Barrel time-of-flight (TOF) detector for the $\bar{P}$ANDA experiment at FAIR

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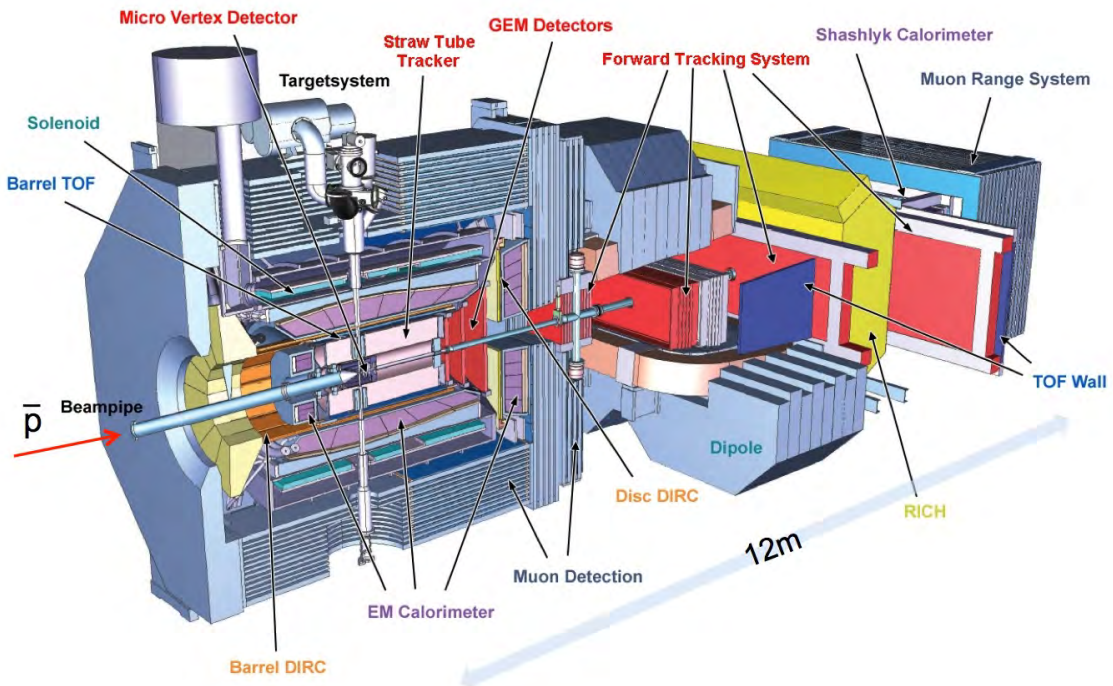
Outline

$\bar{P}$ANDA

- $\bar{P}$ANDA will perform high precision experiments using cooled beams of $\bar{p}$.
- Fixed Target experiment, 1.5 - 15 GeV/c momentum.
- High luminosity mode (L=2 $\cdot 10^{32}$ cm^{-2}s^{-1}); High resolution mode ($\Delta\ p/p = 5 \cdot 10^{-5}$).
- Azimuthal angle coverage: 22,5° - 140°.

- Charmonium spectroscopy with precision measurments of mass, width, decay branches.
- Investigation of exotic quark states, charmed hybrids, glueballs.
- γ-ray spectroscopy of hypernuclei.

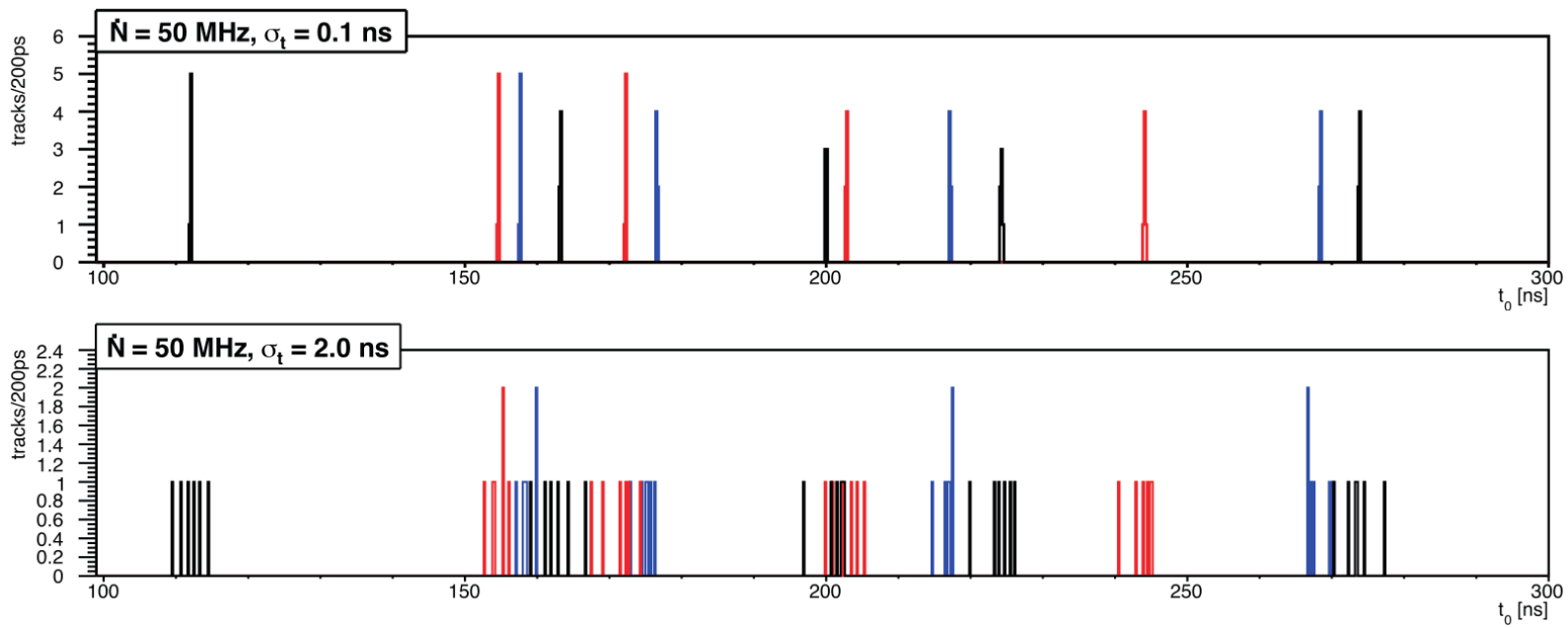


Requirements

- Mechanics shared with DIRC.
- Non-magnetic material.
- Time resolution below 100 ps.
- Withstand radiation during operation time $\phi_{eq} \approx 9 \cdot 10^{10}$ $n_{eq}/\ cm^2$ in 10 years.
- Good granularity for position resolution.
- Software Trigger:
  - Event Sorting.
  - Online event time (t0) calculation.
  - Particle Identification.

Capability (1)

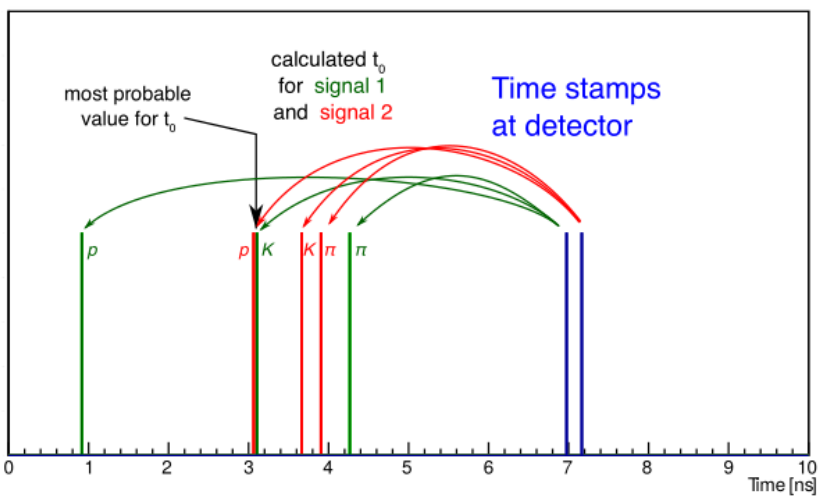
- **Event Sorting**: For high luminosity mode 20 MHz interaction rate. Event Package might overlap.
- **Software Trigger**: High granularity and time resolution provide a robust tool for software triggers and calibration of the more complex detector systems.

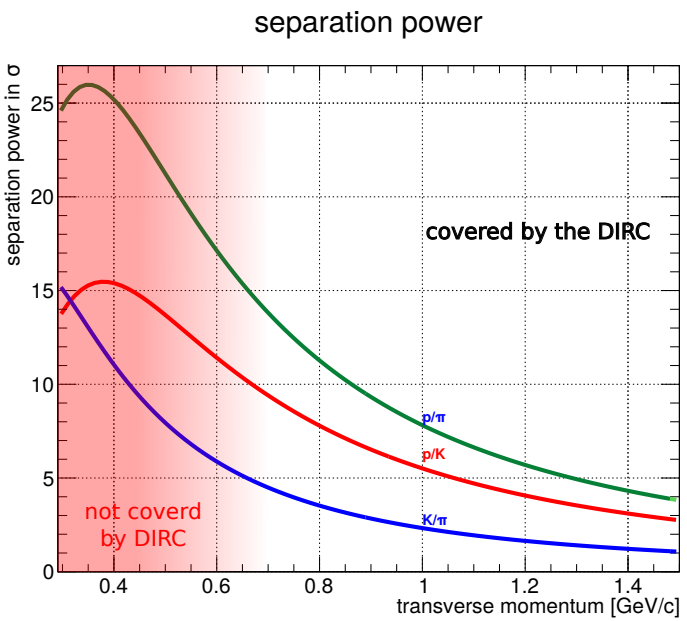


Capability (2)

- **T0 Determination**: No start-stop ToF, relative time of flight uses momentum information and track lenght to determine t0.
- Monte Carlo Simulation: Resolution $\sigma_{t0} = 118$ ps.

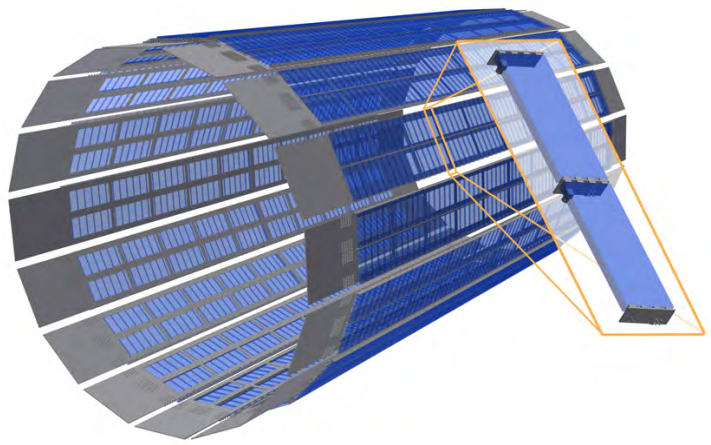
- **Particle Identification**: Barrel TOF allows PID of low-momentum particles (≈ 700 MeV/c) below Cherenkov threshold of Barrel DIRC, for Hypernuclei programme crucial.

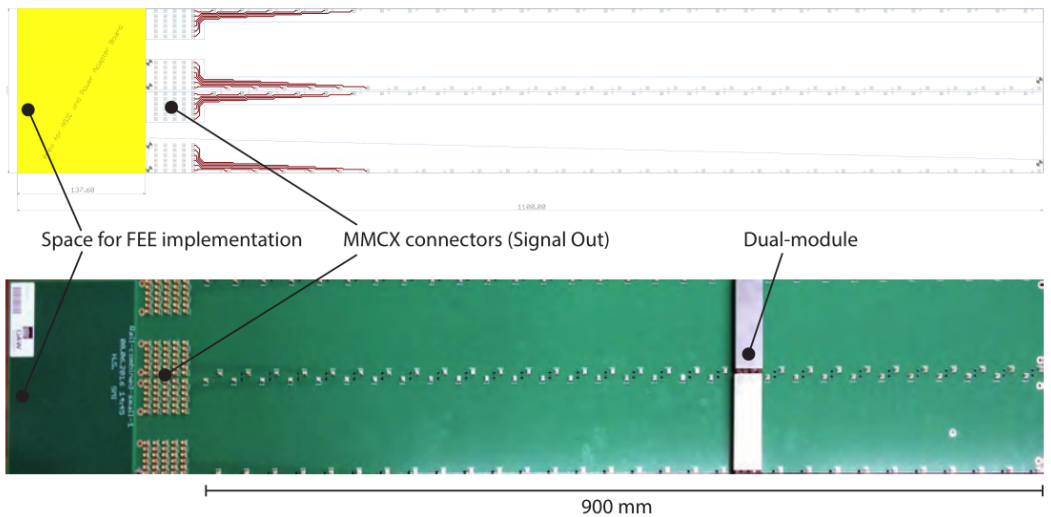




Overall Design

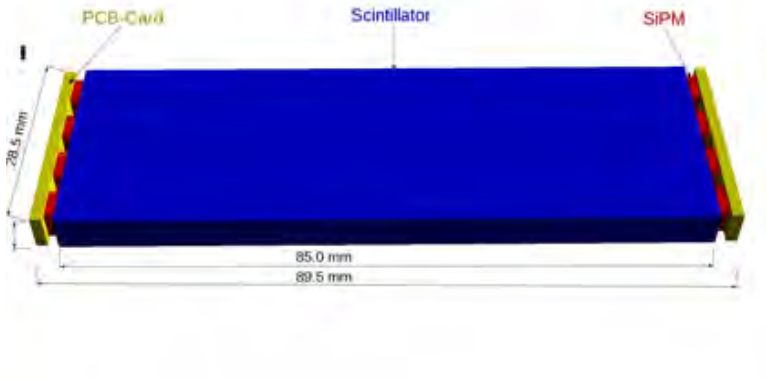
- Barrel TOF consits of 16 independent segments (2460 x 180 x 20 mm^3).
- Electronics concentrated on the end.
- Long signal transmission lines embedded in a multilayer PCB [1]
- 1.920 Single Scintillator Tiles, 15.360 SiPM.

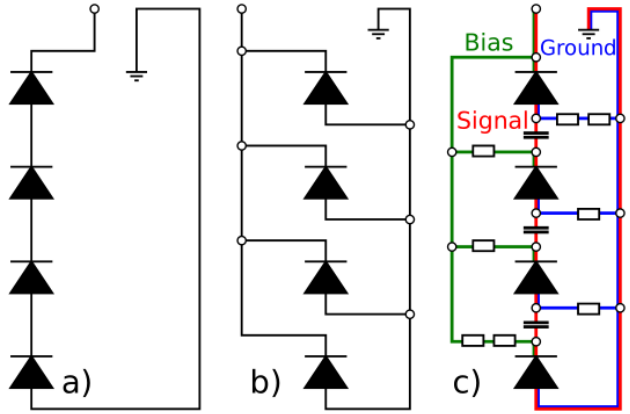




[1] MEG II arXiv:1301.7225v2 [physics.ins-det] 4 Feb 2013

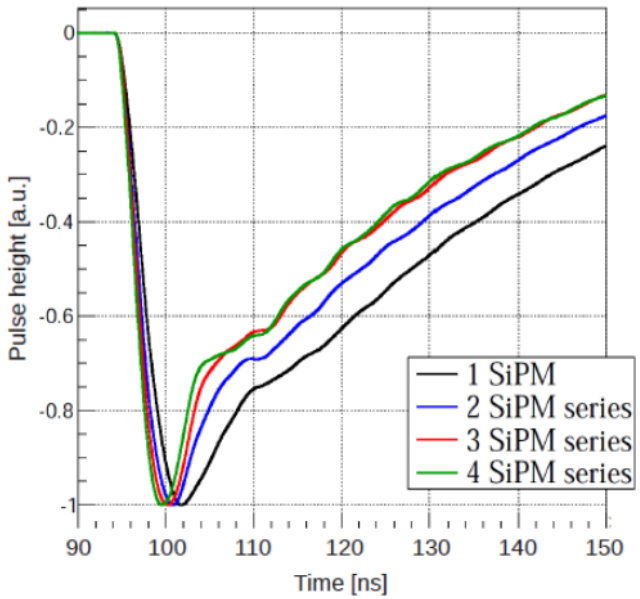
Single Tile Design





- Single Scintillator Tile connected ($\approx$ 90 x 30 x 5 mm^2) to 4 SiPM on both ends.
- Connection: Serial (a), Hybrid (c).

	Sensitive area	Bias Voltage	Signal shape	Gain	V_{BD} adjustment
Single	1	V_{br}+OV	-	1	-
Series	N	N×(V_{br}+OV)	faster	1/C	Yes
Parallel	N	V_{br}+OV	slower	C	No
Hybrid	N	V_{br}+OV	faster	1/C	No



Performance Evaluation: Material & Wrapping

	EJ-228	EJ-232
Photons / MeV e^-	10 200	8400
Signal rise time [ps]	500	350
Decay Time [ps]	1400	1600
Pulse Width [FWHM] [ps]	1200	1300

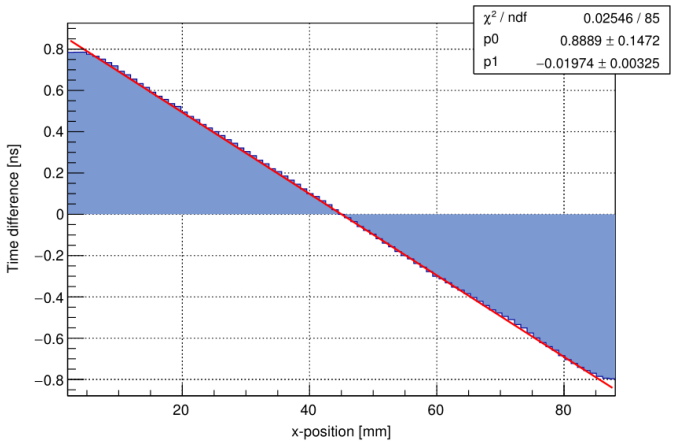
Time resolution with different wrapping EJ-232 (top), EJ-228 (bottom).

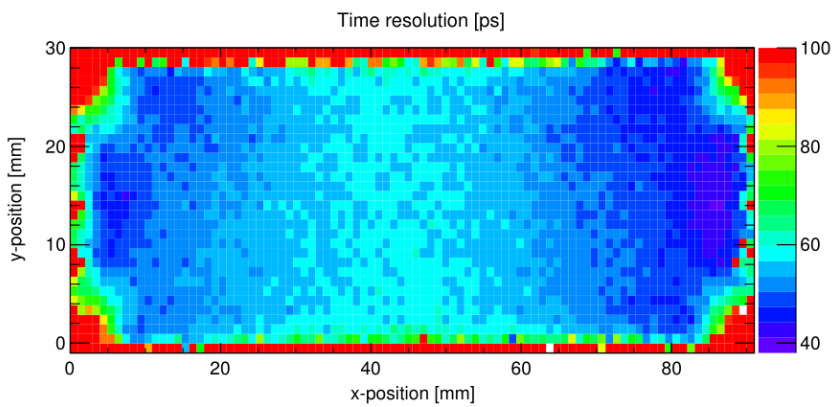
Wrapping material	Time resolution [ps]	Number of detected photons
No wrapping	55.0 ± 0.3	288 ± 2
Aluminised Mylar foil	52.7 ± 0.3	355 ± 2
Tyvek hardstructure 1057D	55.0 ± 0.3	394 ± 3
Enhanced specular reflector (ESR)	55.2 ± 0.3	355 ± 3
Teflon tape	59.4 ± 0.3	408 ± 4
aluminium foil	54.2 ± 0.3	344 ± 3

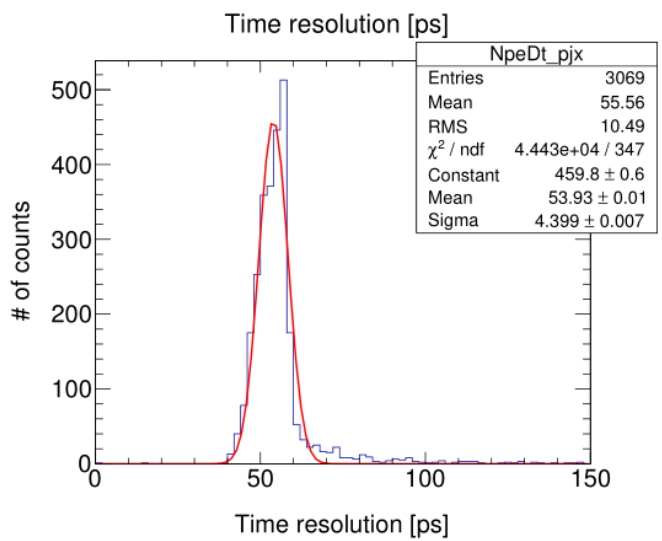
Wrapping material	Time resolution [ps]	Number of detected photons
No wrapping	61.3 ± 0.3	371 ± 2
Aluminised Mylar foil	59.7 ± 0.3	445 ± 3

Performance Evaluation

- Position dependency measurment with optimised condition: EJ-232, with wrapping, 4 Hamamatsu SiPM.
- 2000 events / position, 3069 positions.
- Mean time resolution $\sigma = 53{,}9$ ps.
- Position Resolution:
  - x-direction 5,5 mm (σ).
  - y-direction 29,4 mm.







Beam Time Results

- Beamtime tests in 2014 and 2015 with other geometrical design, consistent with laboratory measurements.
- **CERN June 2016**: without time to optimise operational condition $\sigma_t = 70$ ps with final design.
- **CERN November 2016**
  - Two TOF-Stations, 29m apart.
  - Beam with 7 GeV/c, containing protons, pions, electrons, kaons.
  - Measured distance with Laser: 28,66 m; calculated distance with Beam files: 28,43 m.
  - $\sigma_t = 58$ ps, analysis ongoing.

Conclusion & Outlook

- $\bar{\text{P}}$ANDA at FAIR.
- Barrel Time of Flight Detector.
- Technical Design Report in Review.
- Time Resolution: labor: 53,9 ps; beamtime: 58 ps.
- Further optimization of geometry.
- Radiation hardness.
- Front End Electronics.