53rd International Winter Meeting on Nuclear Physics

Bormio, 27/01/2015

Fast Frontend Electronics for high luminosity particle detectors

Matteo Cardinali

HIM
Helmholtz-Institut Mainz

HGS-HIRe for FAIR
Helmholtz Graduate School for Hadron and Ion Research

JG|U

Requirements

- high luminosity experiments → { high count rates (10-10^3 kHz); large number of channels (>10^3) }

(rare decays, exotic resonances, …)

Requirements

- high luminosity experiments → high count rates (10-10^3 kHz); large number of channels (>10^3)

  (rare decays, exotic resonances, …)

- high precision detectors → timing resolution (<100 ps); charge measurement

  (event reconstruction, PID, …)

Requirements

- high luminosity experiments → high count rates (10-10^3 kHz); large number of channels (>10^3)

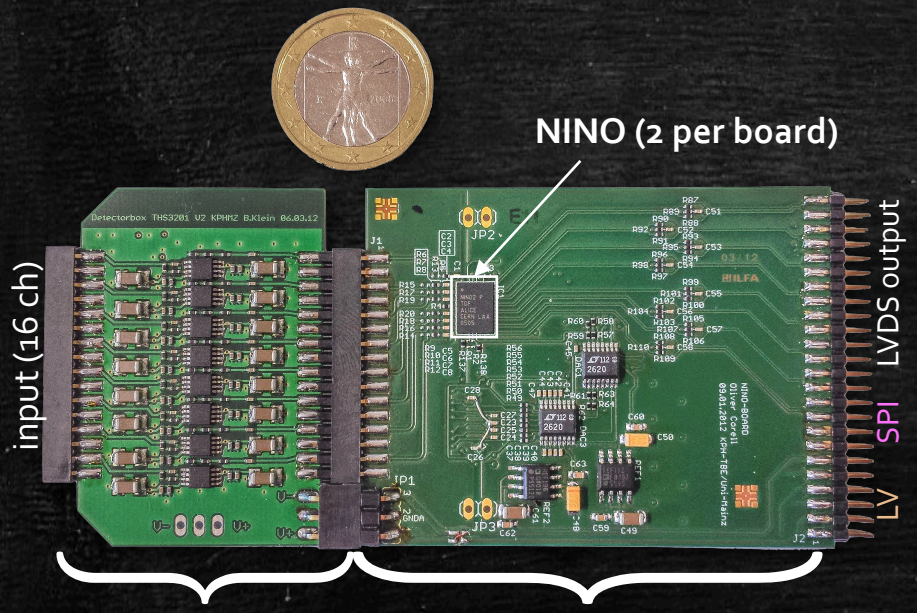
  (rare decays, exotic resonances, …)

- high precision detectors → timing resolution (<100 ps); charge measurement

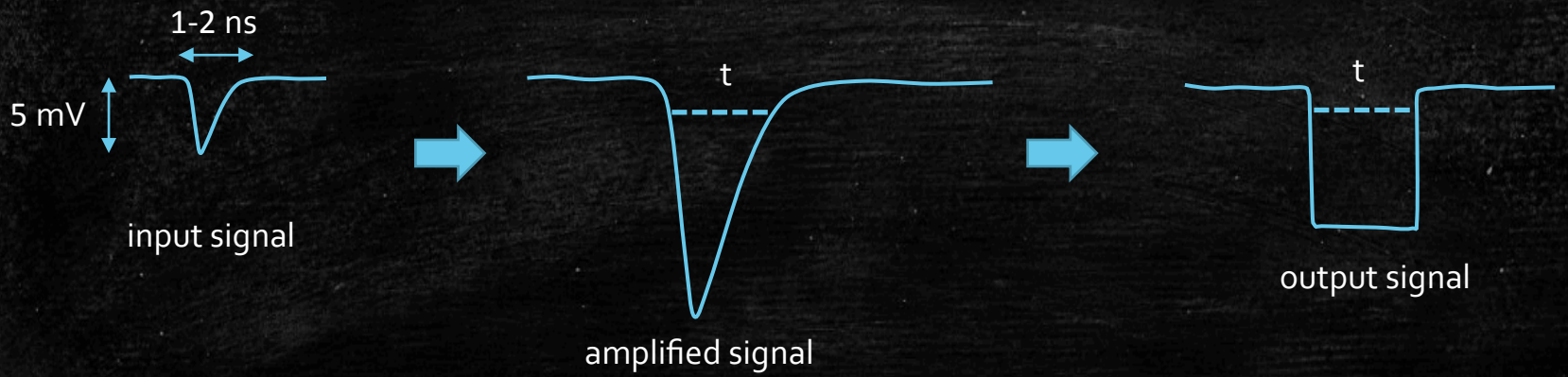
  (event reconstruction, PID, …)

- versatile design based on discriminators →
  - PANDA Barrel DIRC (Cherenkov light) → small signals
  - A1 Neutron Detector (plastic scintillator) → large signals

A Modular Design

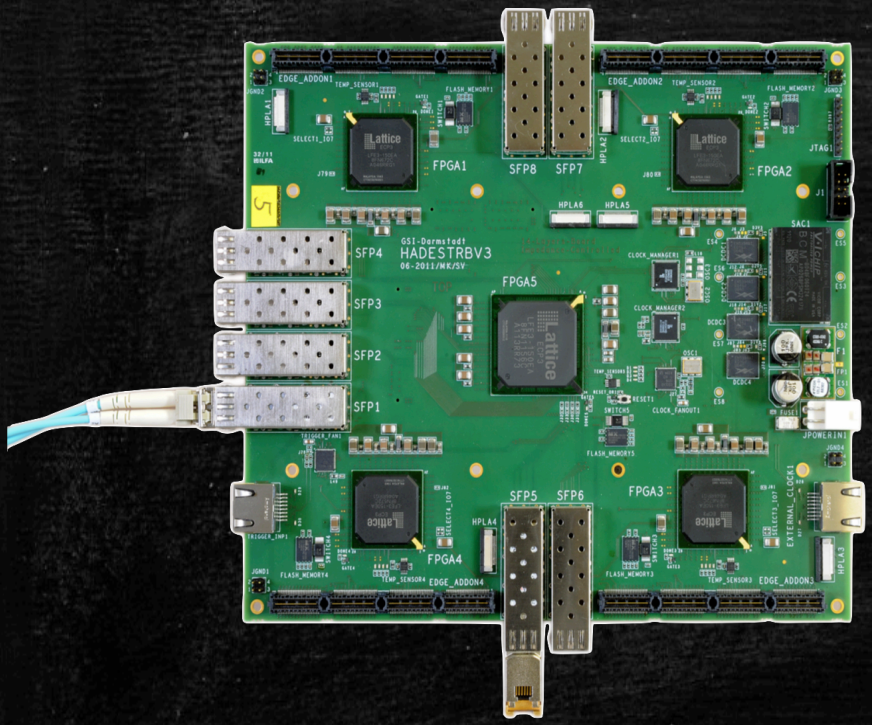


- **Discriminator card**
  - NINO ASICs from CERN
    - differential chip
    - sustained rate >> 10 MHz
  - single ended mode
  - individual channel threshold
  - time over threshold
  - LVDS output
  - 70 mW/ch
- **Optional preamplifier**
  - current feedback amp (THS3201)
  - 18 dB (unitary gain bandwidth 1.8 GHz)



The Readout System

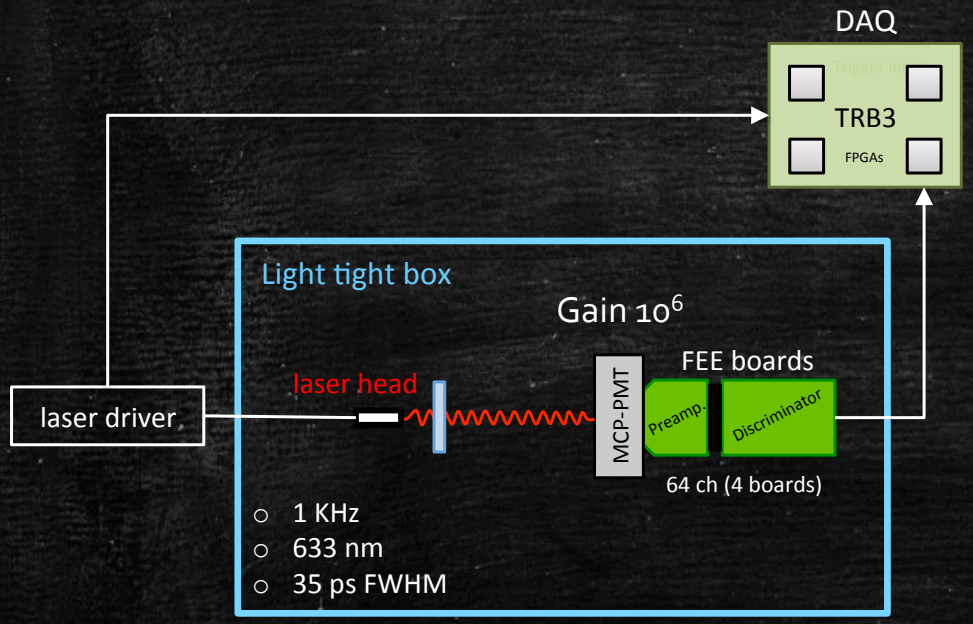
TDC Readout Board 3 (TRB3)

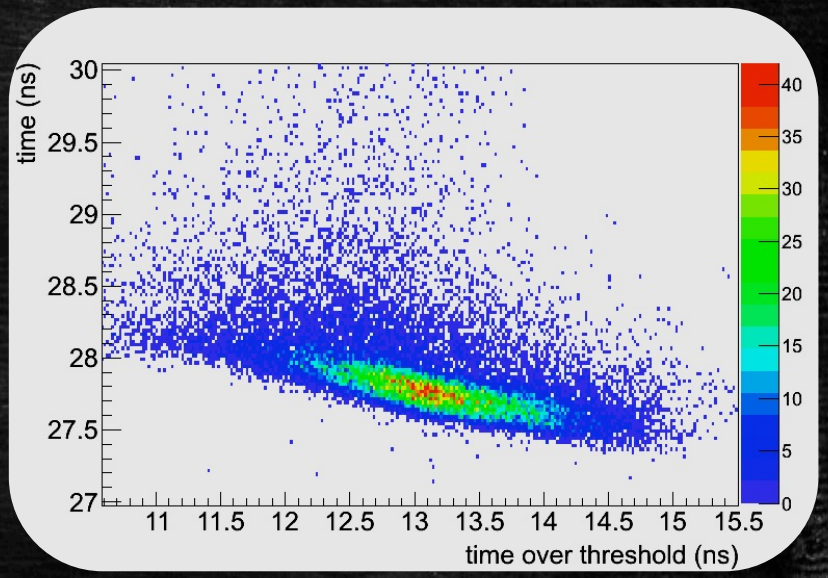


- developed in GSI
- *multi hit TDC* based on FPGAs
- 10 ps RMS time precision
- 700 kHz max data readout rate
- 67 MHz max hit rate

[C. Ugur et al., JINST 7 (2012), C02004]

Laser Studies





- Realistic conditions
  - ✓ single photon
- Electronics characterization
  - ✓ thresholds definition
  - ✓ Time over Threshold proportional to time walk

$$t_{corr} = t_{meas} - (q + m \cdot ToT)$$

$$\sigma_{SP} \approx 122 \text{ ps} \rightarrow 72 \text{ ps}$$

40% improvement

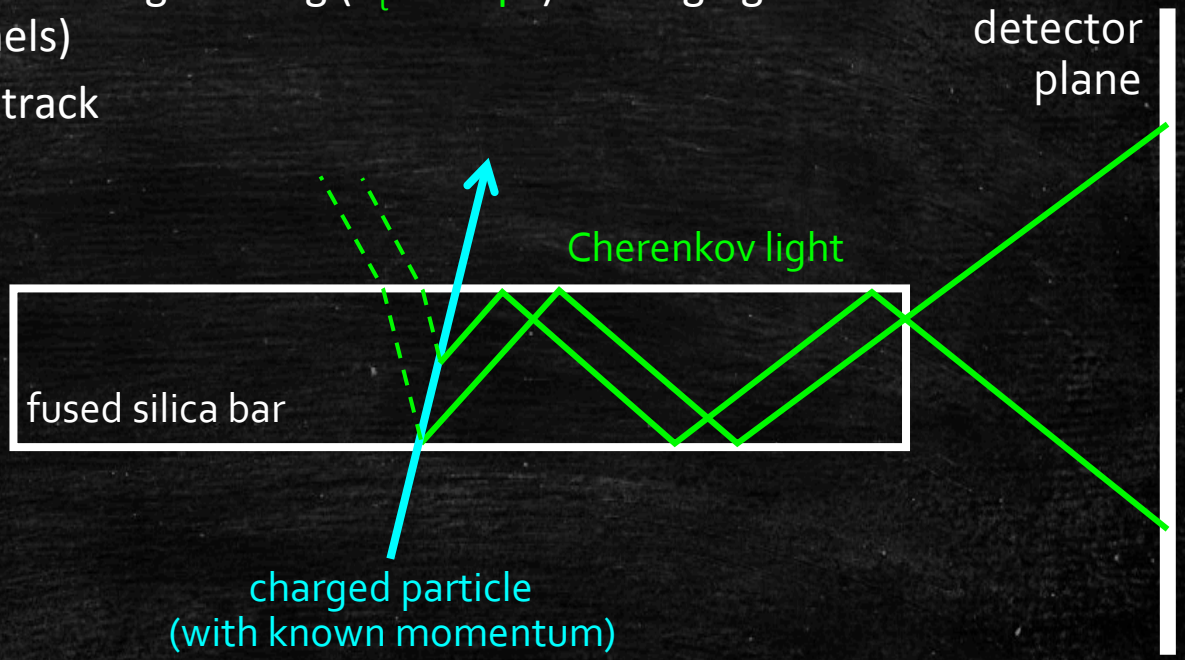
DIRC detector

Detection of Internally Reflected Cherenkov light

- fused silica bar (n≈1.47) for production and transmission of Cherenkov light
- particle identification through timing (σ_t<100 ps) & imaging (about 15.000 channels)
- 15 – 20 photons per track

$$\cos\theta = \frac{1}{n\beta}$$

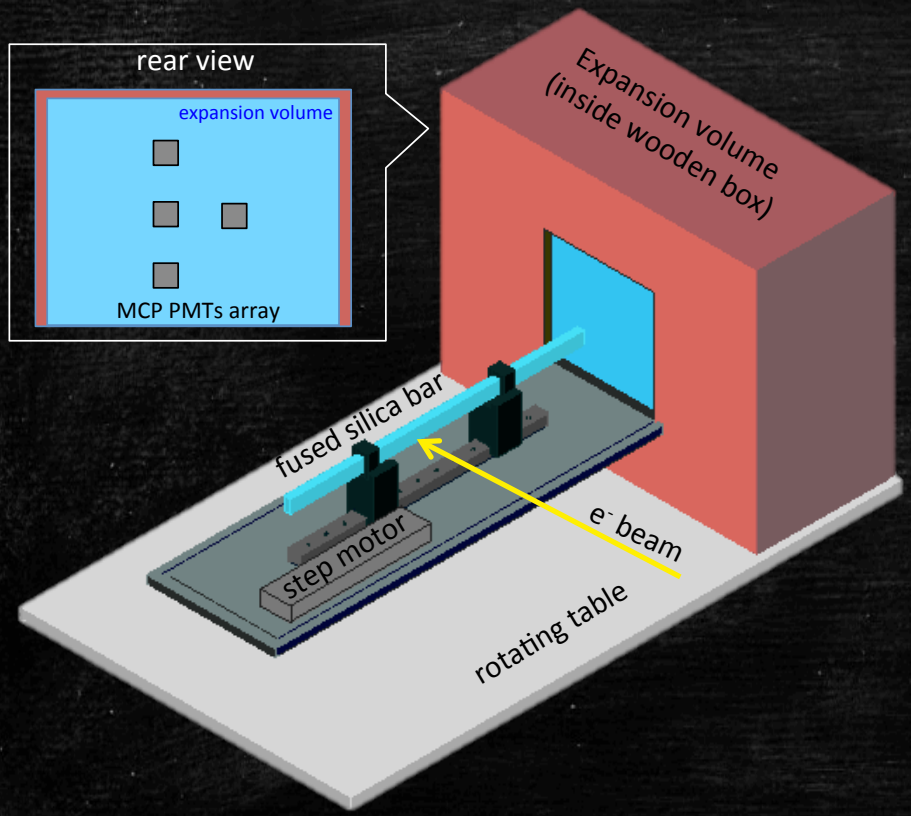
$$\beta > 1/n$$



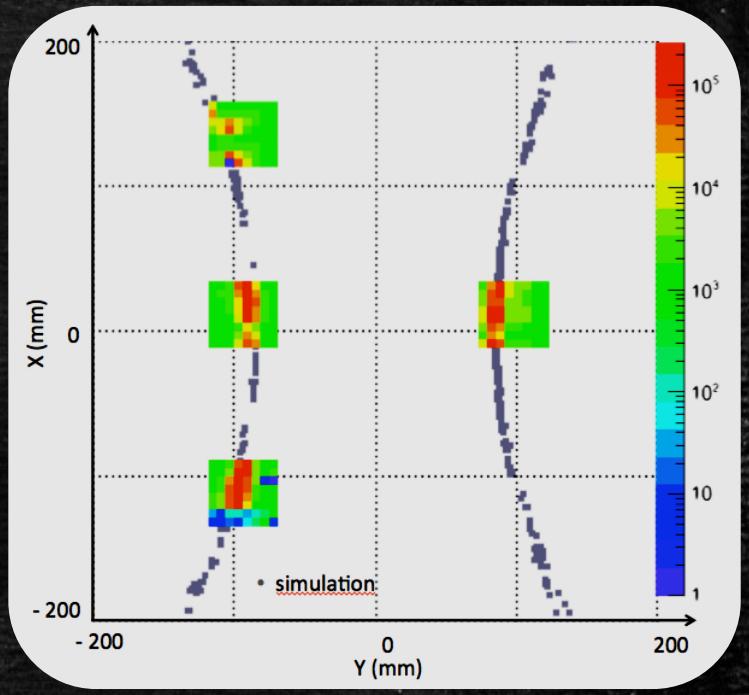
P. Coyle et al., Nucl. Instr. and Meth . in Phys. Res. A 343 (1994) 292-299

PANDA barrel DIRC – Test experiment

- 2013, **MAMI**, 855 MeV e⁻ beam
  - 4 Micro Channel Plate photomultipliers
  - 256 readout channels
  - 2-3 detected photons per event



Incident e⁻ beam at 57°



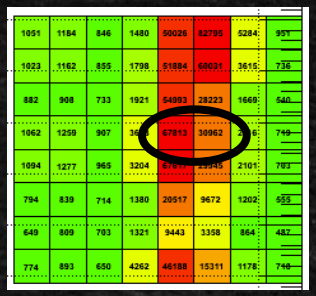
✓ Clear Cherenkov pattern

PANDA barrel DIRC – Test experiment

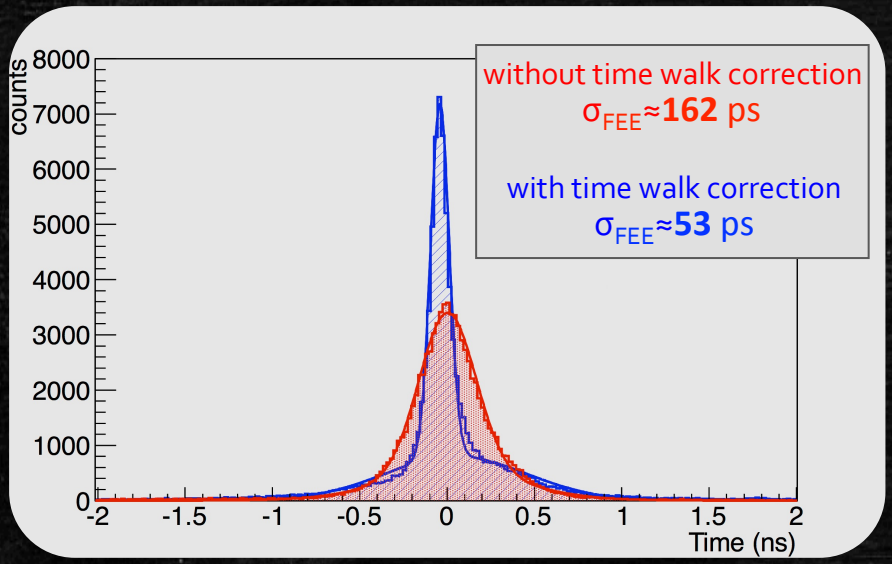
FEE timing resolution

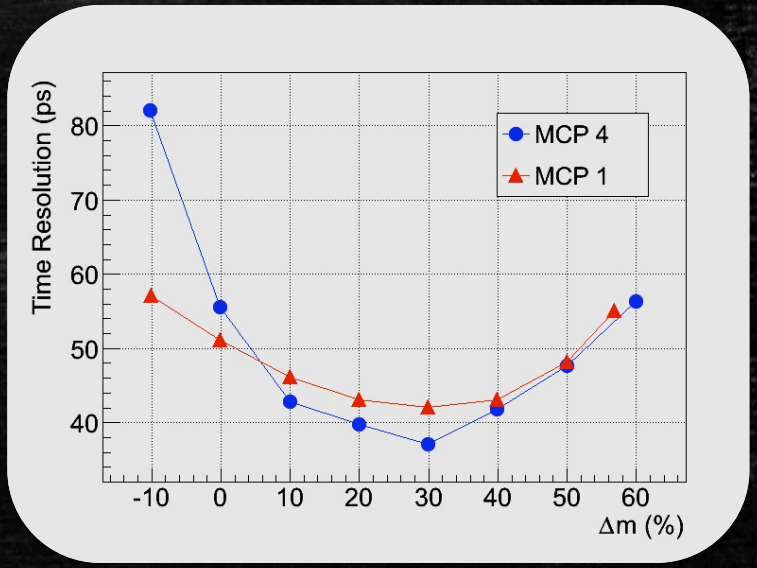
- ✓ charge sharing between neighbouring pixels (single photo-electron)
- ✓ time walk correction validated
- ✓ optimisation algorithm

MCP



$$t_{corr} = t_{meas} - (q + m \cdot ToT)$$

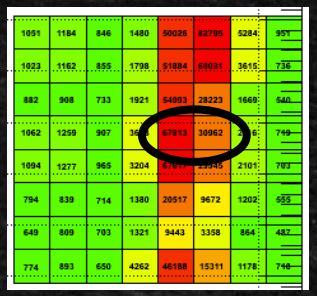




PANDA barrel DIRC – Test experiment

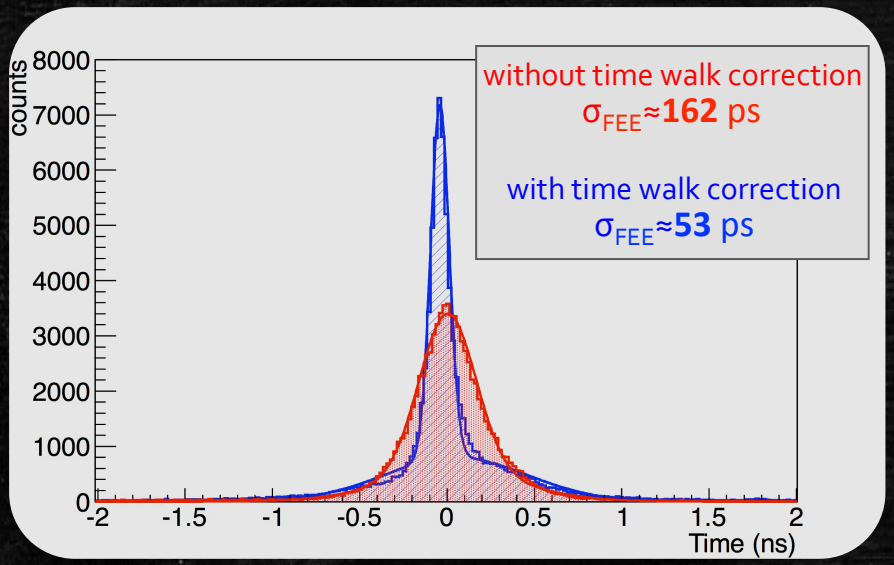
FEE timing resolution

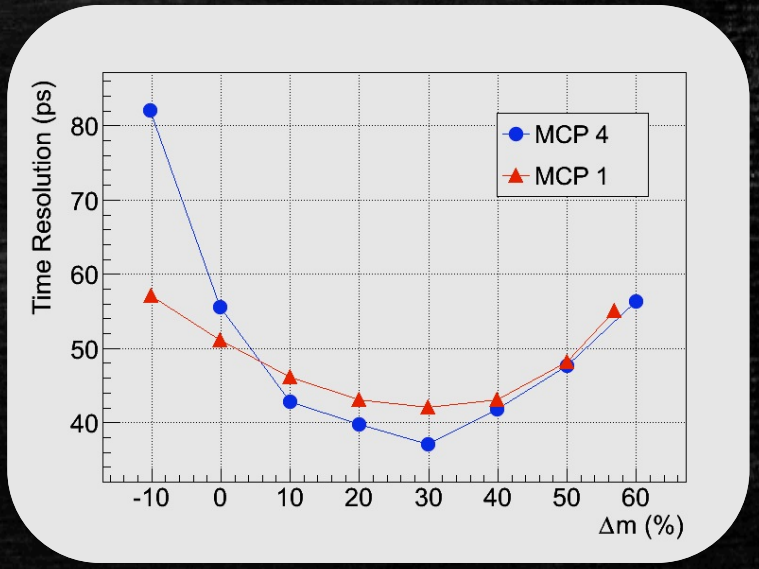
MCP



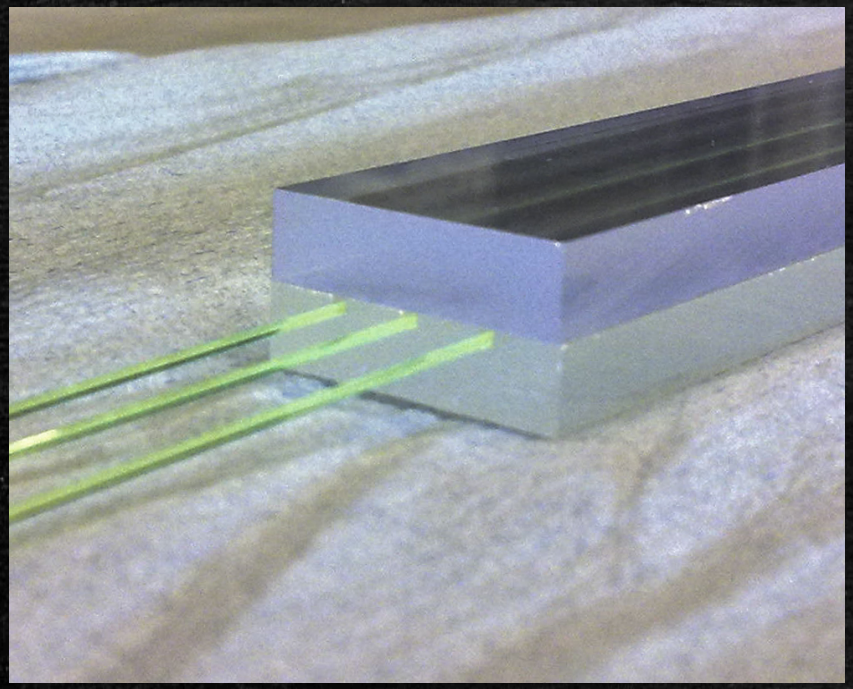
timing resolution ~ 40 ps

$$t_{corr} = t_{meas} - (q + m \cdot ToT)$$





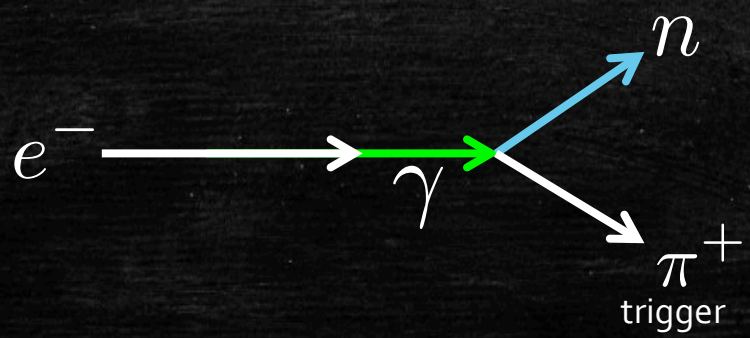
A1 Neutron Detector



Prototype:

- 2 layers of plastic scintillator bars (64 x 2)
- wavelength shifting fibers
- 4 Multi Anode PMT (64 ch)
- 256 readout channels
- Time over Threshold as particle discrimination

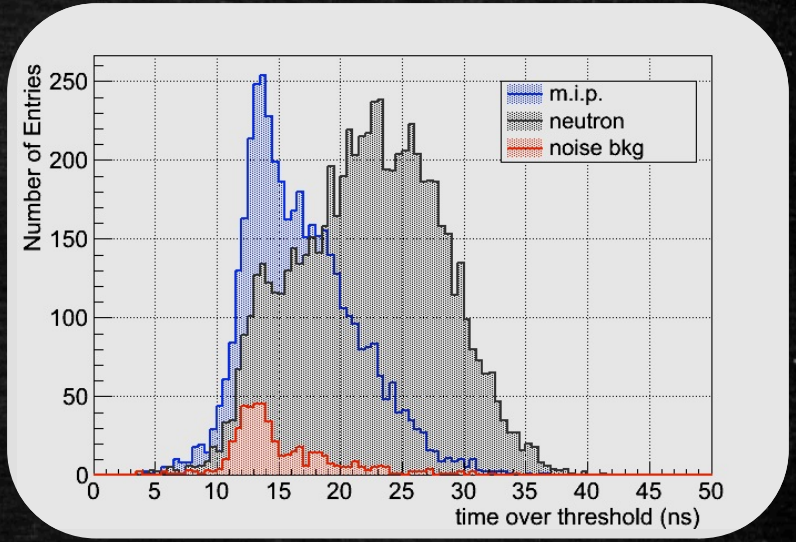
- A1 @ MAMI, Mainz
  - Y. Kohl's poster
- current < 10 μA
  - several MHz/channel

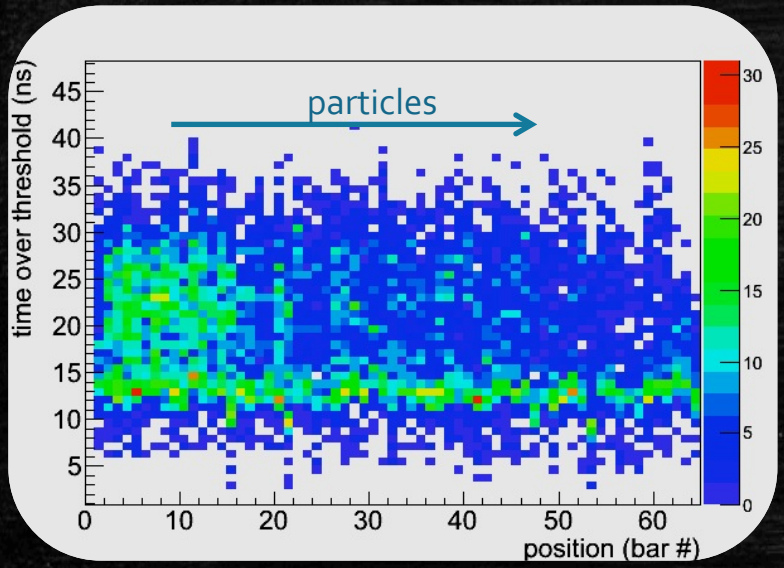


A1 Neutron Detector

Time over Threshold

- ✓ particle identification from A1 spectrometer
- ✓ no saturation effects observed
- ✓ possibilty to disentagle between particle species



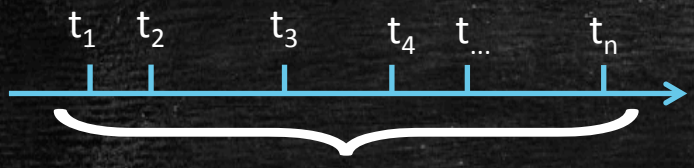


Response across the layers

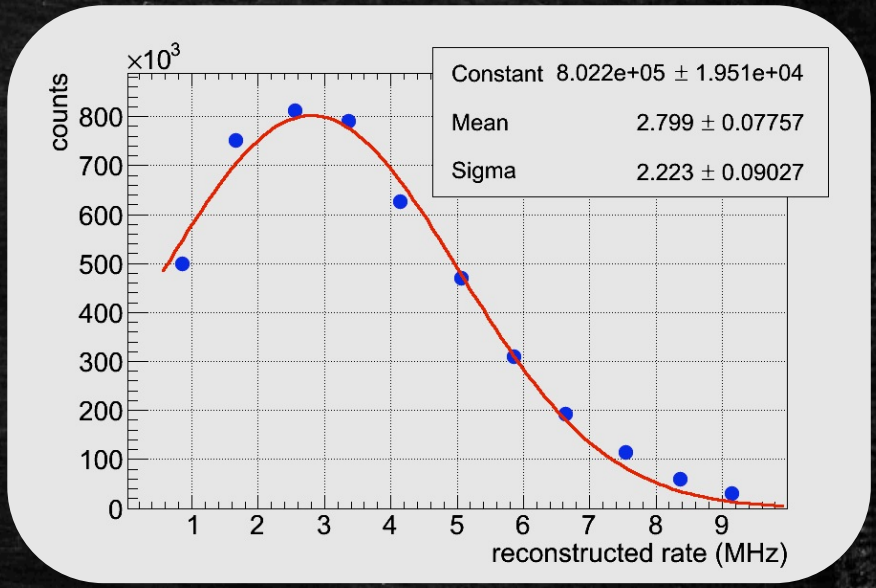
- ✓ MIP uniformly distributed
- ✓ neutrons distribution agrees with simulation

A1 Neutron Detector

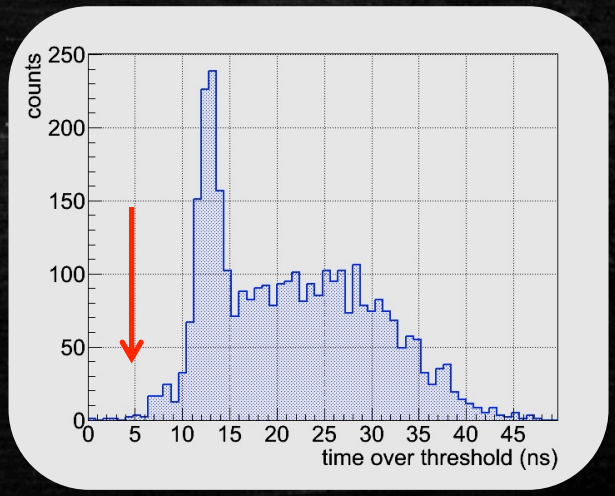
Rate Studies



$$rate = \frac{n}{1\ \mu s}$$



- ✓ number of hits in 1 μs -> rate
- ✓ average rate 2.8 MHz/channel
- ✓ peaks up to 12 MHz/channel
- ✓ no saturation effects observed

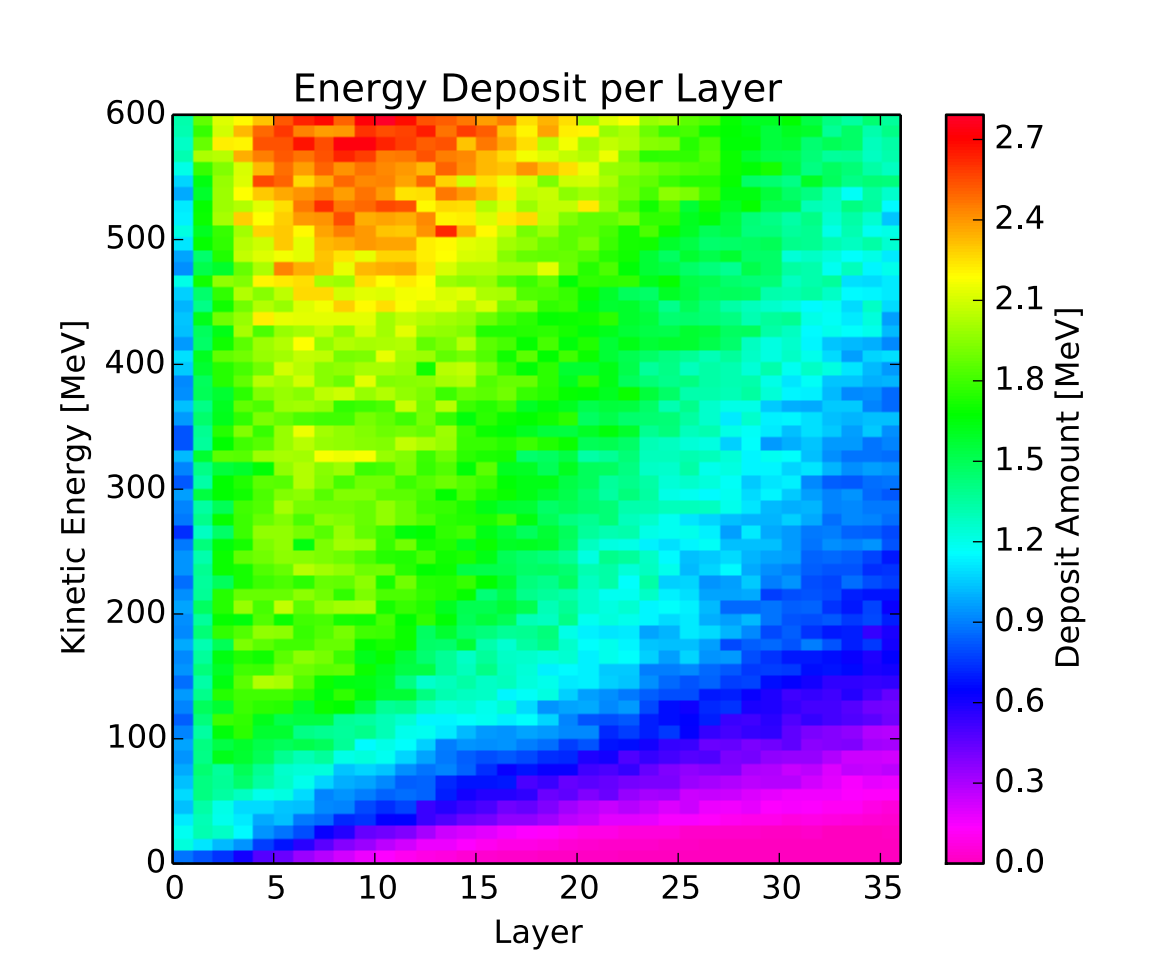


Summary

- Versatile frontend electronics design
- Time over Threshold
  - time walk correction (SP case)
  - charge measurement from scintillators
- very small intrinsic resolution: 40 ps
- sustains high rate: 2.8 Mhz

Backup slides

A1 Neutron Detector



M. Schoth

MCP structure