# The PANDA Barrel Time-of-Flight Detector

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On behalf of the Panda B-TOF group

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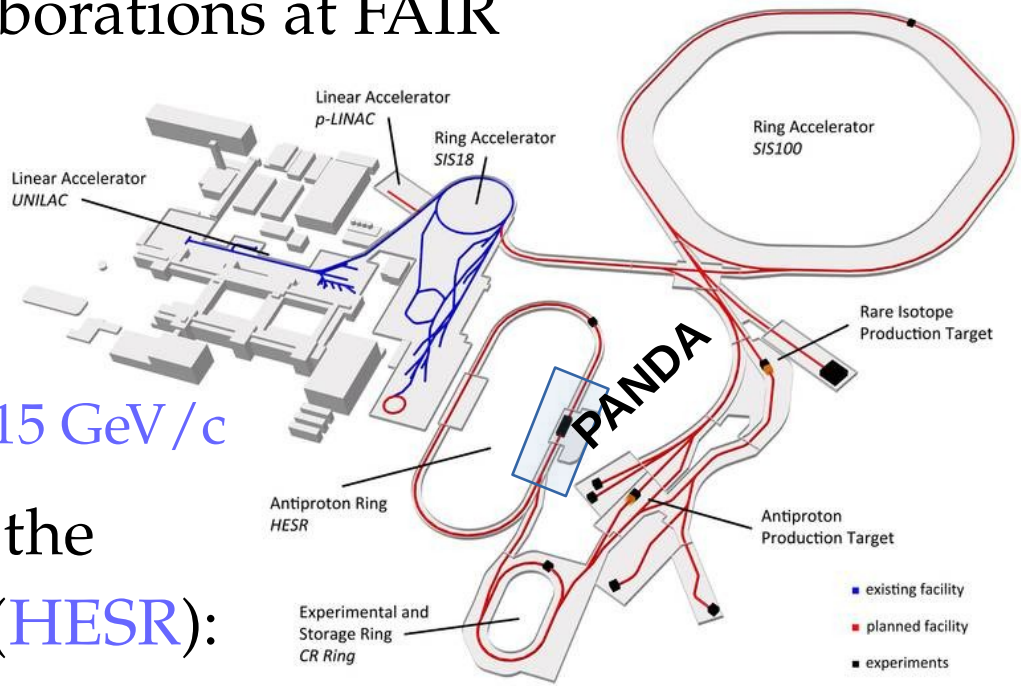
# Outline

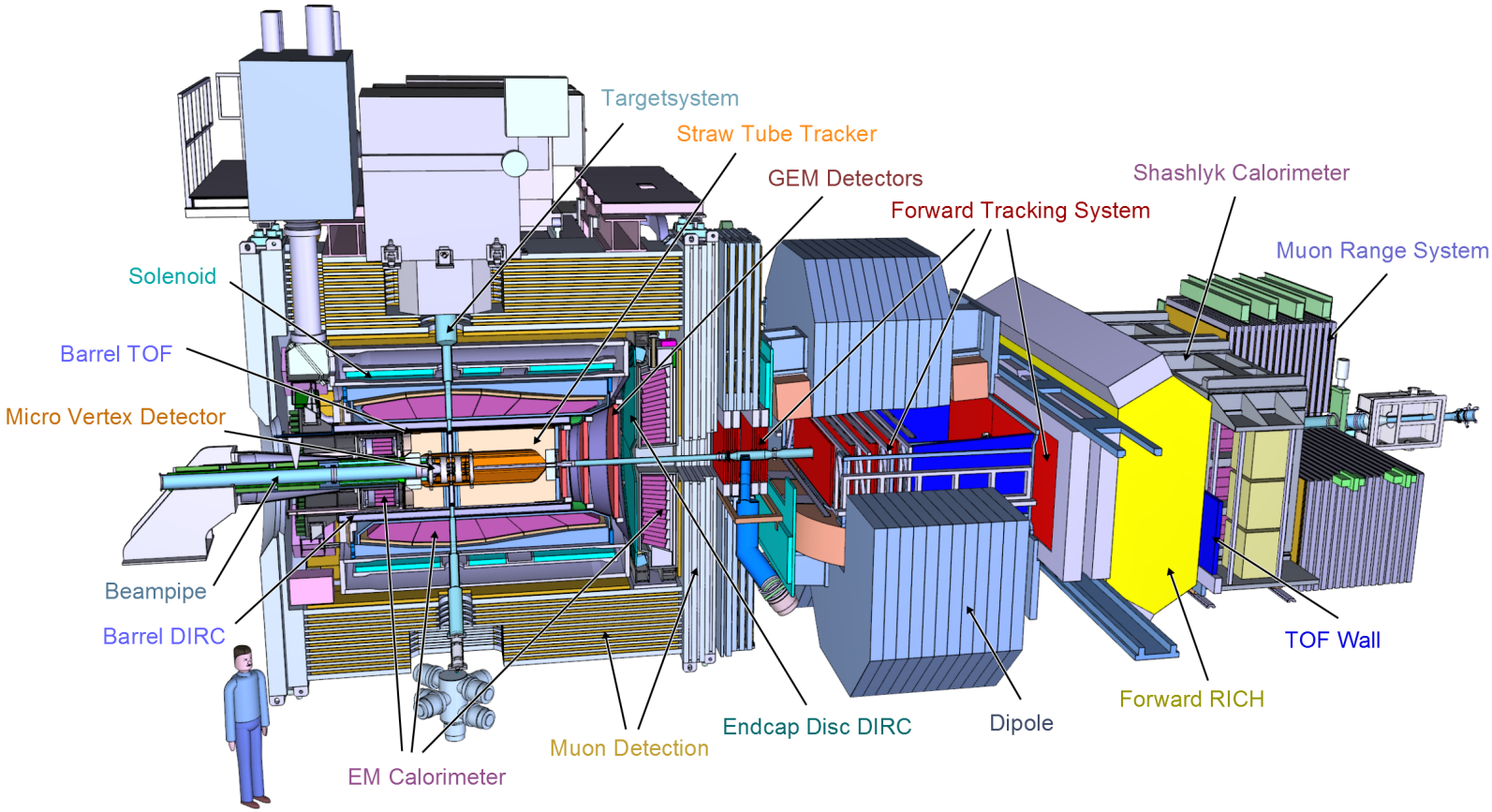
- PANDA at FAIR
- PID Performance
- Detector Setup
- SiPM Configuration
- Detector Performance
- Relative TOF

# The PANDA Experiment

- One of the four pillar Collaborations at FAIR
- Fixed target experiment with cooled anti-protons on protons or nuclei
  - Momentum range of 1.5 to 15 GeV/c
- Two modes of operation of the High Energy Storage Ring (HESR):
  - High resolution mode ($\Delta p/p \leq 10^{-5}$, 2 MHz)
  - High luminosity mode ($2 \cdot 10^{32}$ cm$^{-2}$s$^{-1}$, 20 MHz)

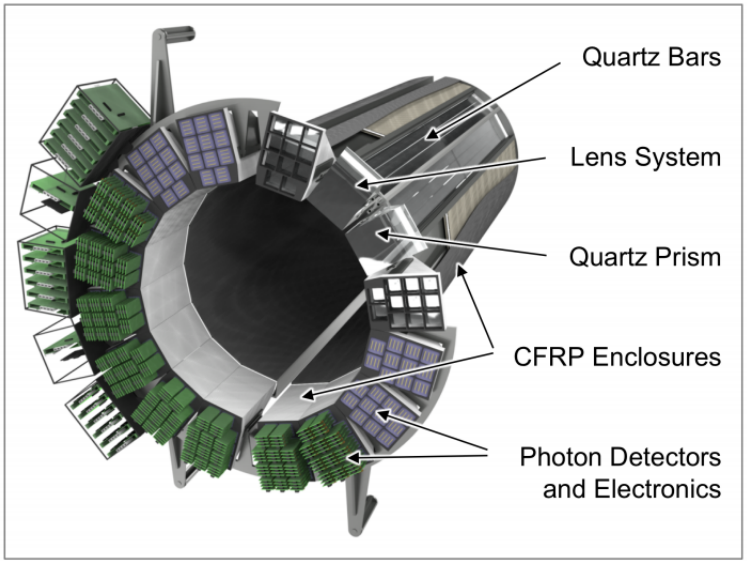


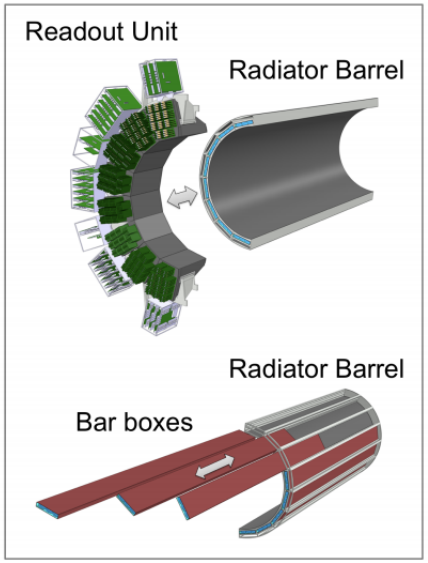
# The PANDA Detector



# PID in PANDA

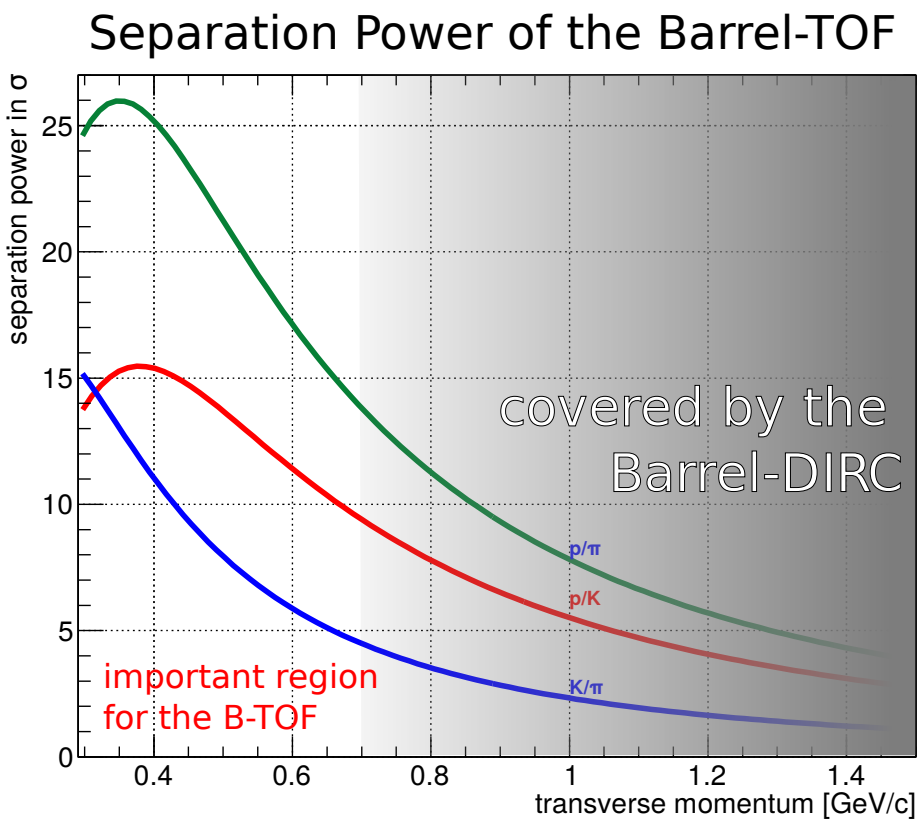
- Main PID detector for PANDA in the barrel is the barrel-DIRC detector
- Blind below the Cherenkov threshold
- More detailed talk by on PANDA DIRC detectors J. Schwiening on 4th Aug at 09:00



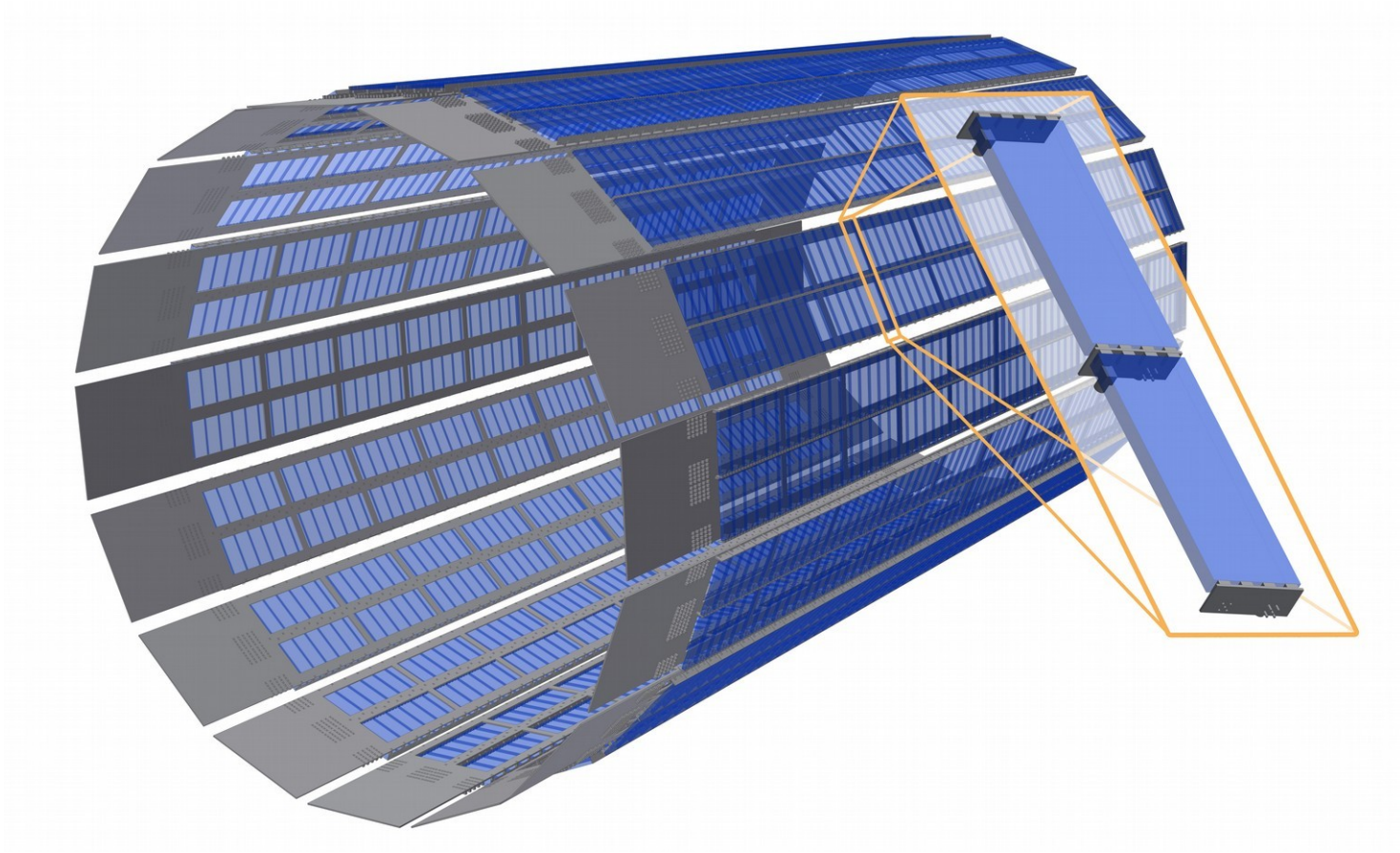



# Particle Identification (PID)

- Calculated assuming knowledge of the ideal annihilation time
- Time resolution of the B-TOF assumed to be 75 ps (including safety margin)
- Result is combination of tracking and time information by multiple detectors
- Excellent separation power below the Cherenkov threshold

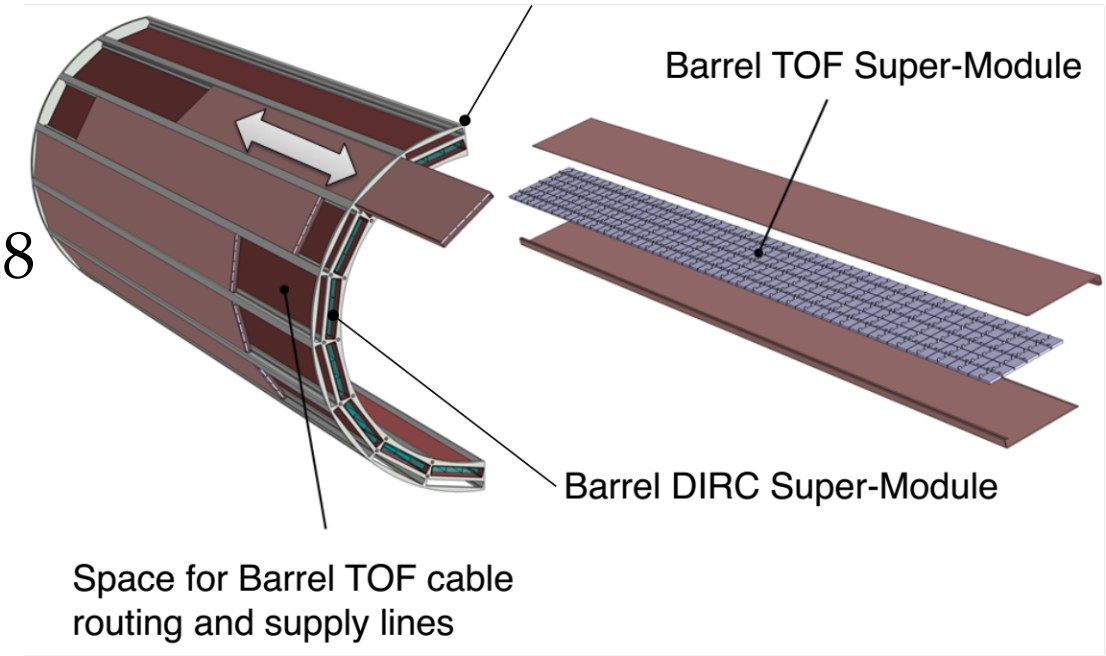


# The Barrel TOF



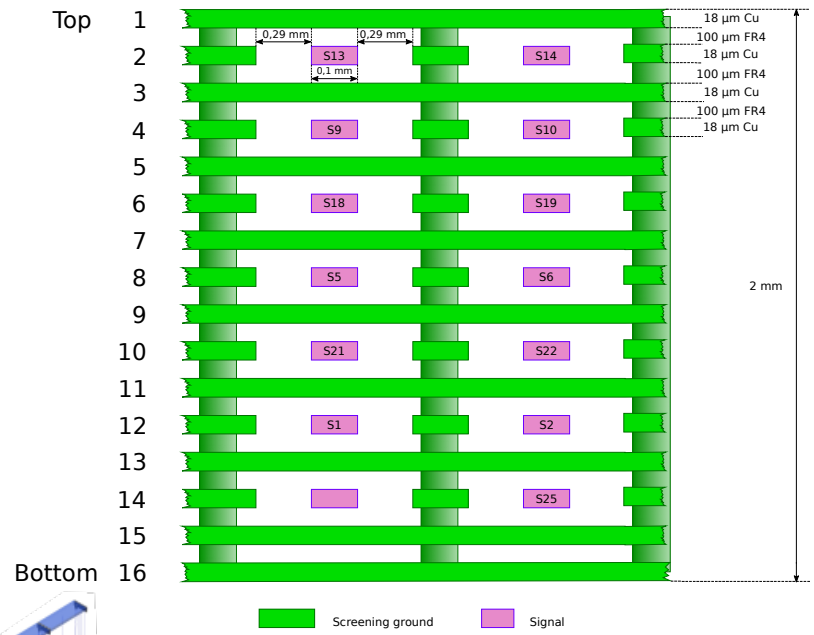
# The Barrel TOF

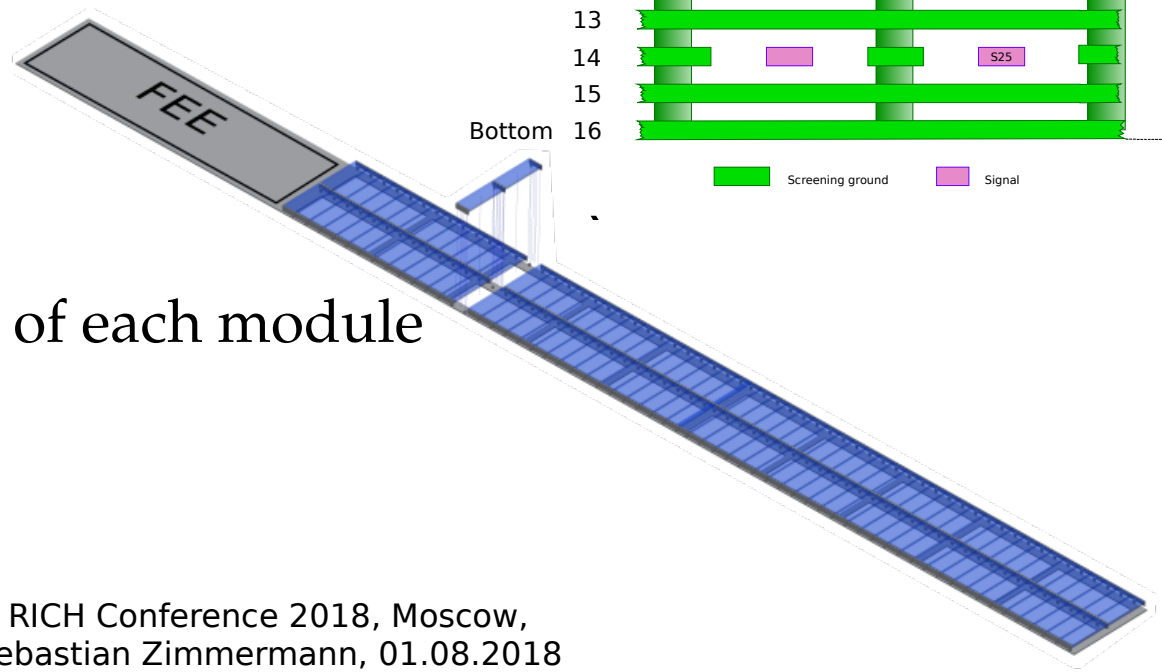
- 16 independent segments
- 120 scintillating tiles per segment in two rows
- Scintillator: EJ-232 or EJ-228 (BC-422 / BC-418)
- Scintillators read out on each short side by 4 SiPMs
- SiPM: 3x3 mm² active area



# The Barrel TOF

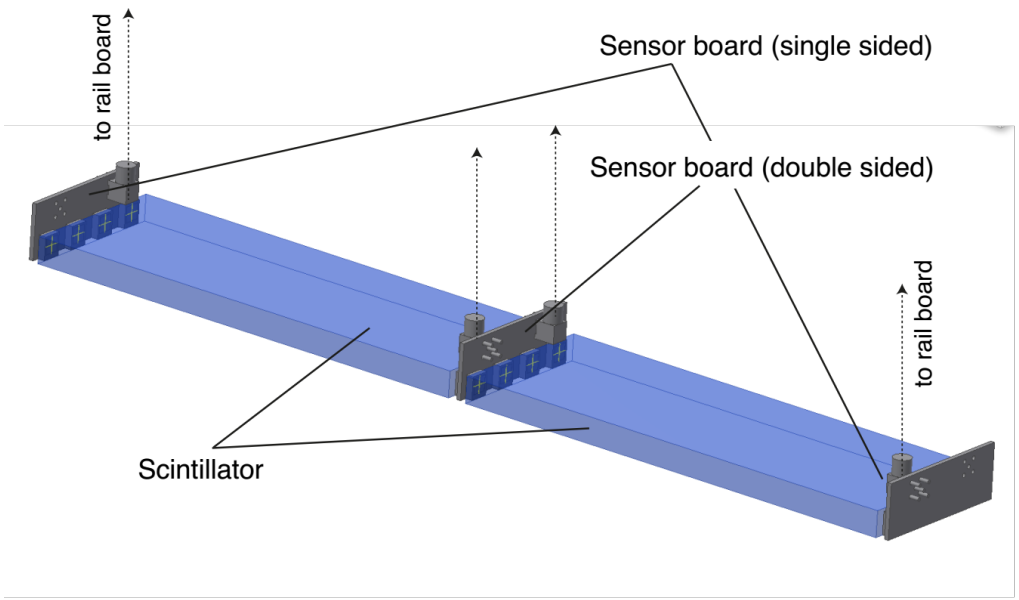
- The 16 independent segments are made up of many separate modules
- Backbone of each segment is a large PCB housing 4 · 60 sinal lines
  - 2400 x 180 mm²
  - Mechanical support for the scintillator
- FEE on backwards side of each module
  - TOF PET 2 ASIC by PETsys electronics



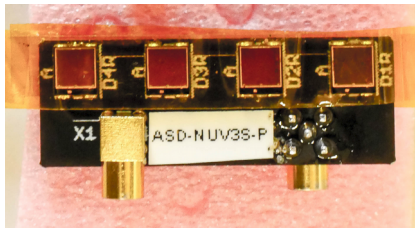
# Scintillator Modules

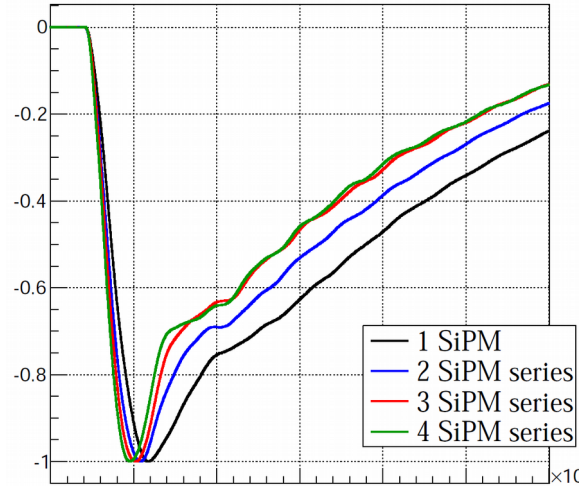
- Two scintillating tiles read out on two sides each
  - Scintillator dimensions: 87 x 29.4 x 5 mm³
- 60 modules per board → 1920 scintillators
- Read out by 4 SiPMs in serial connection on each short side → 15360 SiPMs in 3840 channels

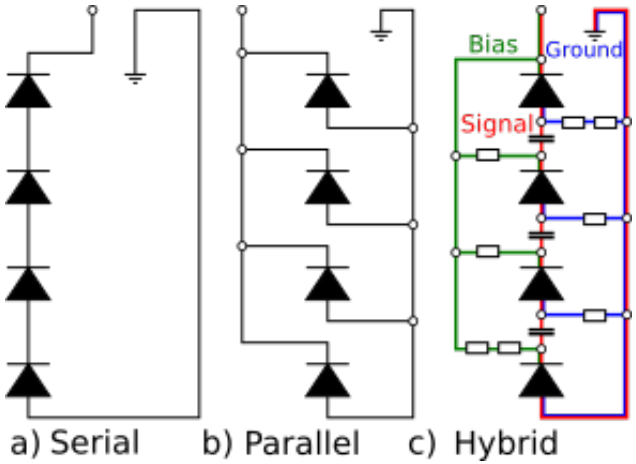


# SiPM Configuration

- Simplifies readout for larger sensitive area
- Serial connection reduces effective capacitance
  → shorter rise and fall times
  → improved timing performance
- Hybrid connection needs a lower bias voltage but voltage evenly split (not ideal)

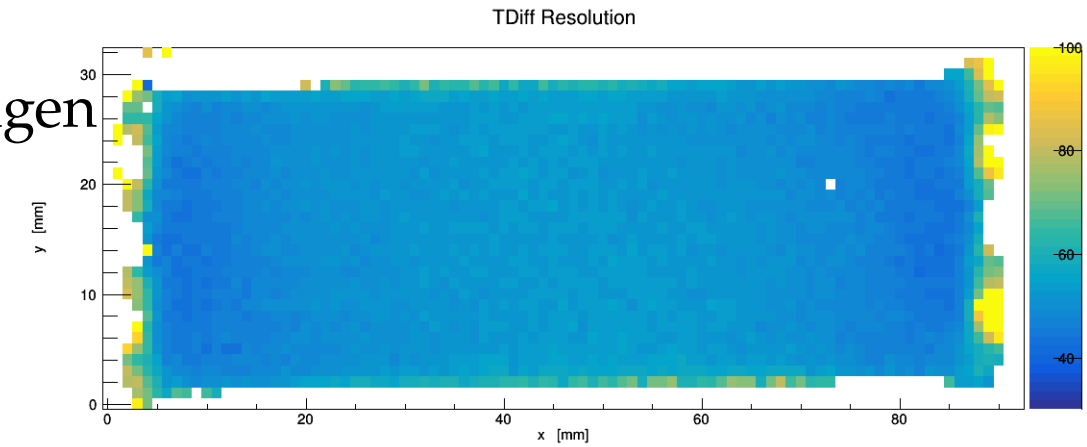


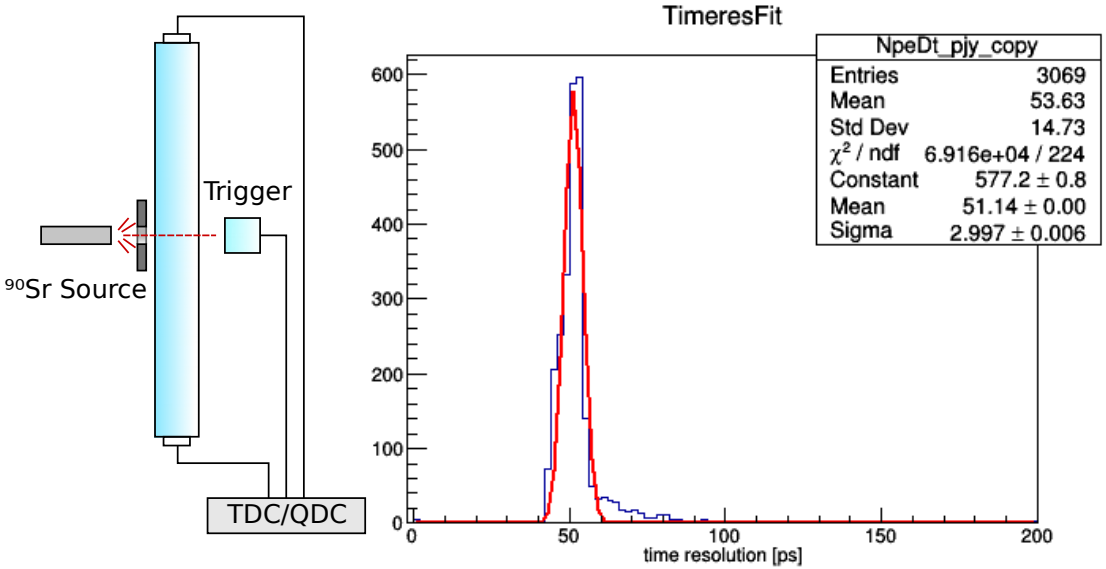



# Performance Validation

- Measurements done in Erlangen
  - Using $^{90}$Sr (beta source)
- Mean time resolution of ~ 51 ps
- High uniformity of the time resolution along the tile
- Time resolution + lower effective speed of light allow position resolution of ~ 1 cm along the x-axis



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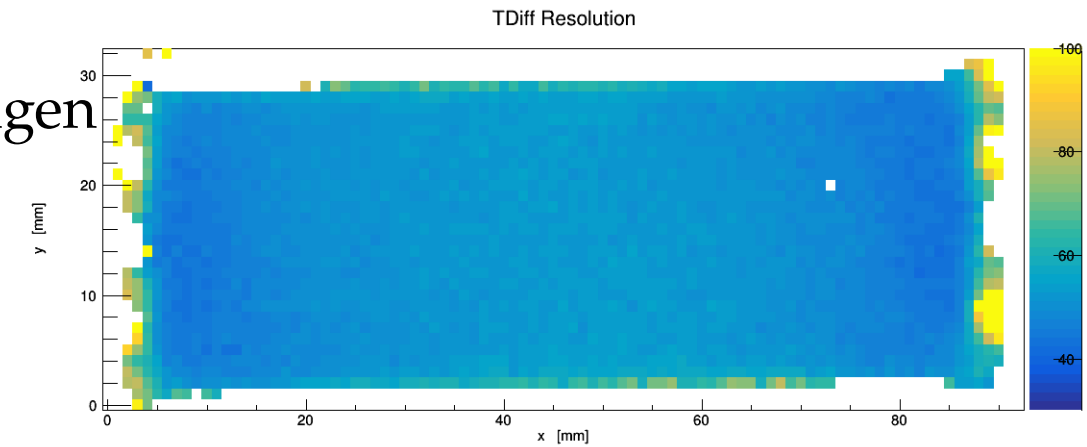
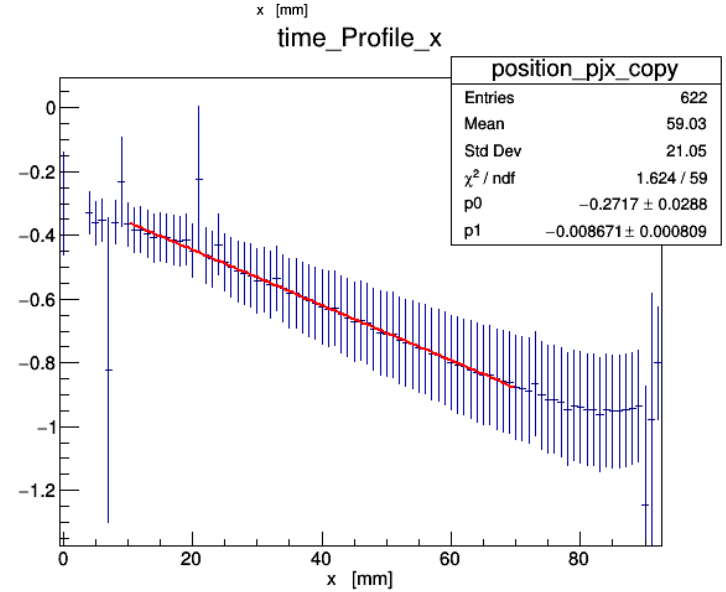
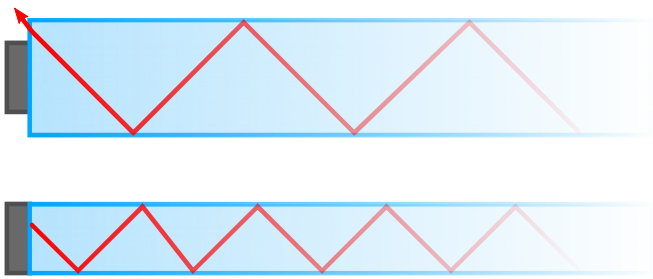


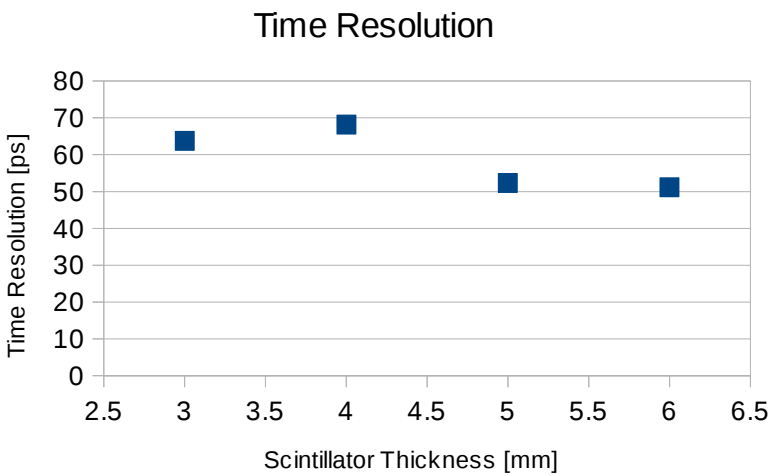



# Scintillator Thickness Study

- Possibilities to improve the performance
  - Increase number of SiPMs (cost increase)
  - SiPMs with larger sensitive area (cost increase)
  - Decrease/Increase scintillator thickness (cost neutral)
- SiPM and scintillator dimensions do not match
  - Potential to save material



| | NpeAve | Time Res [ps] |
|---|---|---|
| 3 mm | 55.4 | 63.7 ± 4.3 |
| 4 mm | 73.6 | 68.2 ± 5.2 |
| 5 mm | 81.5 | 52.3 ± 3.5 |
| 6 mm | 78.0 | 51.1 ± 3.0 |




- Thinner scintillators produce less photons

  → worse time resolution

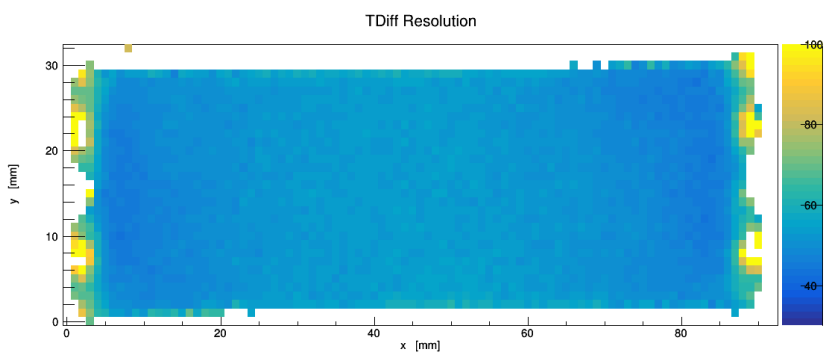
- Thicker scintillators show only a marginal performance increase to the cost of the material budget

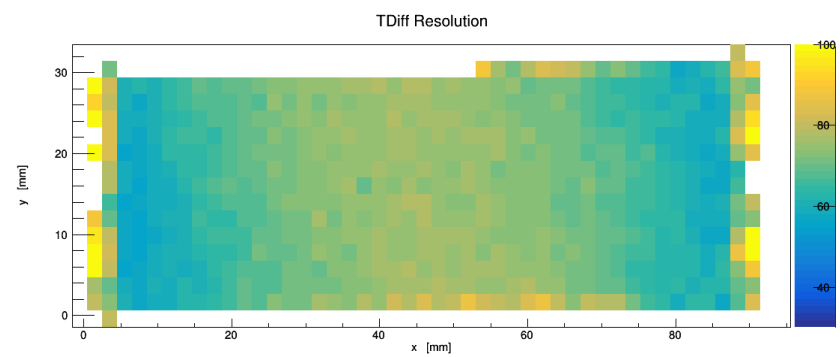
# Polished & Quenched Scintillator

- Polishing the scintillator does not lead to a performance decrease

| | NpeAve | Time Res [ps] |
|---|---|---|
| 5 mm | 81.5 | 52.3 ± 3.5 |
| 5 mm p | 79.8 | 51.5 ± 3.0 |

- A quenching agent in the scintillator might improve the time resolution by reducing the slow emission component
  - EJ-232Q0.5
- An overall reduction in time resolution (~ 71 ps)
- Worse uniformity

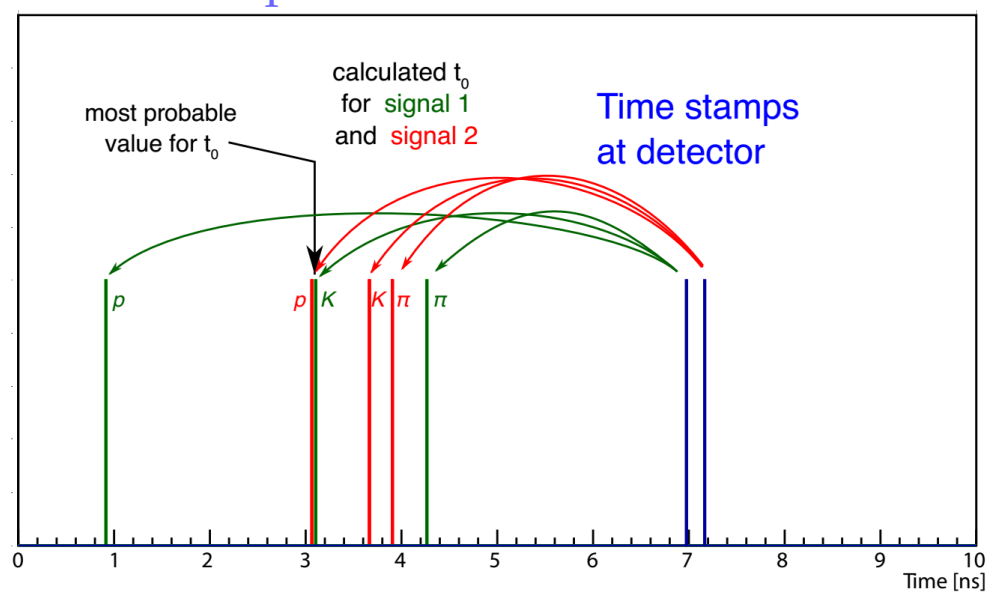


# Relative TOF

- No start time detector in PANDA
  - No conventional TOF measurement possible
- Method determines annihilation time and particle identity
- Utilizes information from other detectors
  - Path length
  - Momentum
- Results improve for higher particle multiplicities

- Permutes through possible mass assumptions
- Calculates most likely combination
- Simulations achieved a time resolution of $\sigma \leq 71$ ps



# Summary

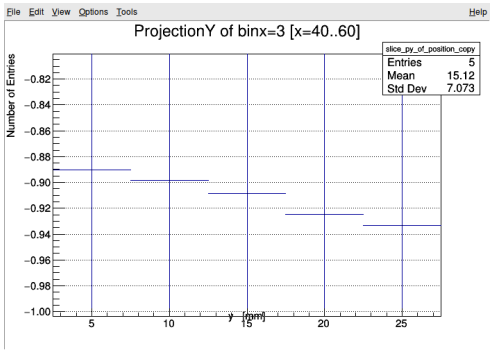
- Excellent separation power for particles below the Chrenkov Threshold
  - Ideal complement to the barrel DIRC
- Using scintillating tiles and SiPMs to read out the detector
- Achieve a time resolution of ~51 ps
  - Position resolution of ~1 cm in x direction
- Utilizing a serial connection of 4 SiPMs
- Using relative TOF have an annihilation time resolution of ~ 71 ps

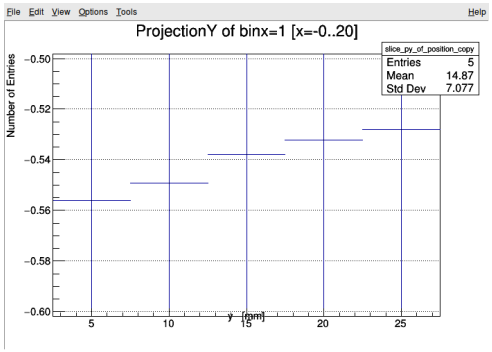
# Thank you for your attention

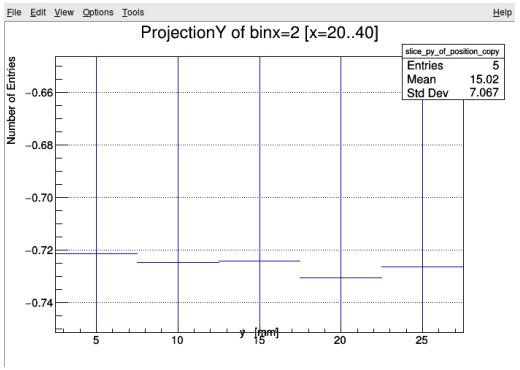
# Backup

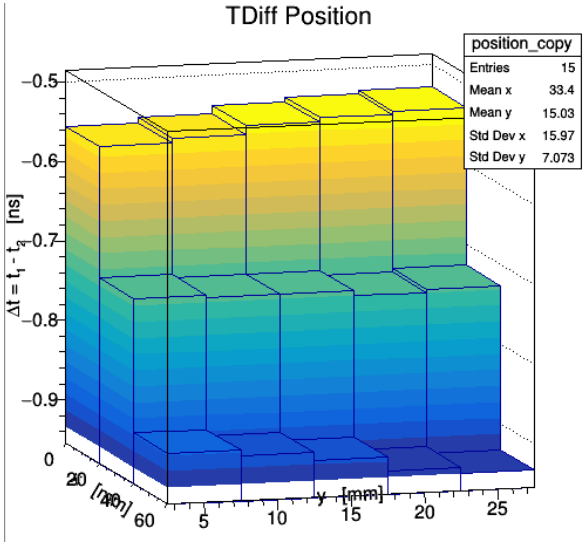
# SiPM Position Effect

- Serial connection of SiPMs introduces position dependent timing
- Time difference in the order of 18 ps/cm close to the SiPMs
- No effect visible further than ~ 1 cm



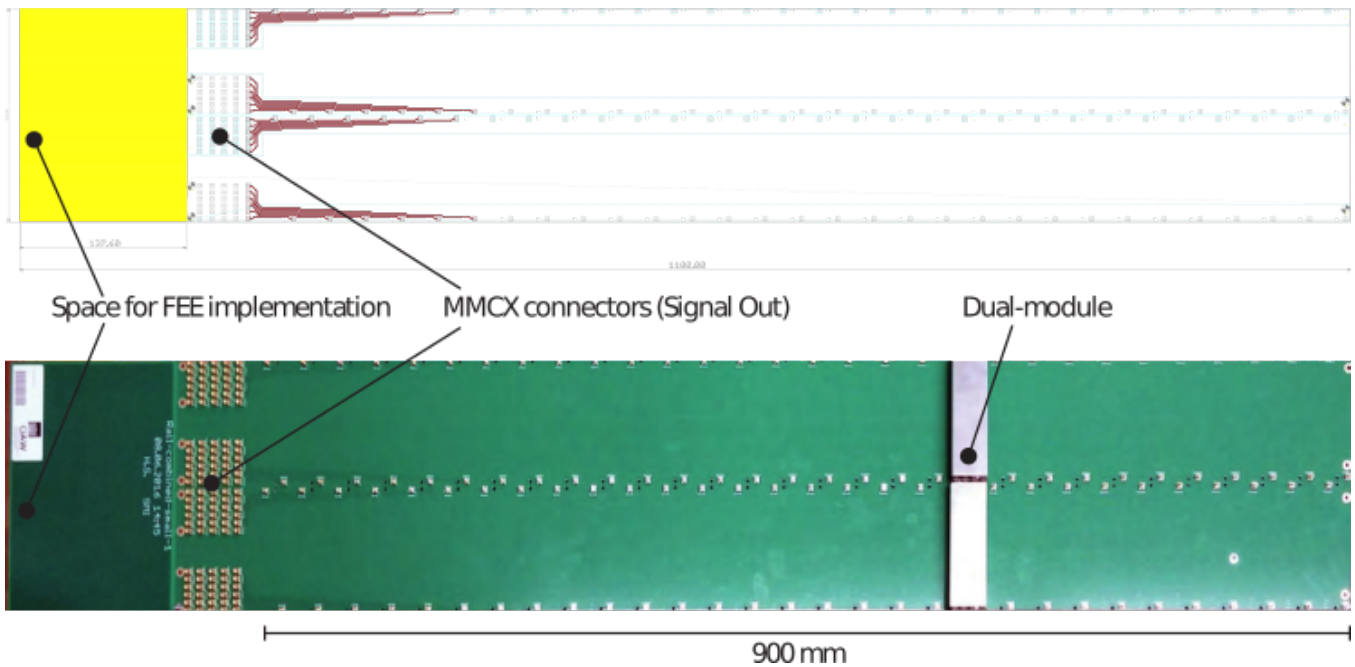



# Railboard

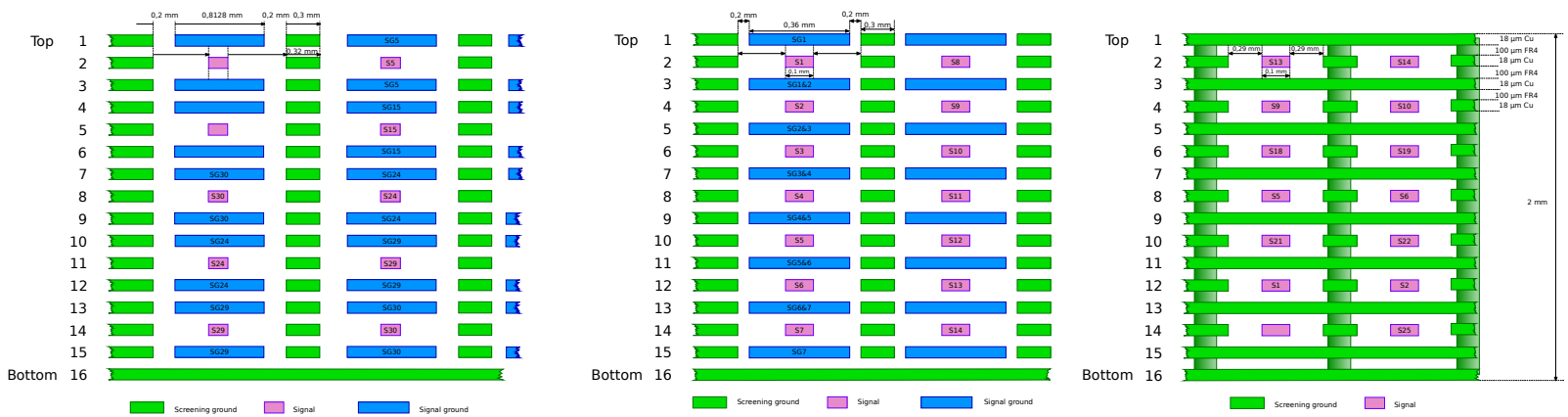
- 16 layers PCB
- 2400 · 180 mm²
- 4 · 60 lines per board
- Detector designed to be cable less
- Multiple designs are being tested

- Space efficient transmission and mechanical support
- Signal lines in coaxial structure with shielding in between lines



# Railboard Crossection

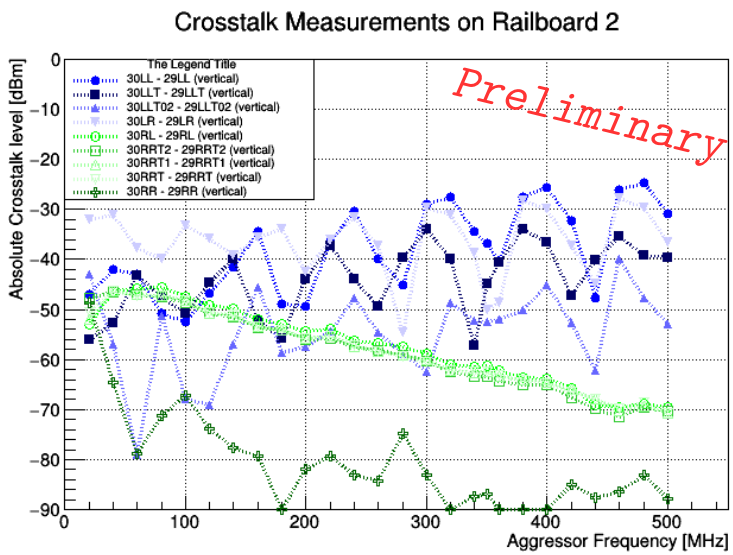
- Three structurally distinct designs with 3, 2 and 1 seperate ground layers
- Tested for crosstalk levels and attenuation



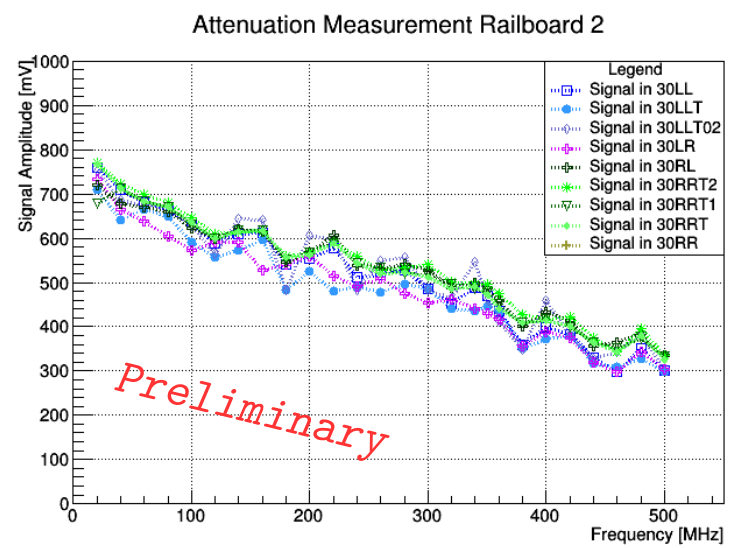

a) b) c)

# Crosstalk & Attenuation

- Measured using a 1V amplitude sinusoidal signal
- Crosstalk levels measured with a spectrum analyzer
- 1 ground design shows smoother distribution with less crosstalk




- All lines terminated in 50 Ω scope input
- Attenuation measured by measuring amplitude after passing through PCB
- 1 ground design shows slightly lower attenuation



# Experimental Challenges

- The PANDA detector will be operated with a free flowing data acquisition
- Data rate in the order of 200 GB/s
  - Needs to be reduced by a factor of 1000
- The barrel time of flight detector plays a vital role in this regard

- The Barrel TOF provides:
  - Interaction time
  - Particle identification
  - Event selection

all important for data reduction

# Event Sorting

- PANDA will be utilizing free flowing data acquisition
- Event rates up to 20 MHz
  → occasional overlap of events
- Challenge is to find all events and save all interactions with minimum of doubled data
- Simple speed of light correction applied
- 99% of primaries and 75% of all arrive in 4 ns