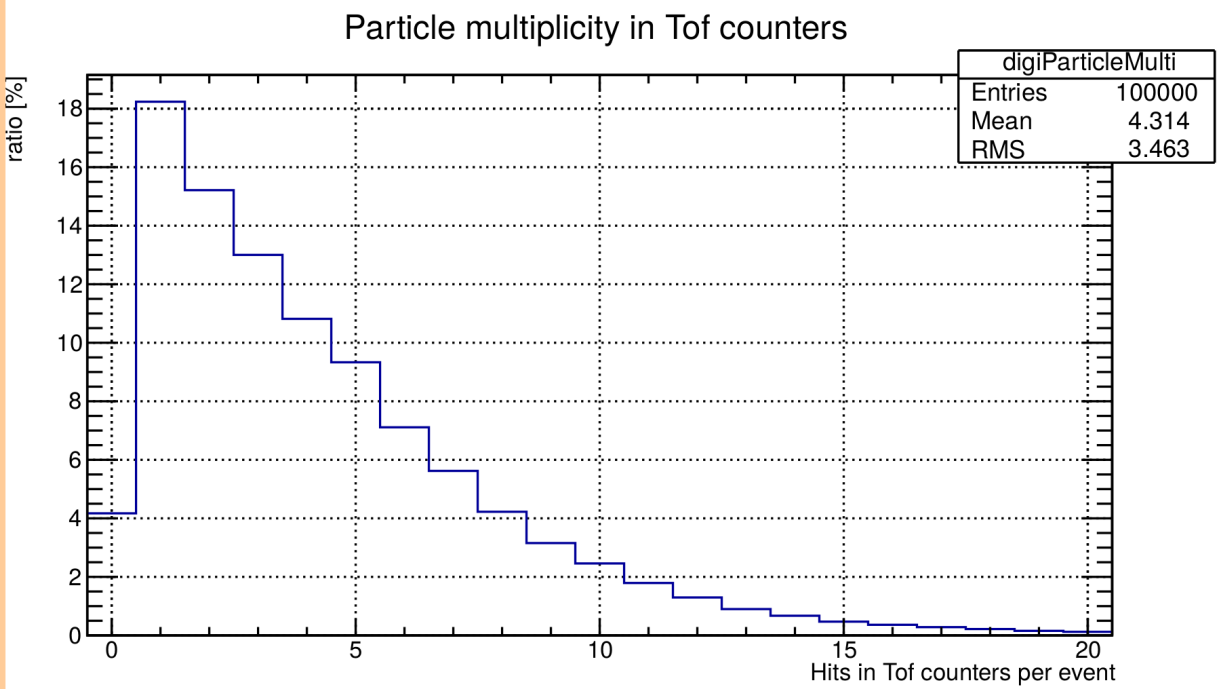
Distribution of determined t 0 for events with three or more primary tracks with the relative time-of-flight algorithm.

The T0 resolution σ = 57 ps

Including secondaries → σ = 71 ps

Open issues

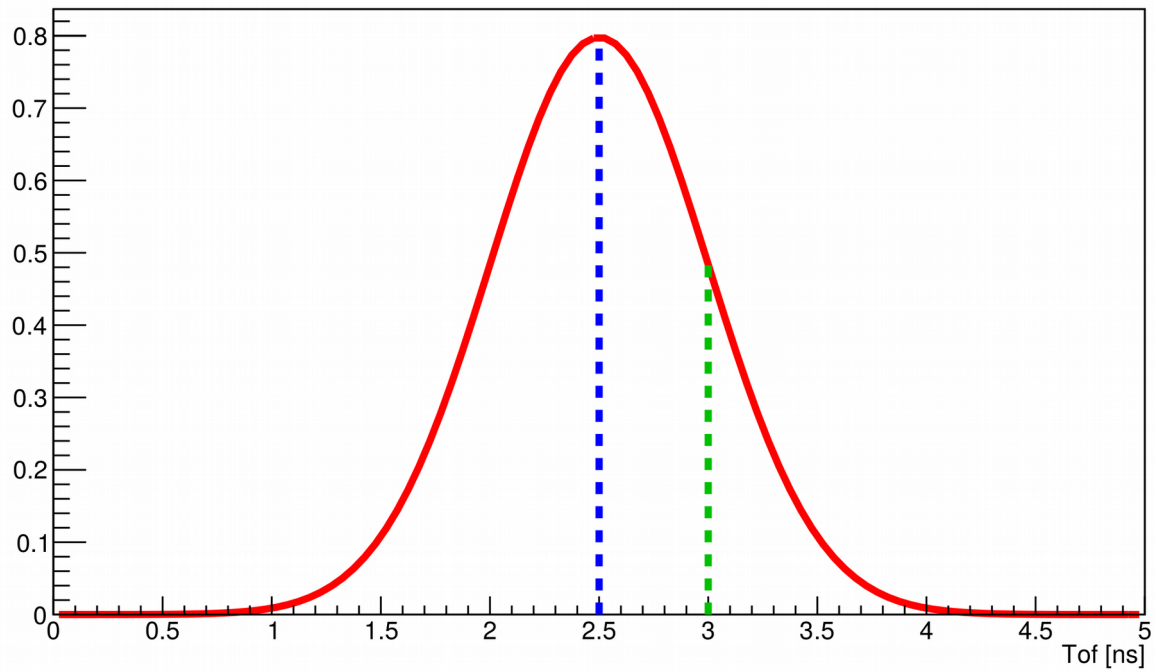
- Proper event sorting needed?
  - Ignore outliers
    - ALICE Collaboration
- Multiple reconstructed and matched tracks needed
  - Combined TOF counters!
  - Special treatment of secondaries?
- T0 window would improve failure rate
- Only implemented in PandaRoot locally
  - Only using Barrel TOF at the moment
  - Low Efficiency!



- Unbiased by previous T0 determination
- Get p.d.f and T0 in one step
- Get a probability for a T0 !

Time-of-Flight based PID

- TOF based PID
  - Use tracking information and mass assumption
  - Calculate expected time of flight
    - $t_i \equiv l \cdot \sqrt{\left(\frac{m_i}{p}\right)^2 + 1}$
  - Compare with the measured time of flight
    - Consider resolution of the TOF System



A normalized Gaussian is created at the expected time-of-flight for the mass assumption of a proton (blue). The probability density is evaluated at the measured time-of-flight in the Barrel TOF (green).

Time-of-Flight Resolution

Evaluation of the TOF system

- Including momentum, path length and time resolution
  - Comparison of calculated time-of-flight and measured time in the Barrel TOF
- Evaluated for various parameters
  - Momentum, transverse momentum, track length, particle species, hit position . . .

Simulation Settings

- Box generator
- Only inner barrel detectors activated
  - MVD, STT, GEM, DIRC, BTOF
  - Very clean events!
- MVDSTTGEM tracker
- Only tracks with a MC True Matching of the Track and the BTOF signal were considered

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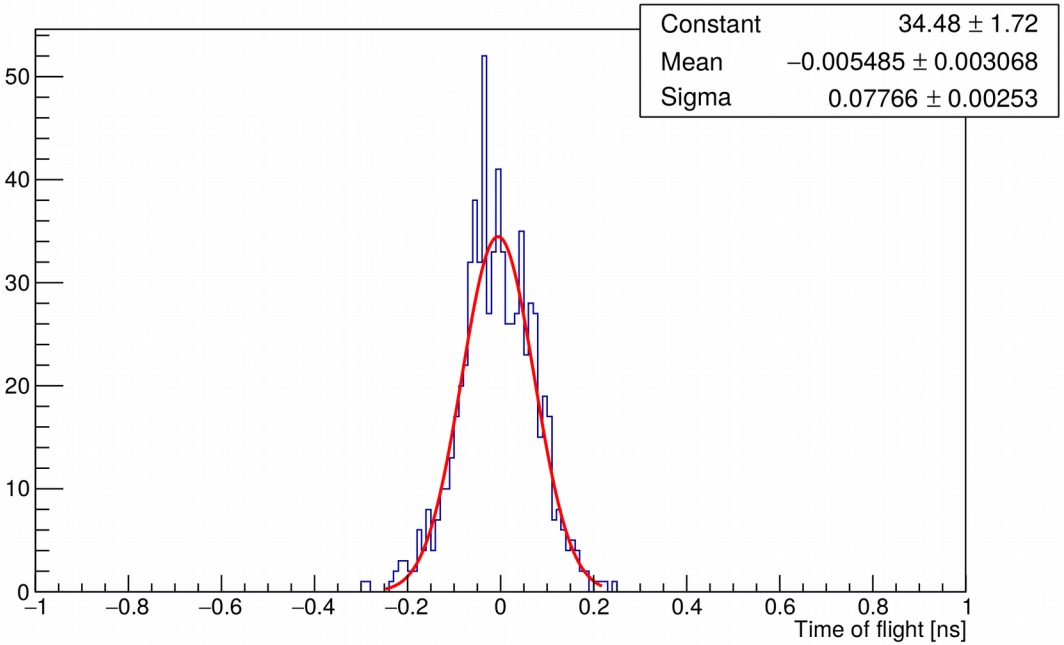
- Dependence on
  - Particle species
  - Transverse momentum pt
  - Minimum pt required ~ 200 MeV/c



- TOF destribution
  - π^-
  - pt = 1.5 GeV/c
  - 43 cm in forward direction
  - Resolution $\sigma = 78$ ps

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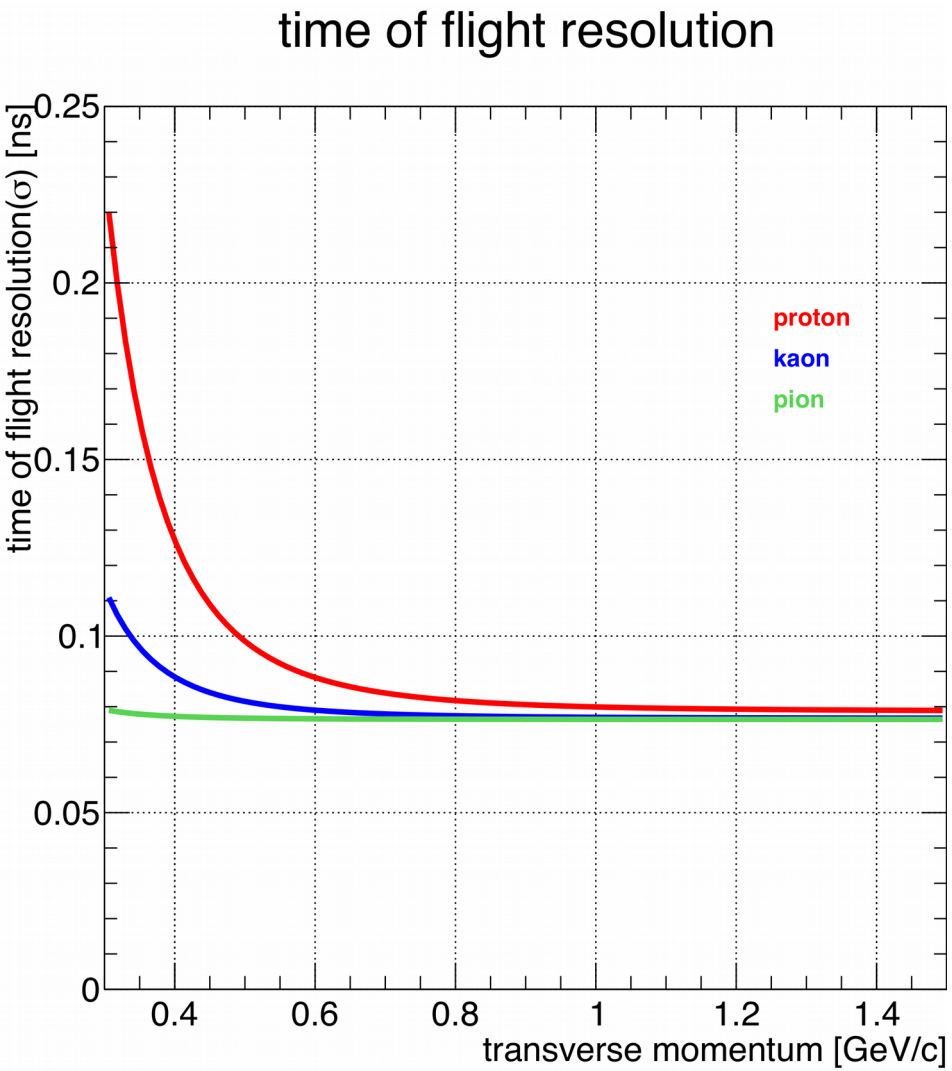
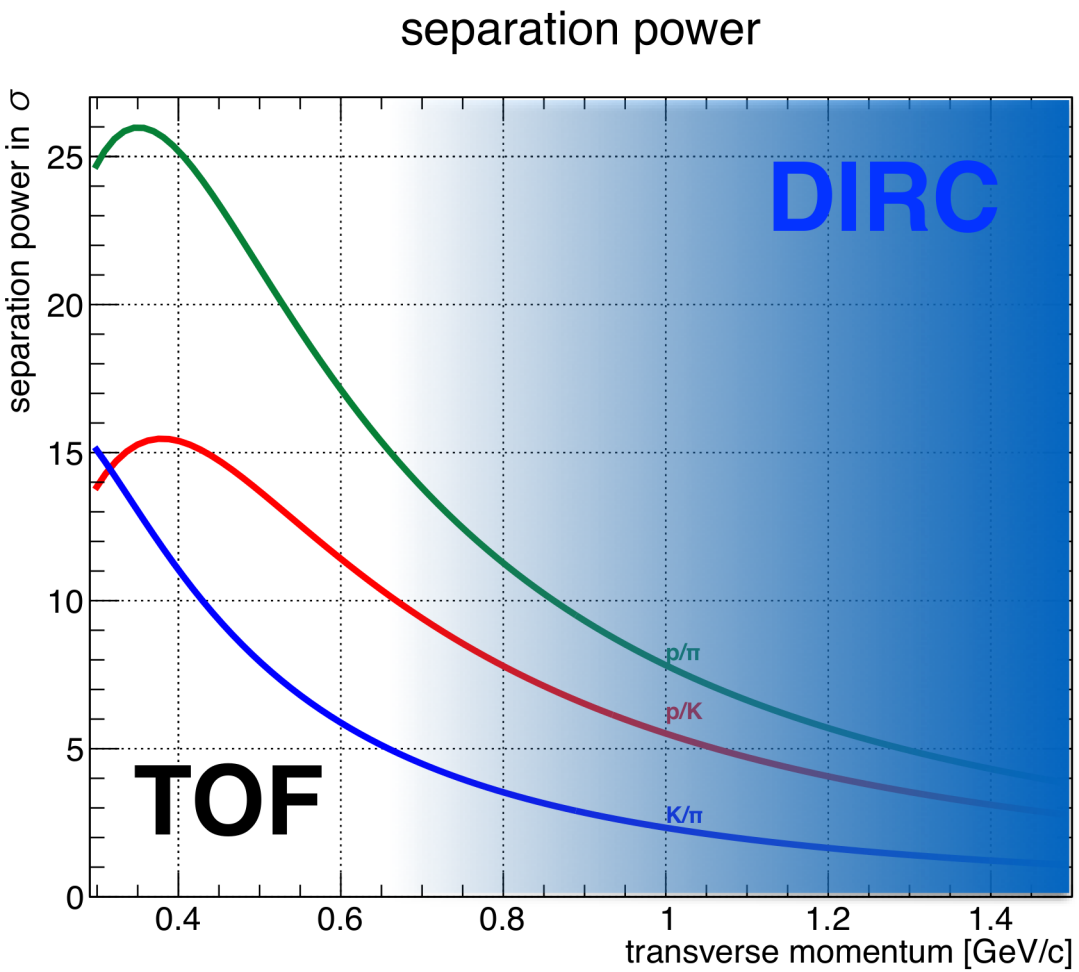


- TOF based PID
  - Separation power

$$n_\sigma = \frac{|tof_p - tof_K|}{max(\sigma_p, \sigma_K)}$$

  - >2σ below 1 GeV/c



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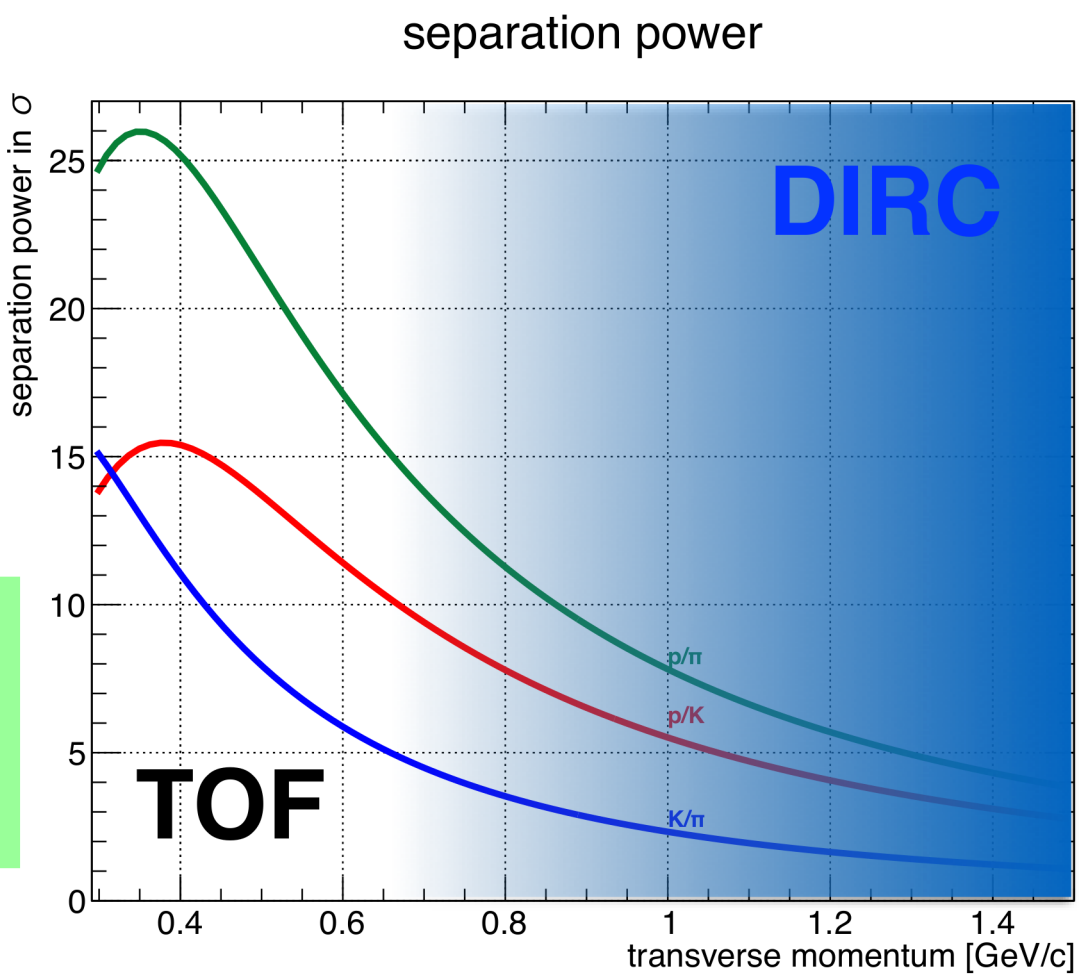
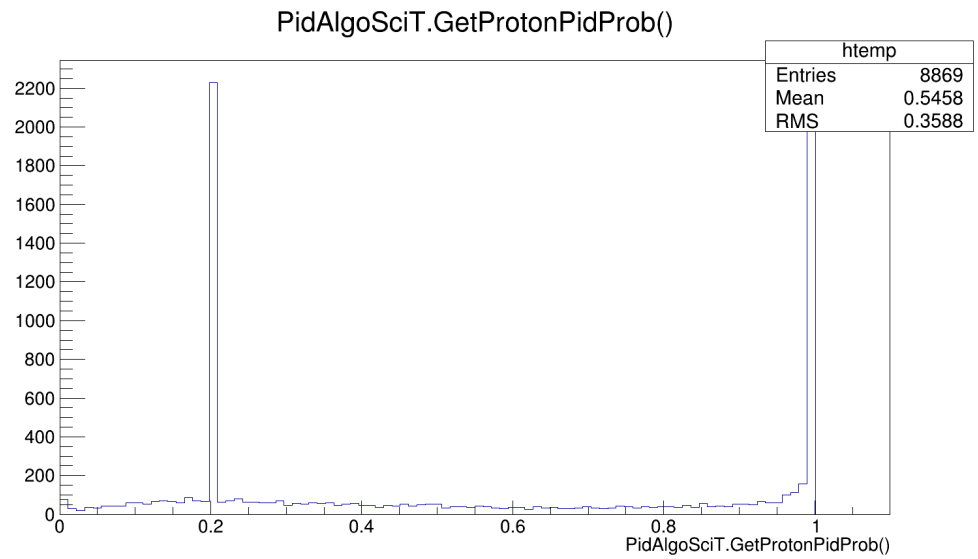
- Implemented in PandaRoot
  - PID Stage
  - TOF resolution functions
  - Normalized p.d.f



- Implemented in PandaRoot
  - TOF resolution functions for every particle hypothesis
  - Normalized p.d.f

PID stage

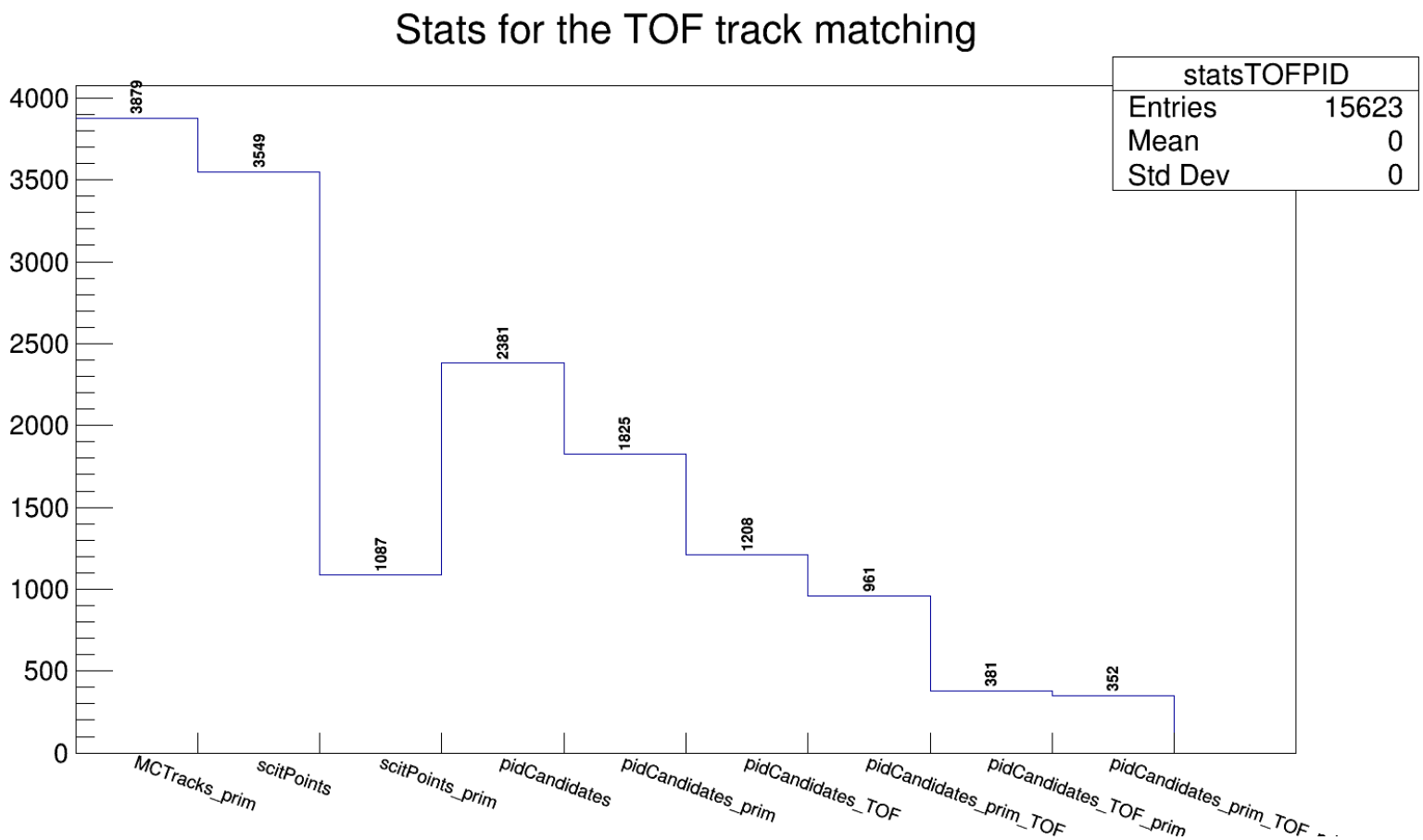
- Add new task
  - PndPidSciTAssociatorTask *assSciT= new PndPidSciTAssociatorTask();
  - fRun->AddTask(assSciT);



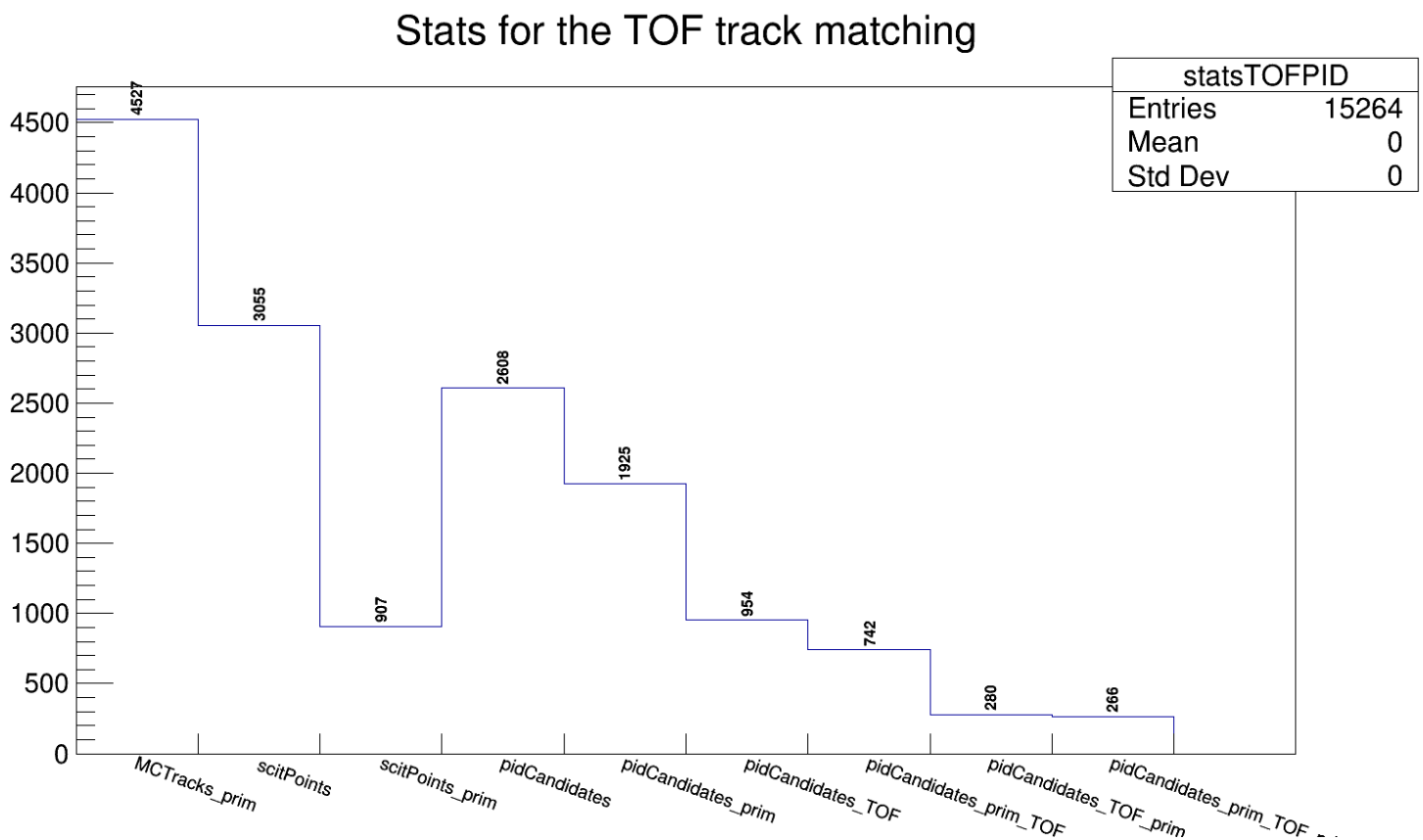
Open Issues

- Pattern matching

- DPM generator
  - 1.5GeV/c
- Full Panda detector
- Ideal tracking



- DPM generator
  - 6 GeV/c
- Full Panda detector
- Ideal tracking



Open Issues

- Pattern matching
- T0 determination
- Secondary treatment
  - Track creation times
  - Path length
  -