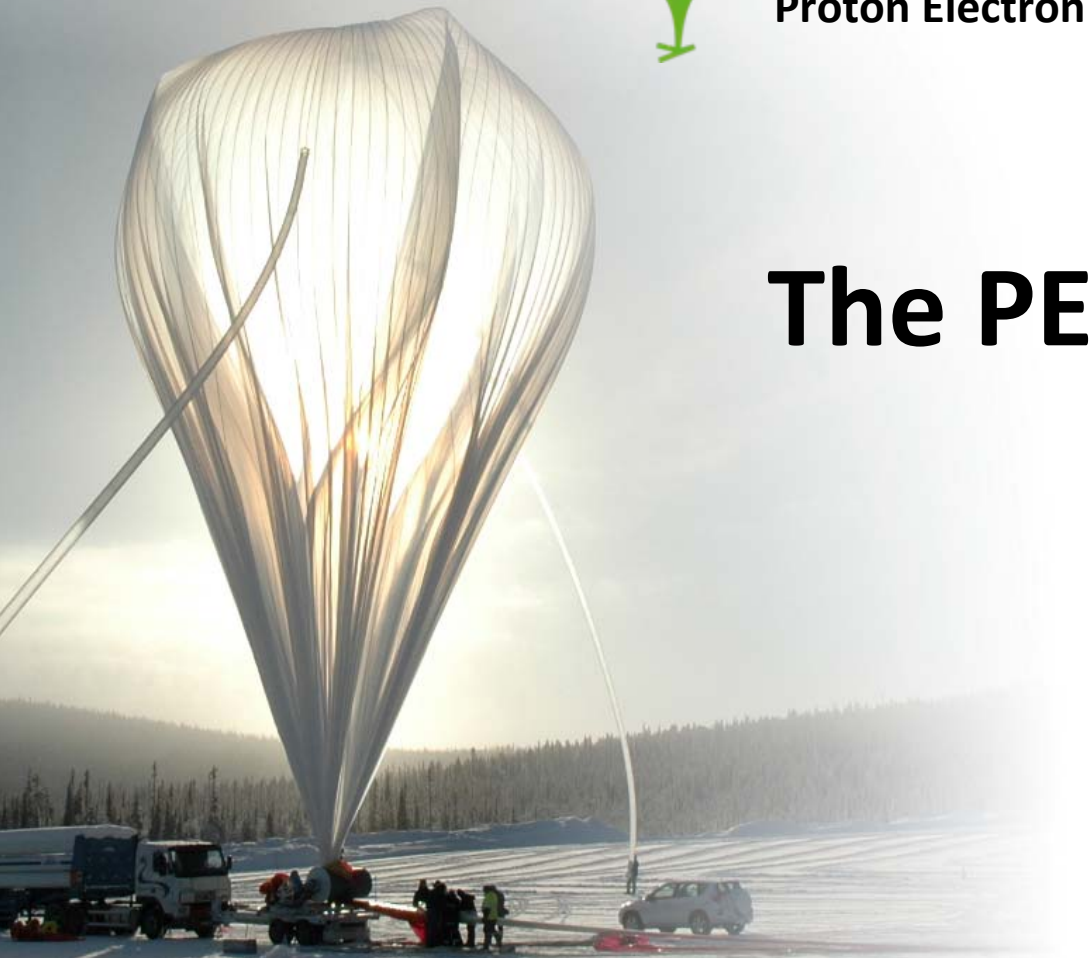
PERDaix

Proton Electron Radiation Detector Aix-la-Chapelle



The PERDaix Detector

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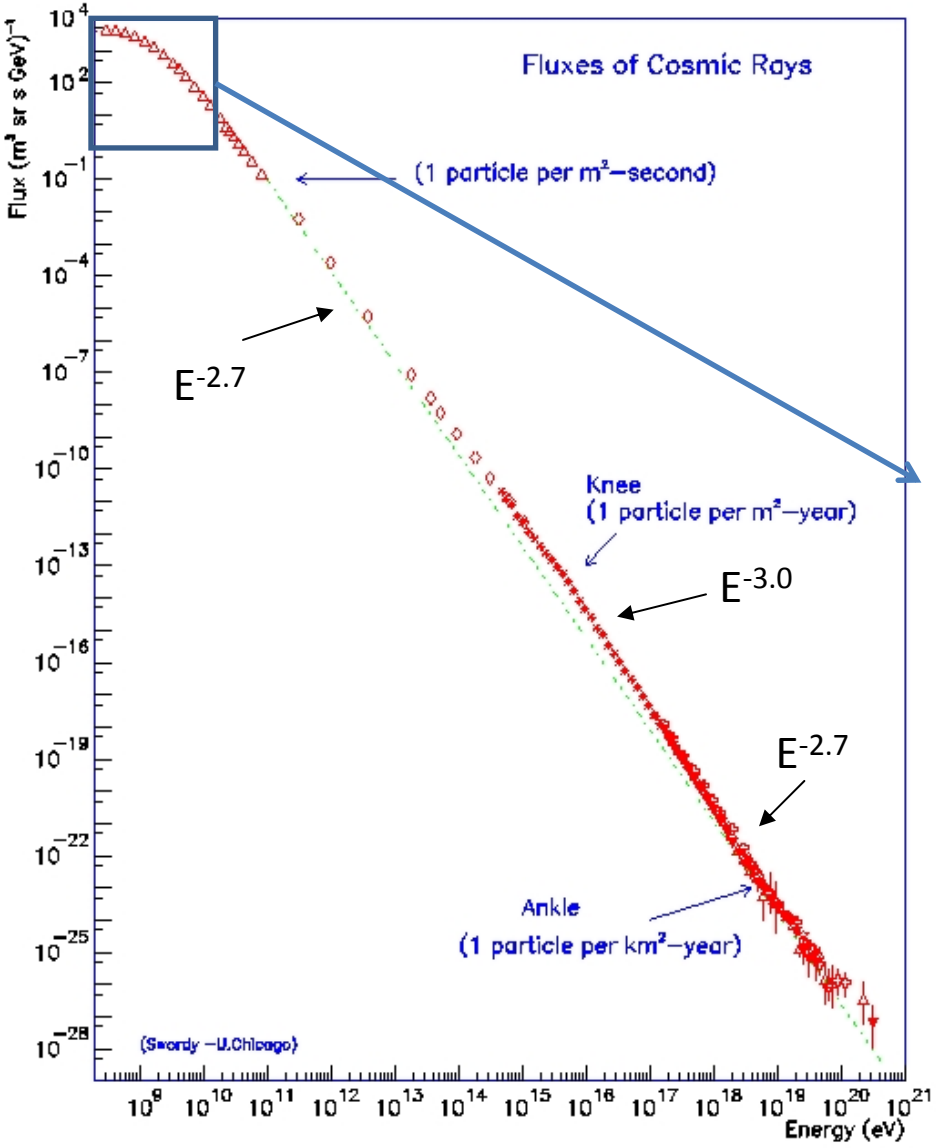
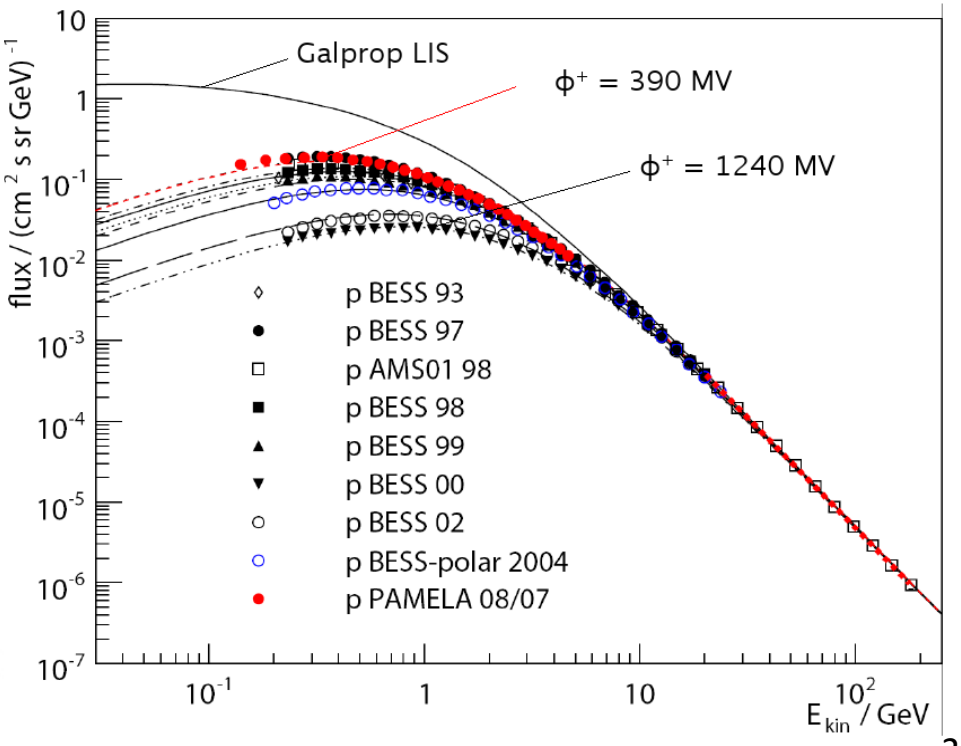
July 5th 2011, 6th International Conference on
New Developments In Photodetection

Motivation

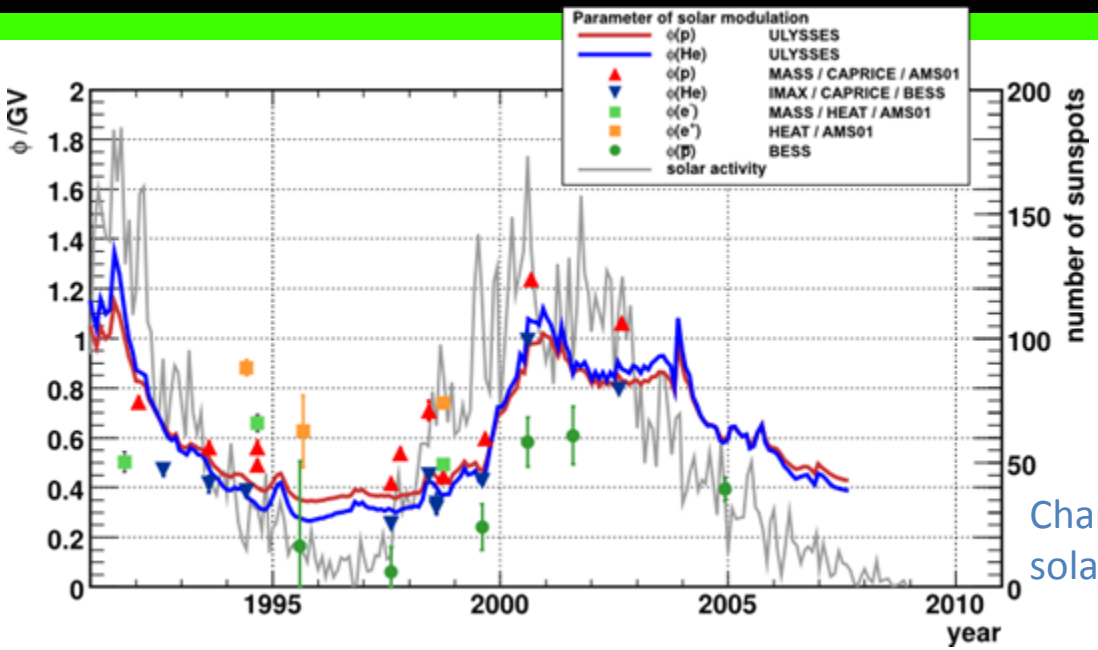


Cosmic Ray Composition:

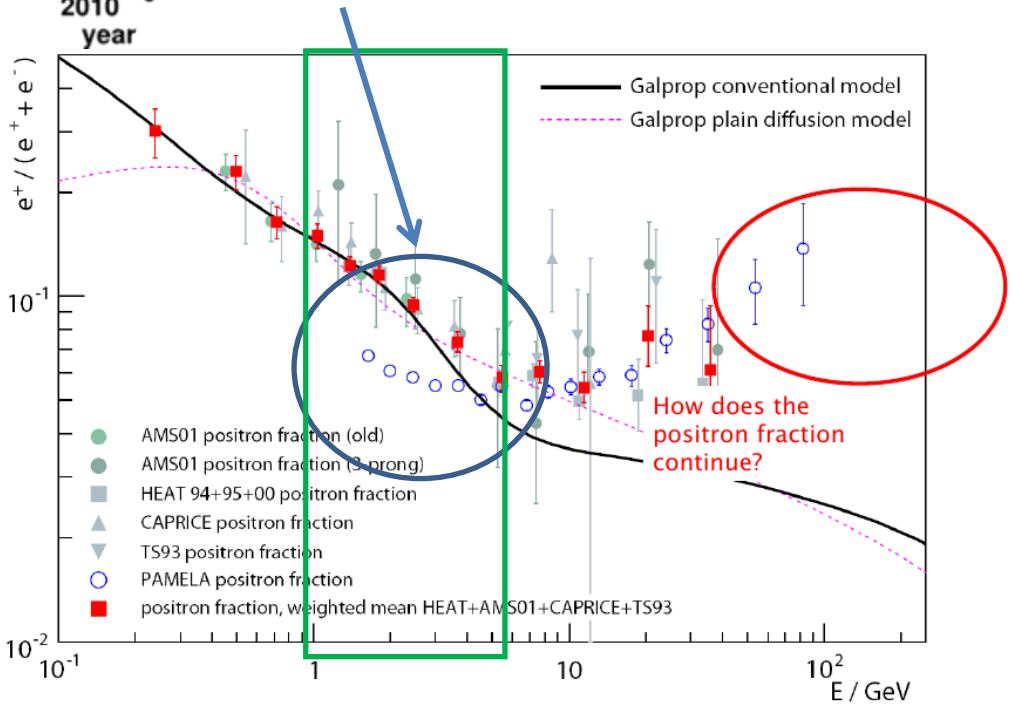
Protons	88 %
Helium	10 %
e^-	1 %
e^+	0.1 %
Antiprotons	0.01 %



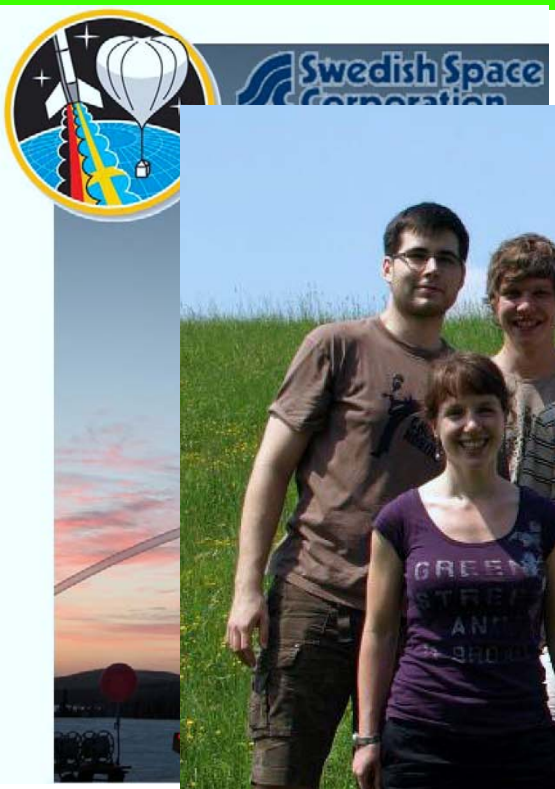
Motivation



Charge sign dependent solar modulation?



REXUS/BEXUS program

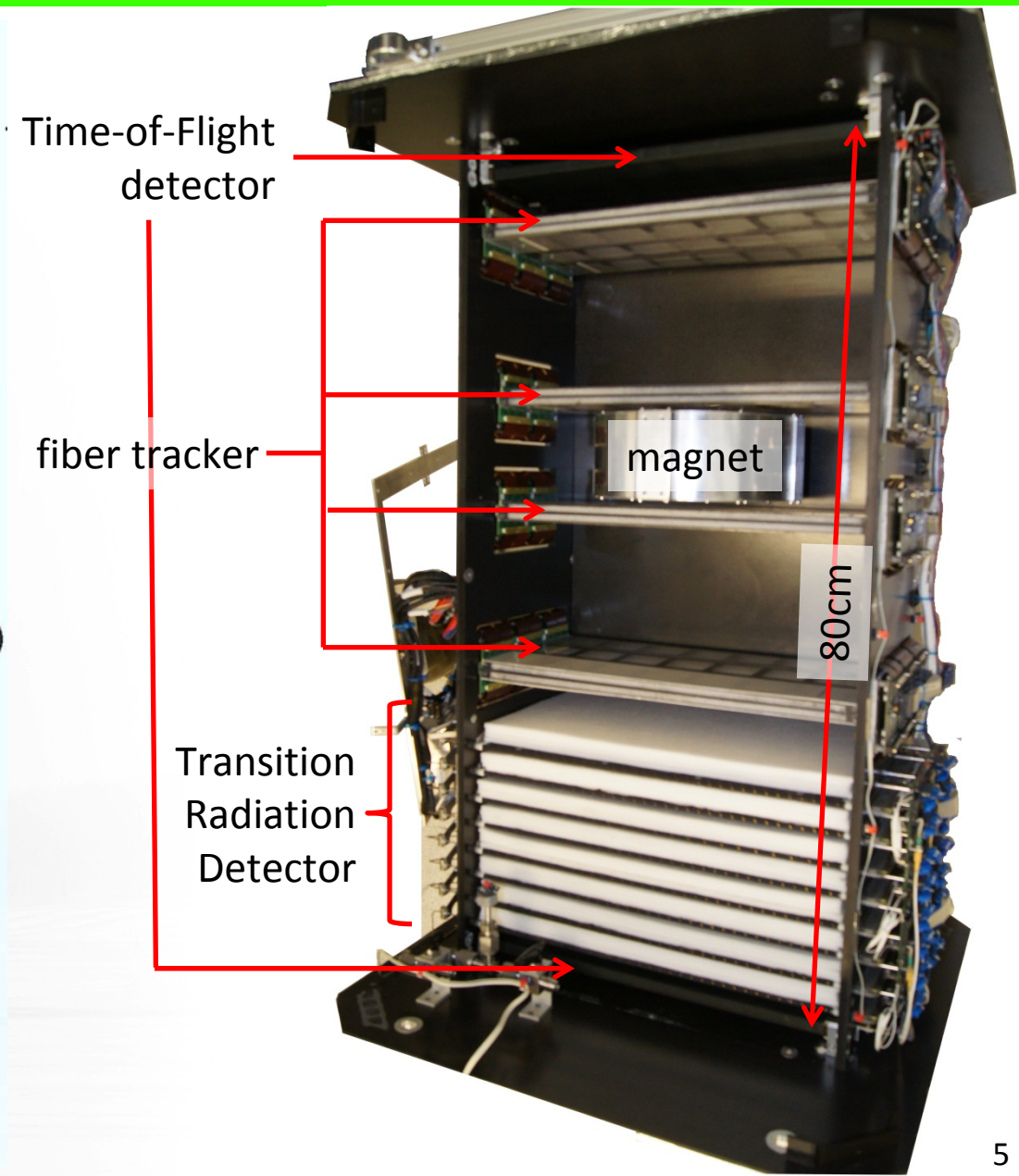


- **R**ocket and **B**alloon **Ex**periments

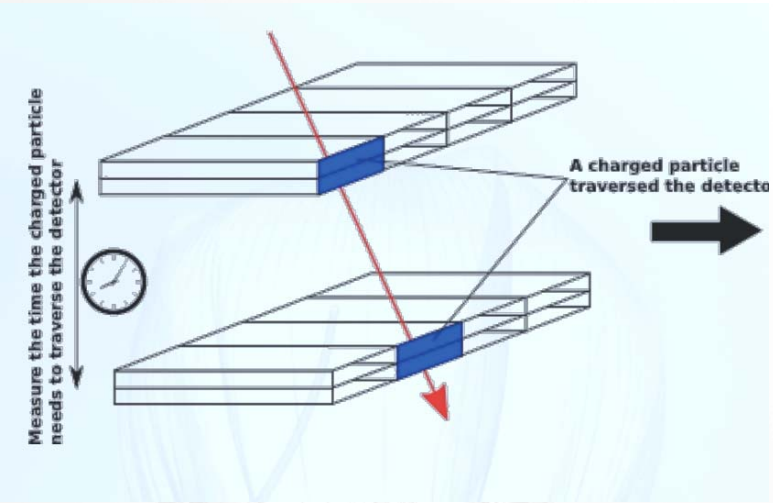
- Temperature -50°C
- Low pressure ≈1mbar

The PERDaix detector

- Spectrometer (Tracker)
  - Permanent magnet 0.2 T in Halbacharrangement
  - Scintillating fiber tracker
  - $\frac{\sigma_p}{p} = 0.08 \cdot \frac{p}{GeV} \oplus 0.25 \cdot \frac{1}{\beta}$
  - Charge-sign separation up to a rigidity of 5 GV
- Transition radiation detector (TRD)
  - Fleece radiator
  - Proportional counter tubes ($XeCo_2$)
- Time-of-Flight (TOF) detector
- Acceptance 32 cm^2 sr
- Total weight 40 kg
- Total power consumption 60 W
- Flight in November 2010 northern Sweden (Kiruna)
- 2 h float at 33 km
- 177.000 trigger events



Time-of-Flight System

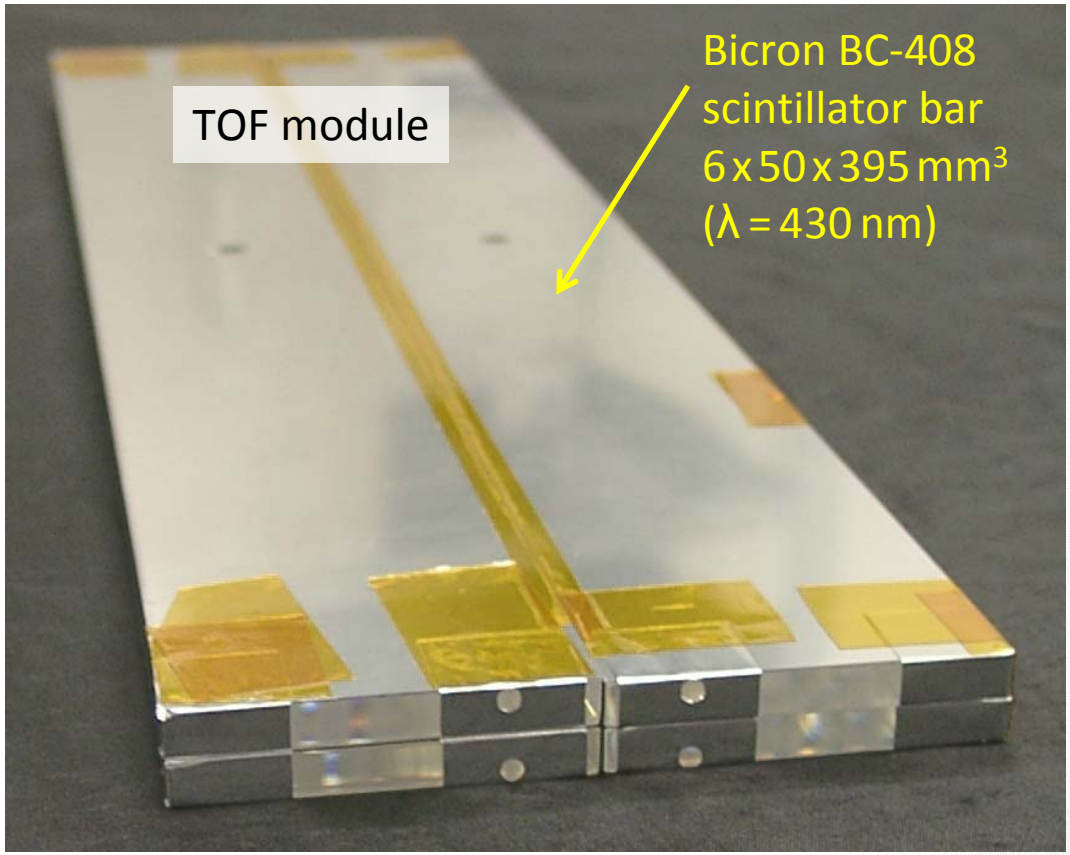


Time-of-Flight detector

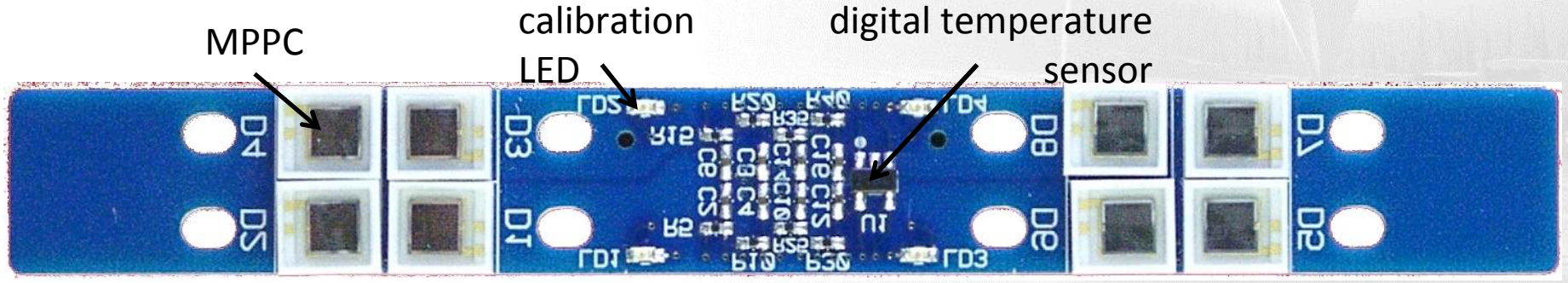
Mandatory tasks

- Main trigger
- Rejection of upward from downward flying particles (Albedo particles)
- Four layers of scintillator bars
- Two at top and two at bottom
- Distance 80 cm → 2.7 ns flight time
- Modular design

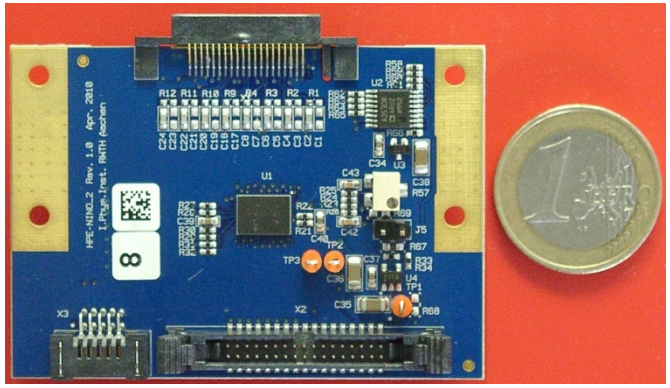
Time-of-Flight System

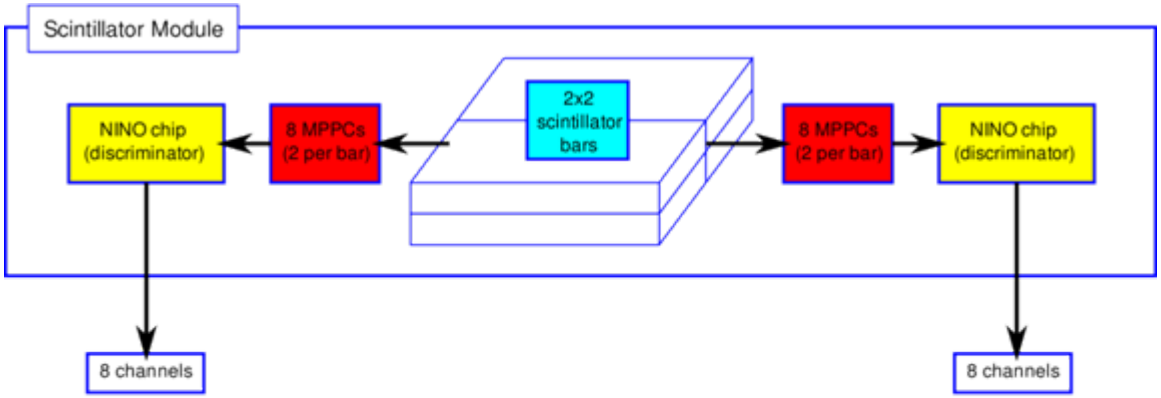


- two top and two bottom modules
- scintillator bars optically separated, wrapped in reflective aluminized Mylar foil
- 2 optical hybrids
  - 8 Hamamatsu S10362-33-100C on each side of module
    (440 nm peak sensitivity)
- Coupling with optical grease

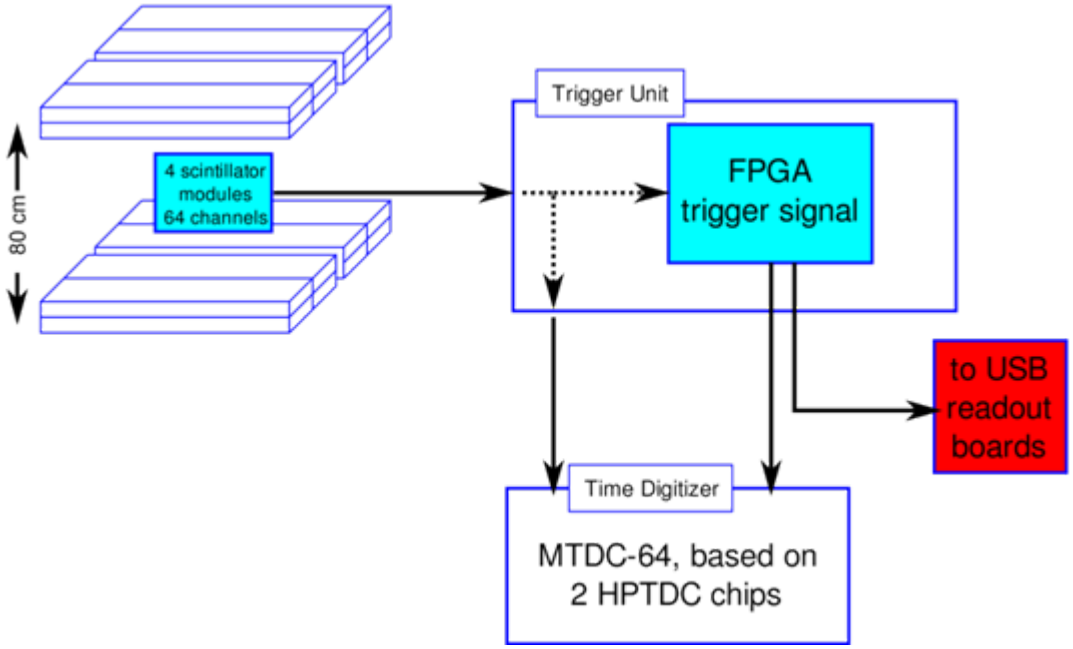


Time-of-Flight system





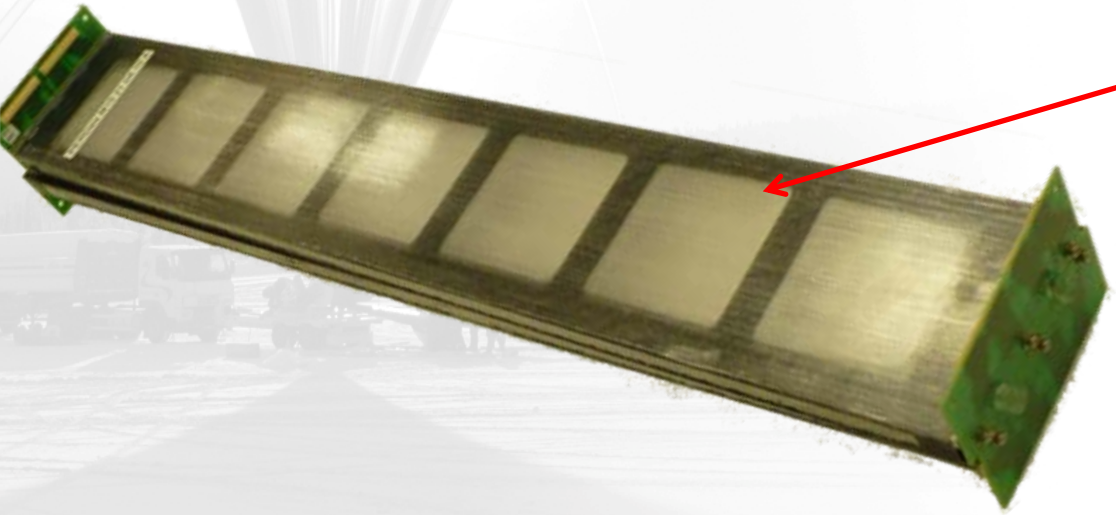
- NINO: 8 channel preamplifier discriminator ASIC
- power consumption 30 mW/channel
- fully differential readout chain
- 1 ns rise time
- DAC for individual MPPC voltages on PCB

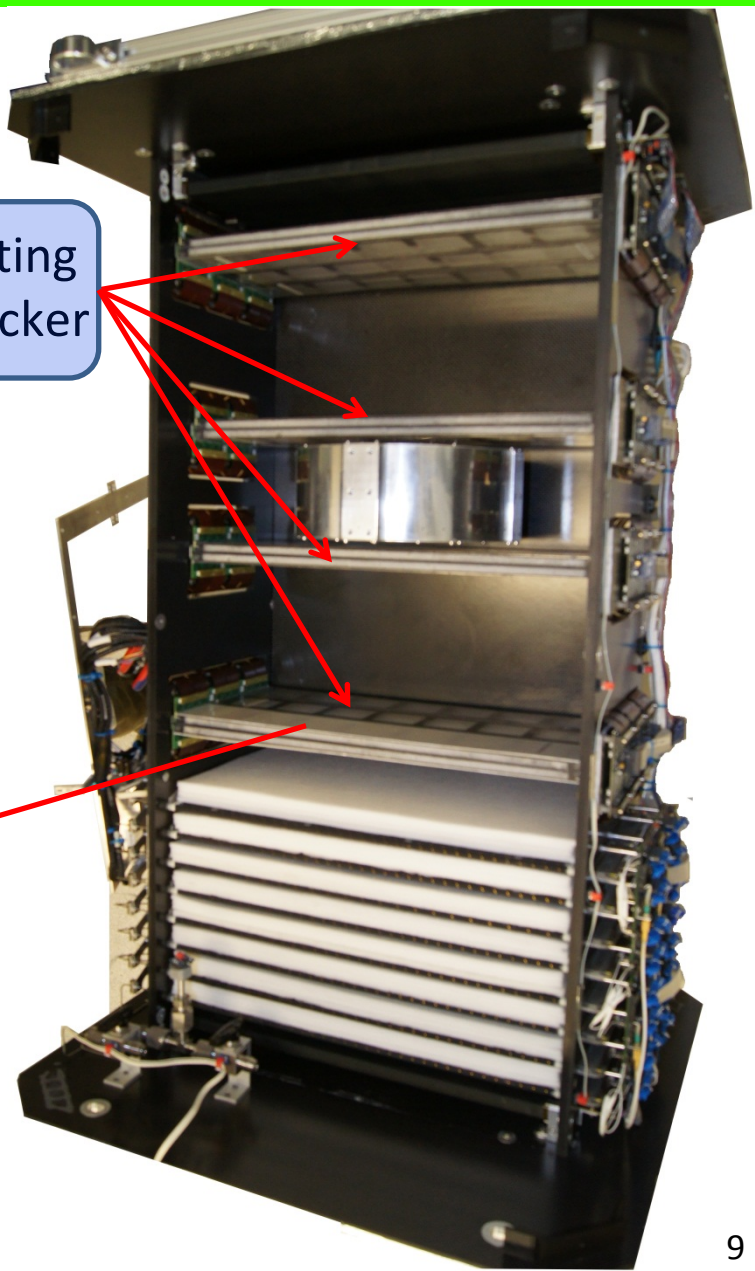


Scintillating Fiber Tracker

4 double layers of scintillating fiber tracker

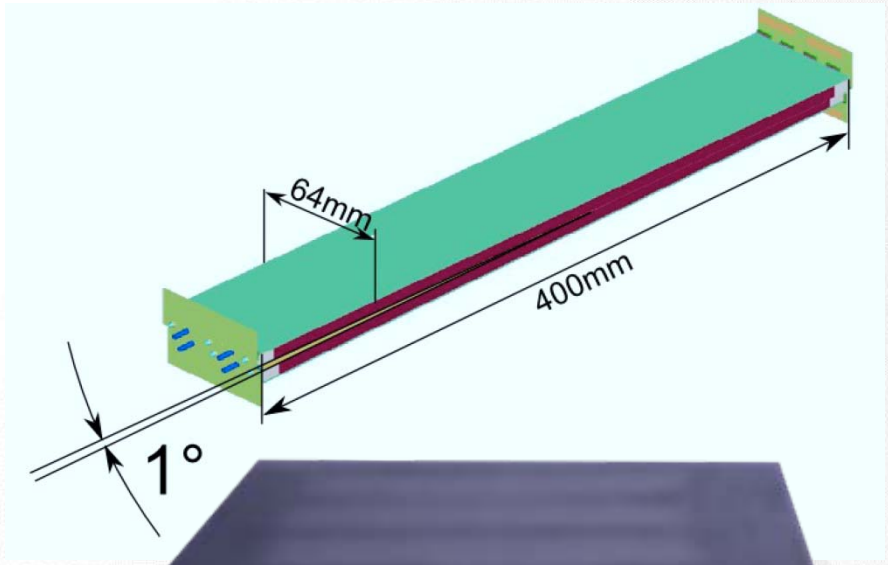
- 10 stereo modules
  → 20 fiber ribbons
  → 160 SiPM arrays
    → 5120 channels
- two ribbons made of 5x256 250µm thick scintillating fibers mounted on Rohacell foam/Carbon fiber support structure (ladder structure for material saving
  → 1,1 % X0 per module)

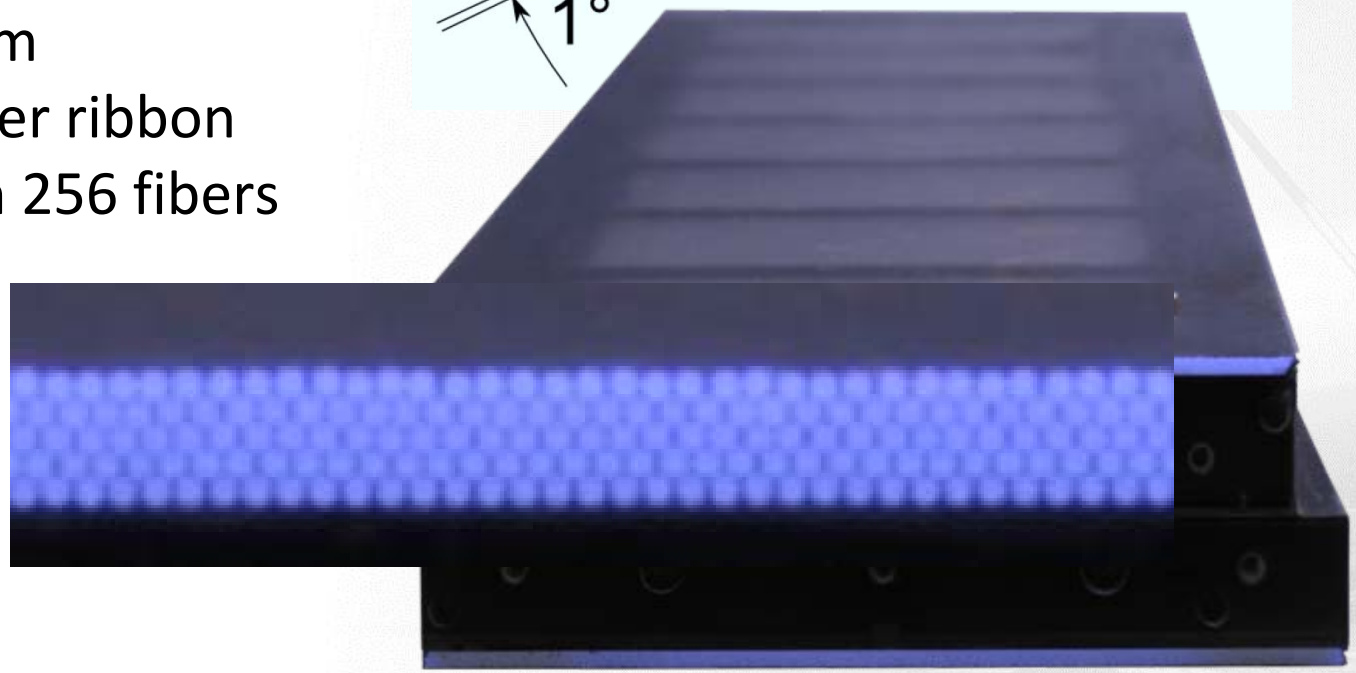




Scintillating Fiber Tracker

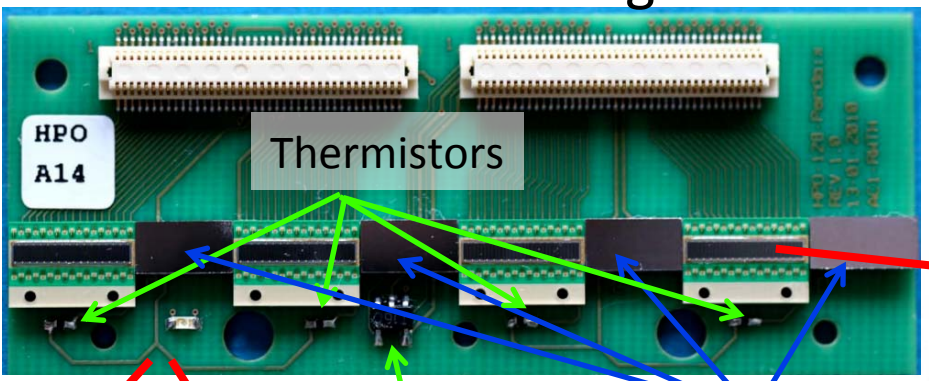
- CFC module carrier
  - fiber ribbons on top & bottom
  - 1° stereo angle
  - 1.1% X0
- Kuraray SCSF-78MJ fibers
  - (250 ± 6) µm fiber diameter
  - $\lambda_{Emission}$ = 450nm
  - 5 fiber layers per ribbon
  - Each layer with 256 fibers

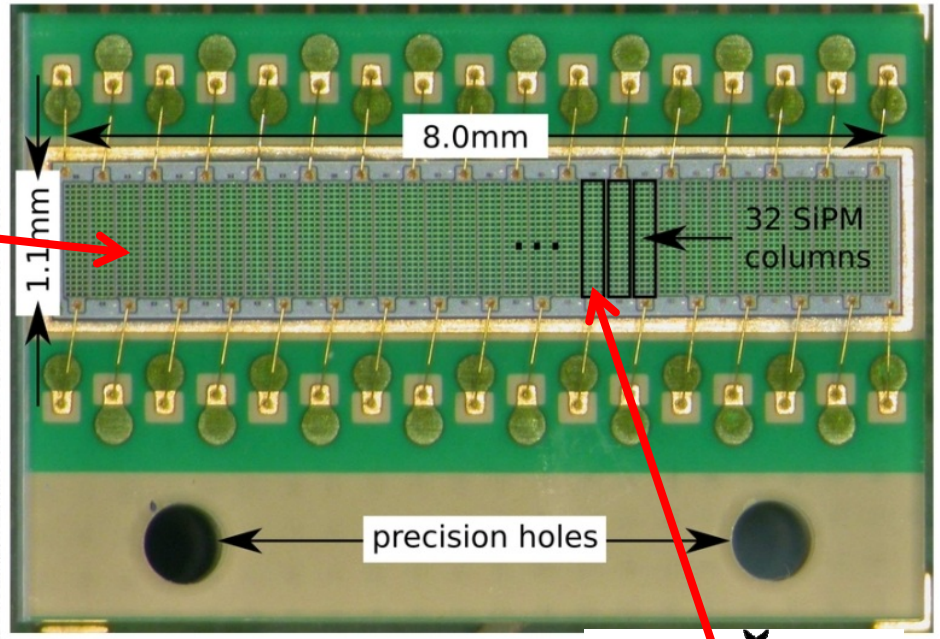




Scintillating Fiber Tracker

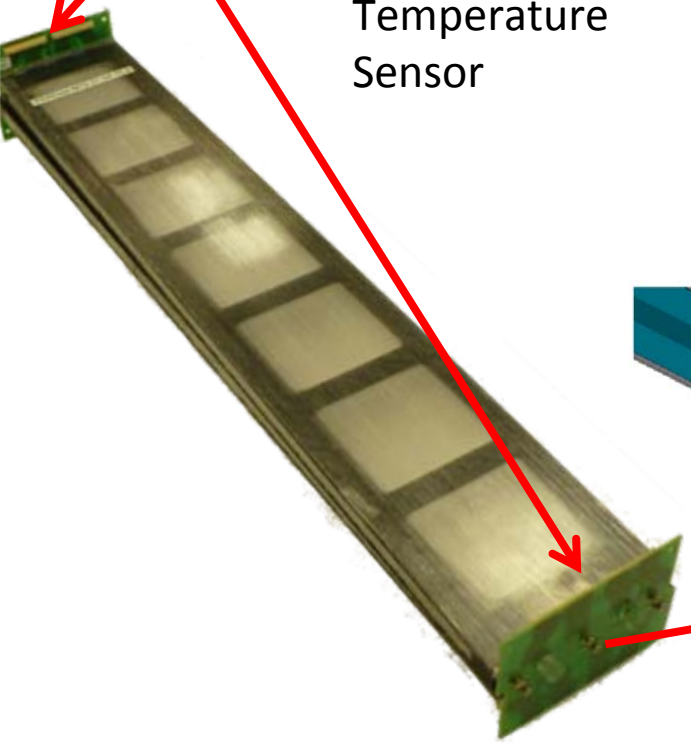
- Readout of scintillating fibers with 32 channel MPPC 5583 arrays

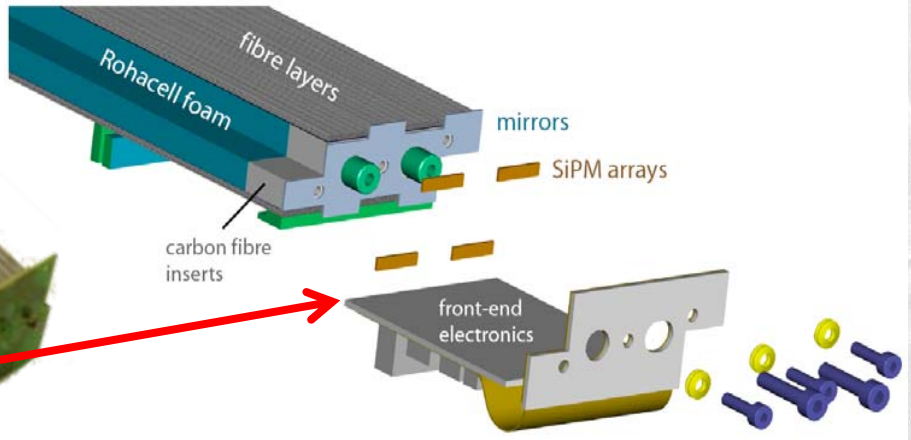


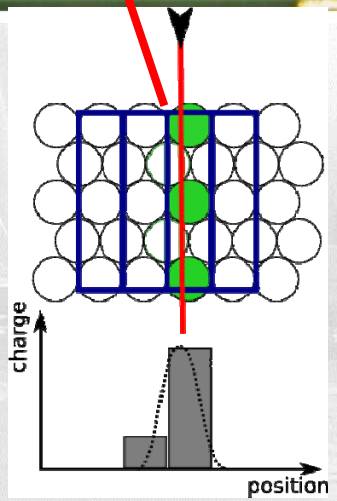


Temperature Sensor

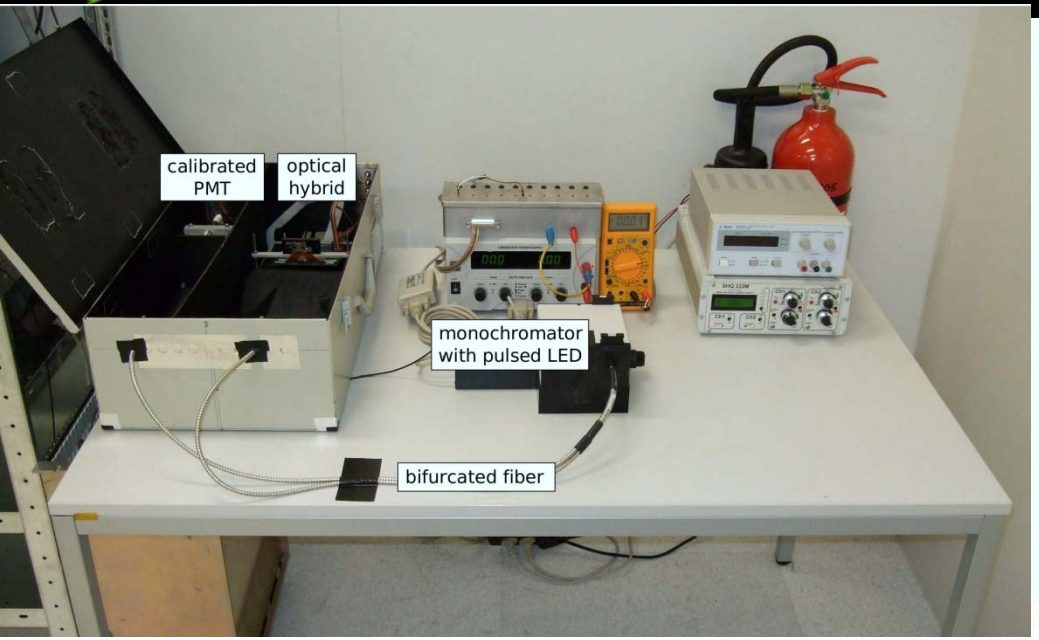
Mirrors

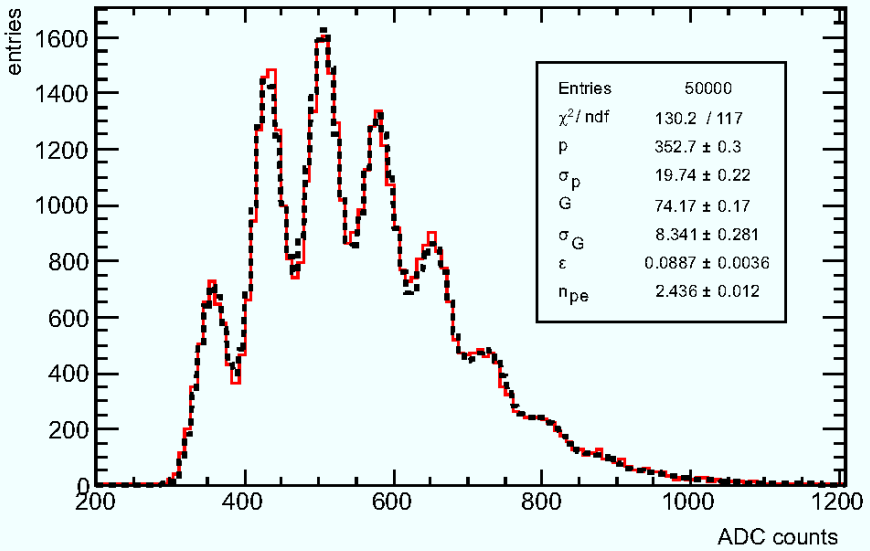


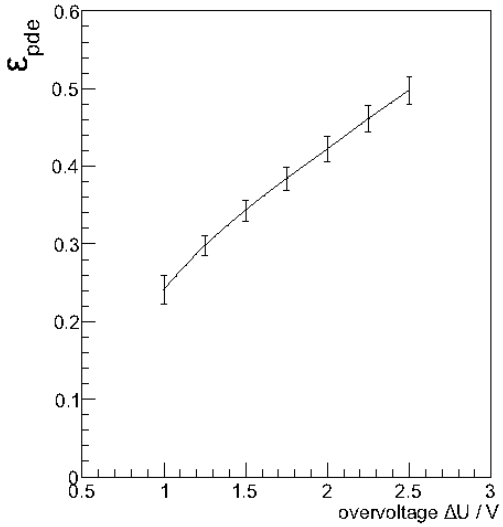


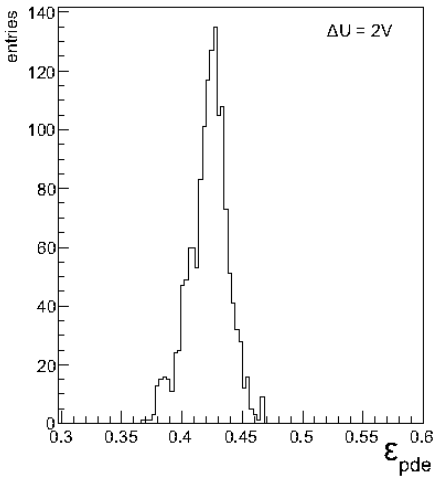


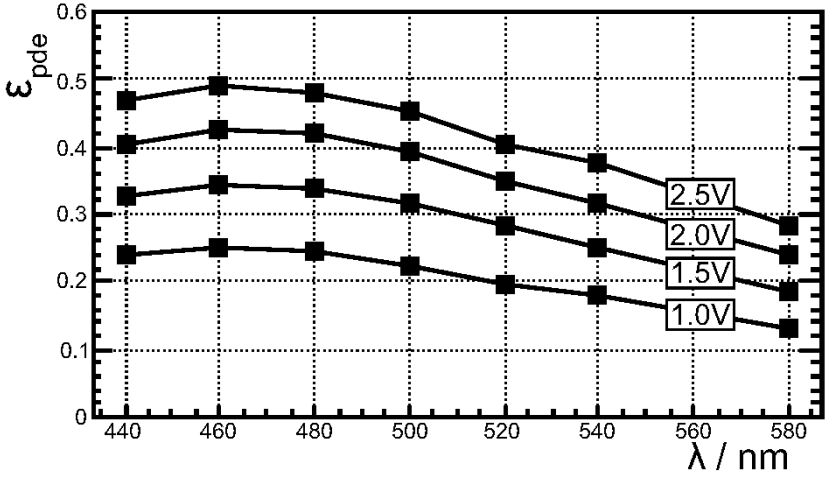
Scintillating Fiber Tracker



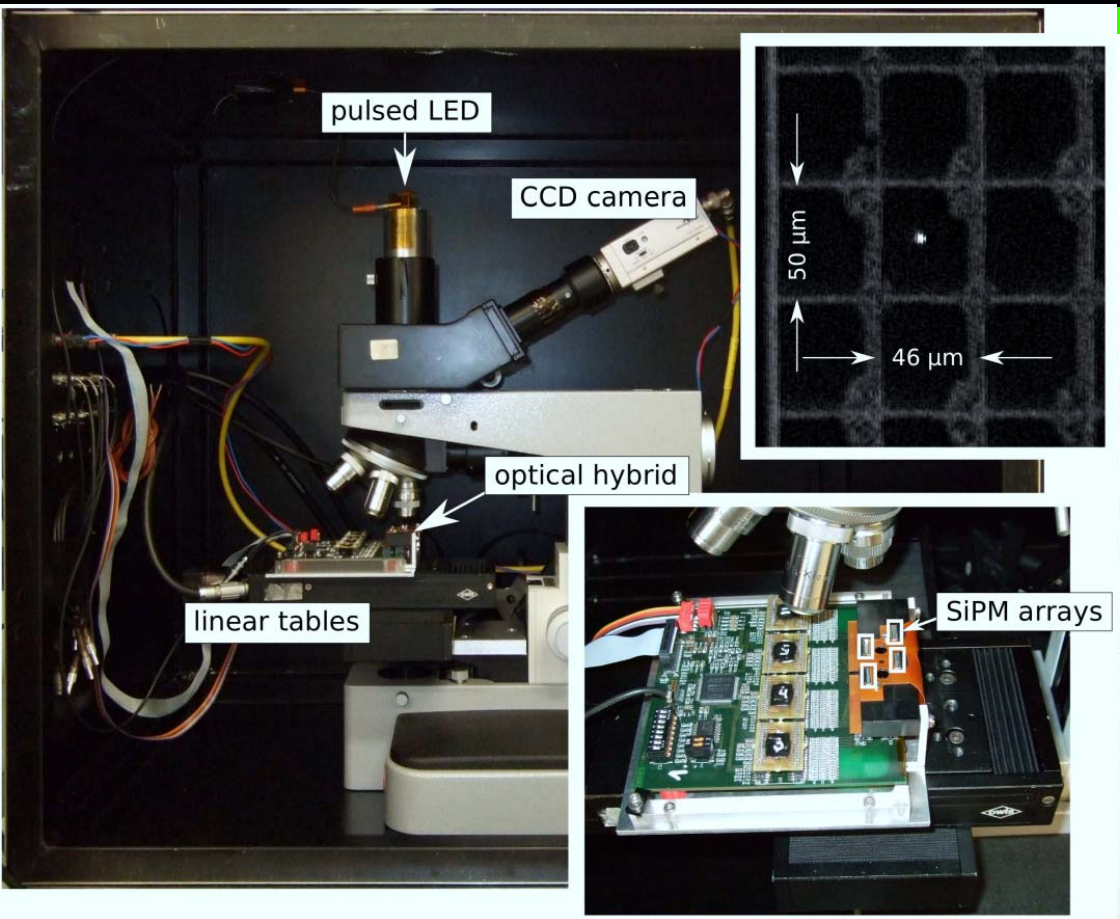


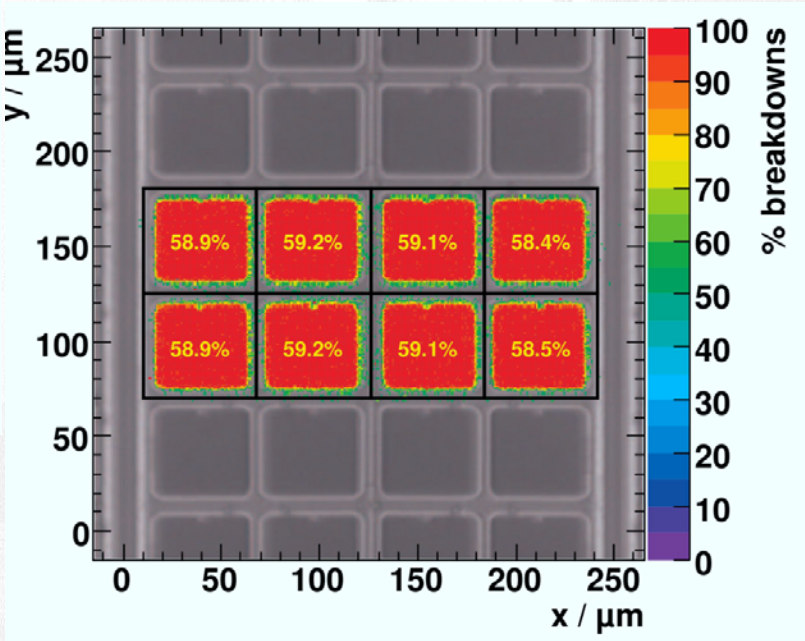




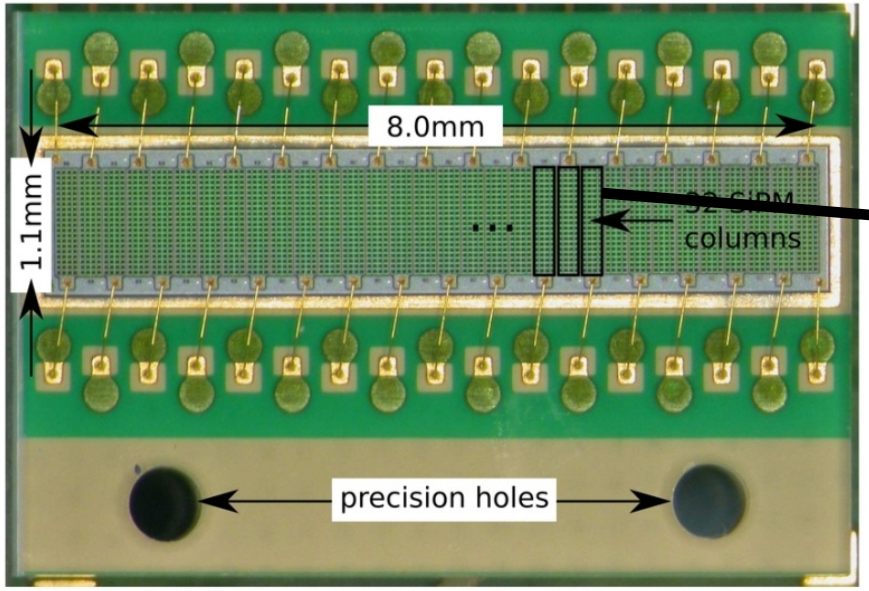


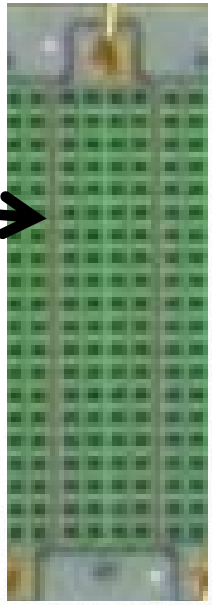
Tracker


pulsed LED
CCD camera
optical hybrid
linear tables
50 µm
46 µm
SiPM arrays

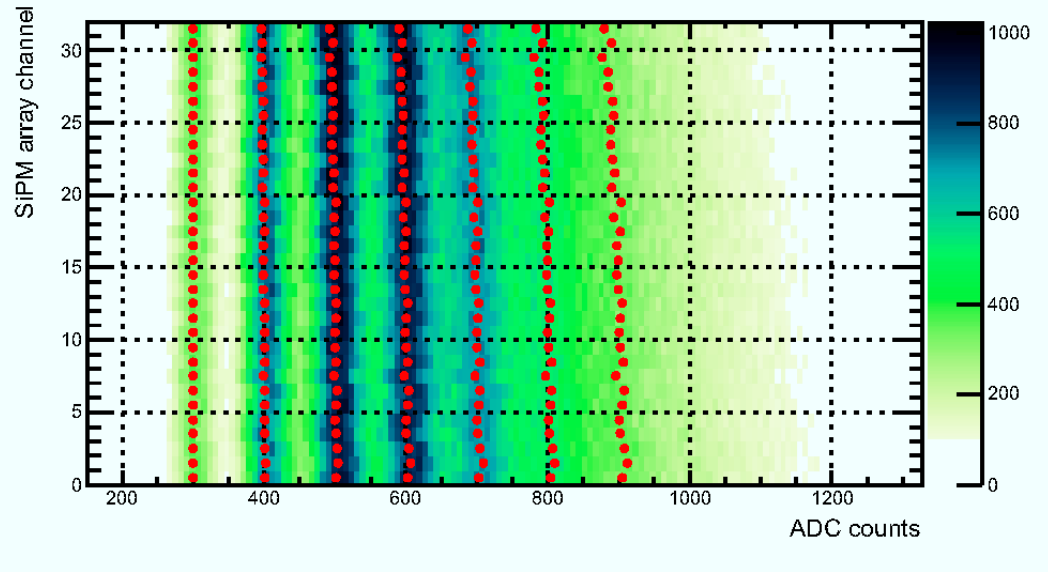

y / µm
x / µm
% breakdowns
58.9%
59.2%
59.1%
58.4%
58.9%
59.2%
59.1%
58.5%

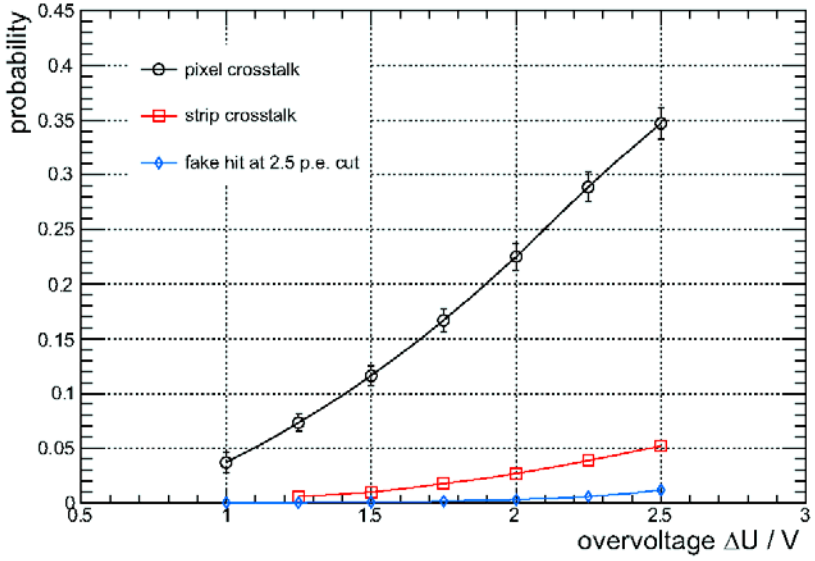
Scintillating Fiber Tracker



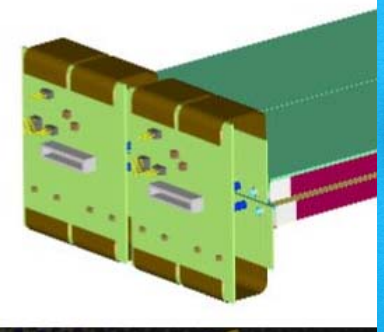


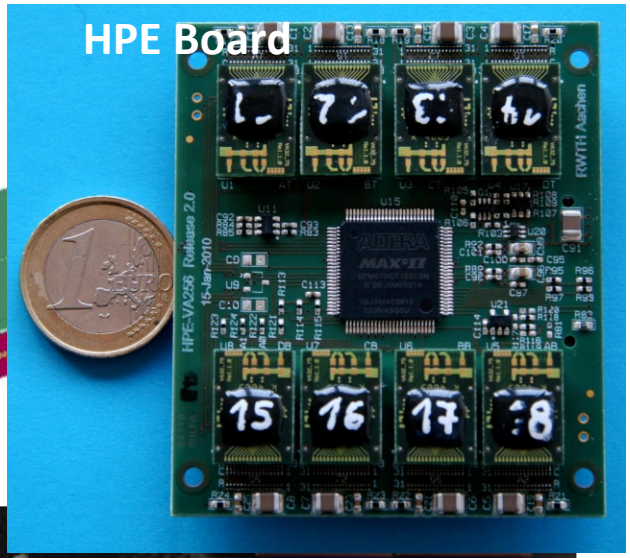
- Hamamatsu MPPC 5883
  - 32-channel SiPM arrays
  - 0.25mm channel pitch
  - 80 pixels (dynamic range)
  - U_{bias} = 70V
  - PDE 50%, Gain 10^6
  - Pixel Crosstalk 30%
  - Dark count ~200kHz/channel

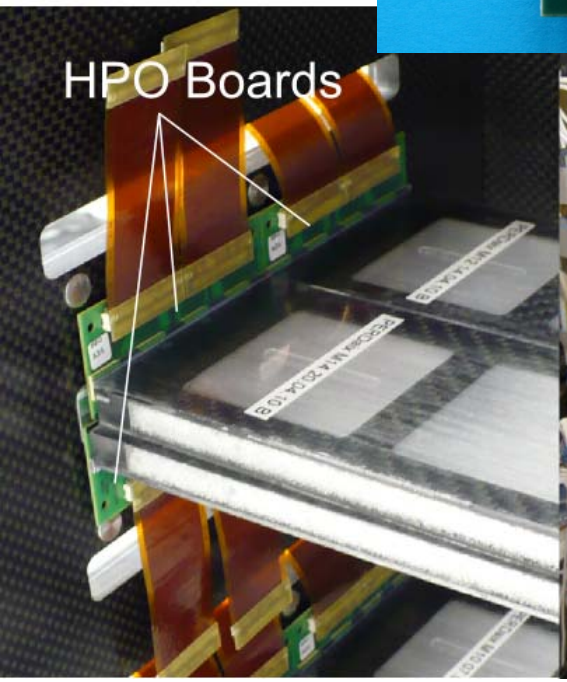


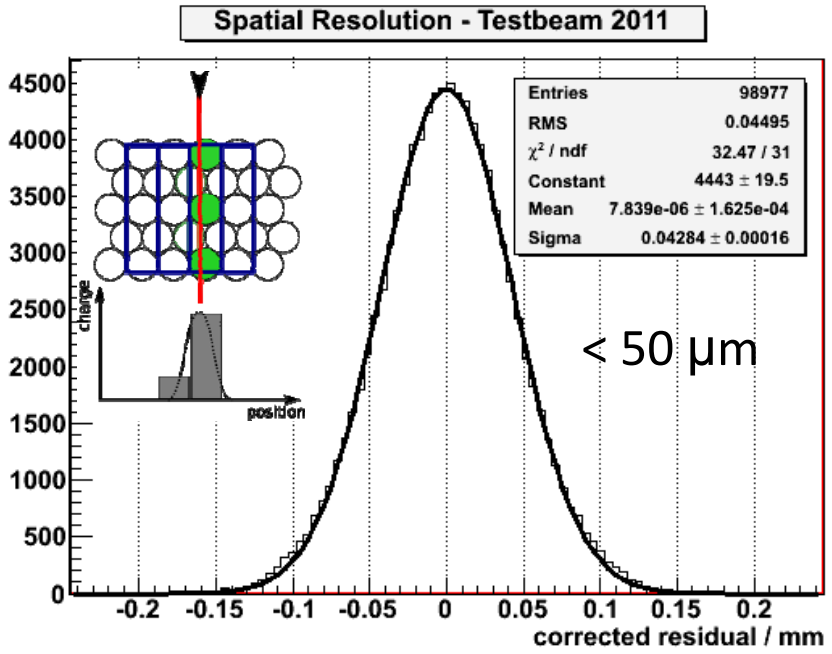


Scintillating Fiber Tracker



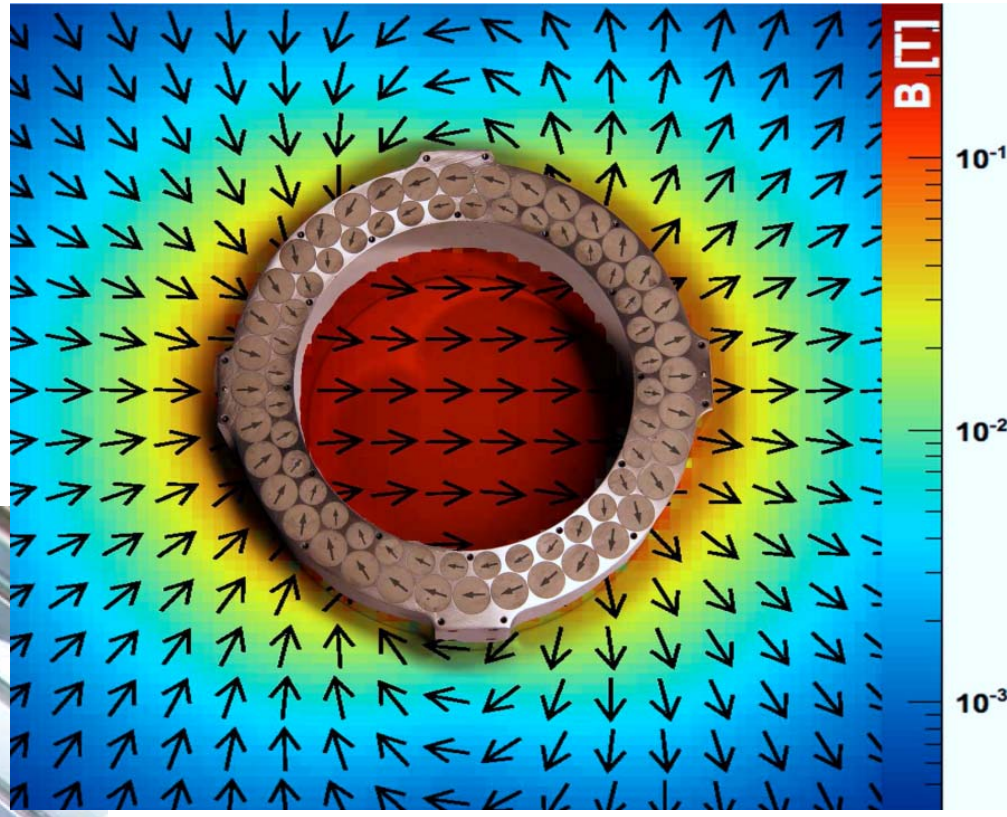


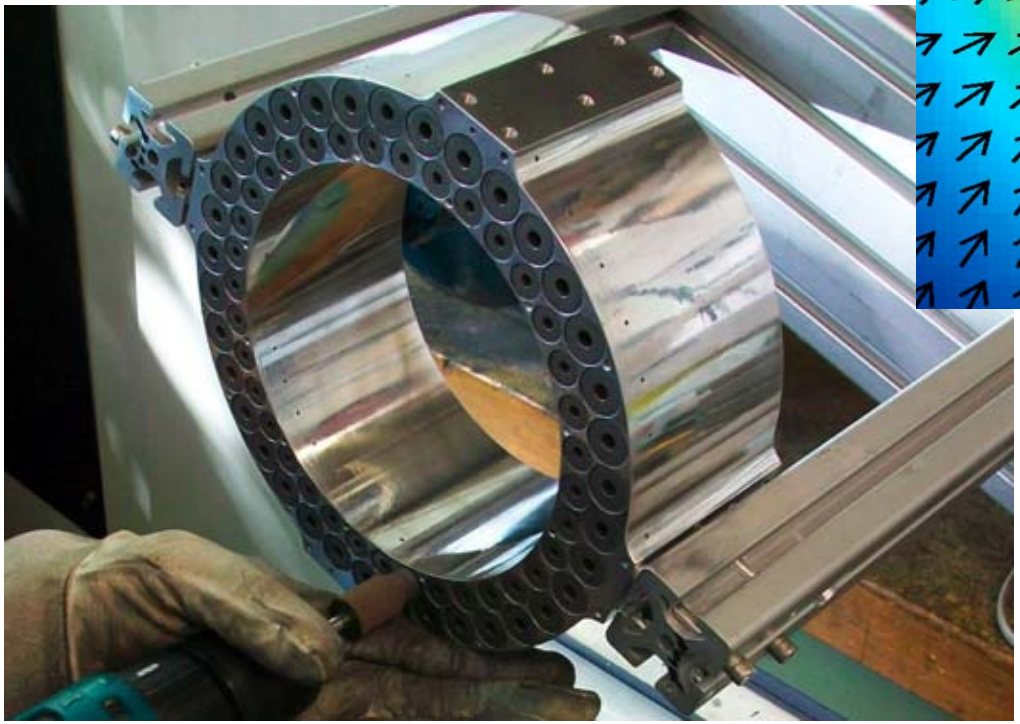




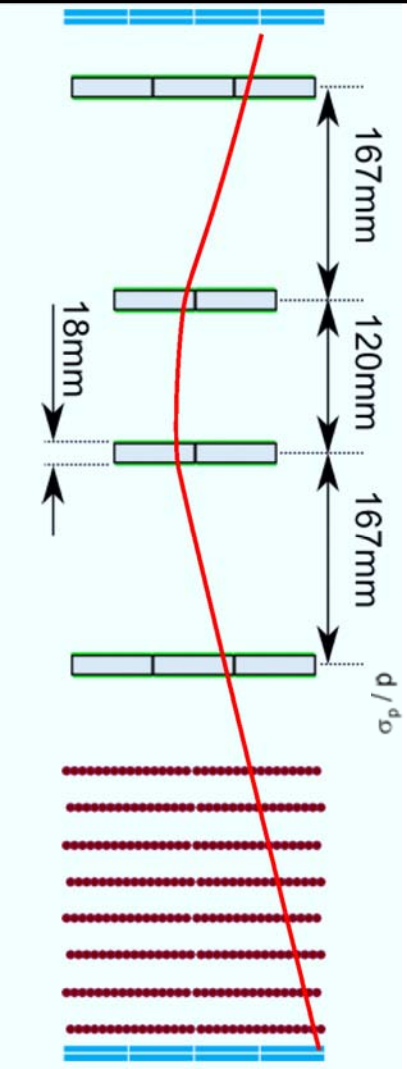
Magnet

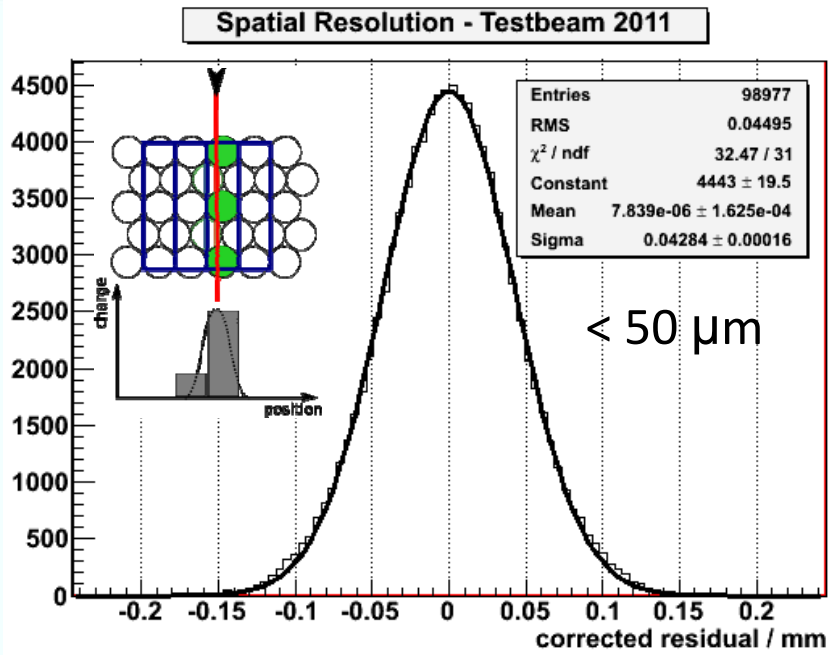
- small zylindrical magnets
- inner magnetic field: 0.2T
- weight: 7.4kg
- inner diameter: 15cm
- outer diameter: 21cm
- height: 8cm





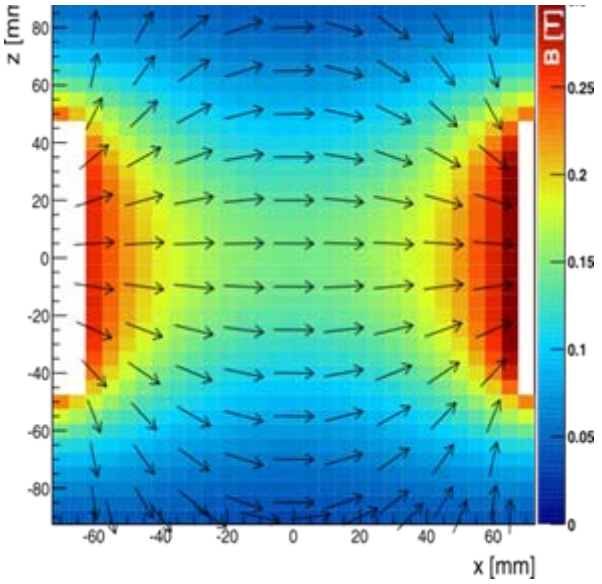
Momentum resolution

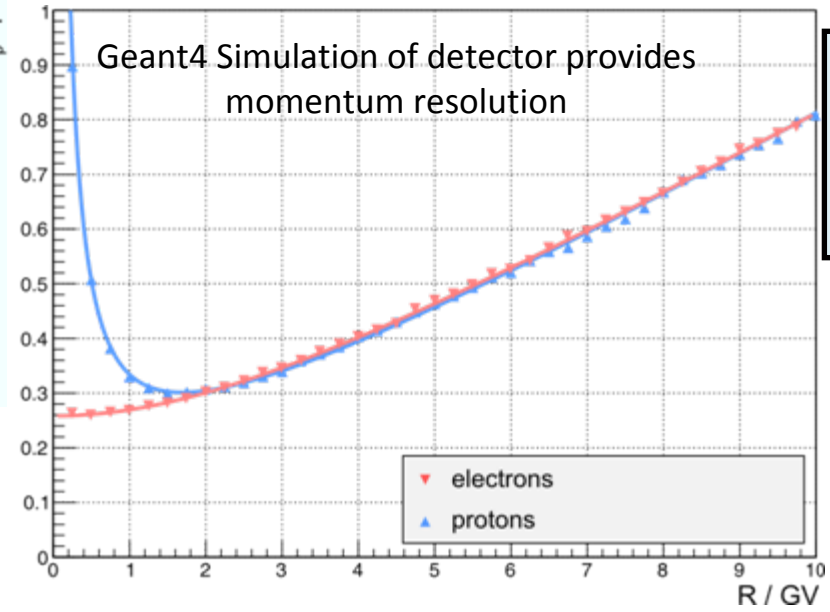




< 50 µm

PERDaix magnetic field 0.2T



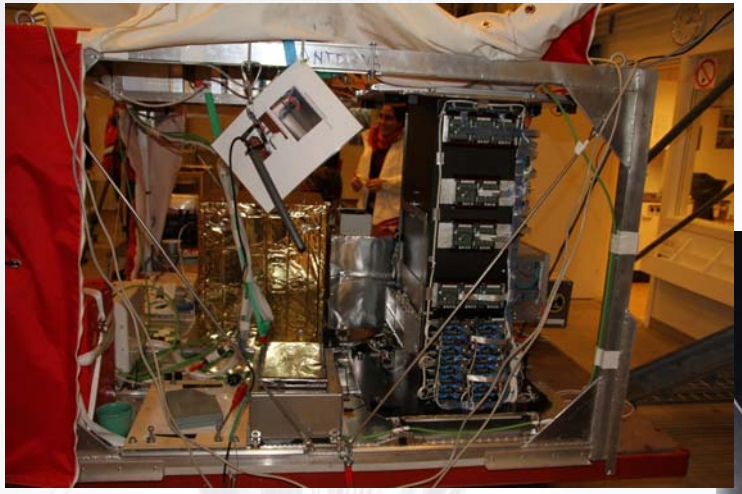


3d reconstruction algorithm:
- inhomogeneity of magnetic field
- stereo angle in modules
- multiple scattering

maximum detectable rigidity ~10GV

Bexus 11 Launch & Flight

November 23rd, 2010 03:00 am
T-5:30 Start Countdown



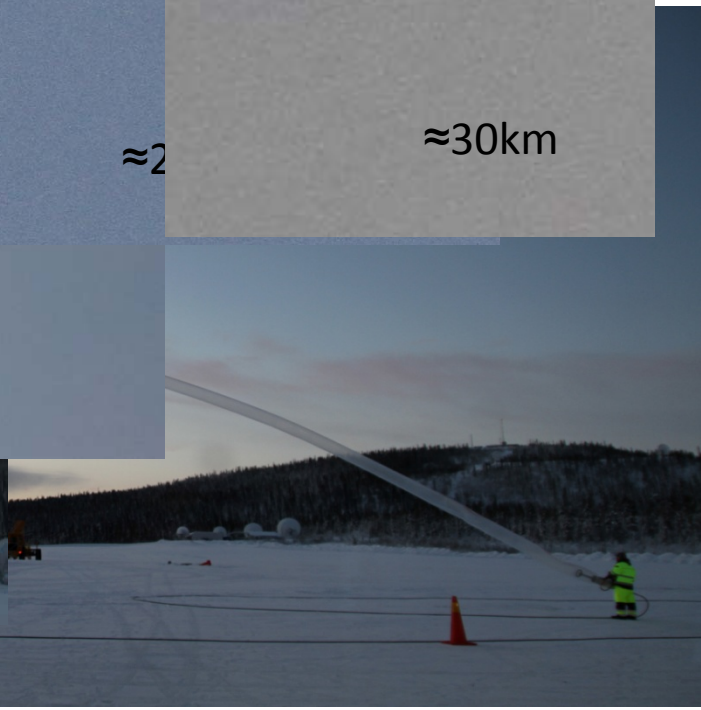
November 23rd, 2010 05:30 am
T-3:00 Gondola to Launchpad

Bexus 11 Launch & Flight

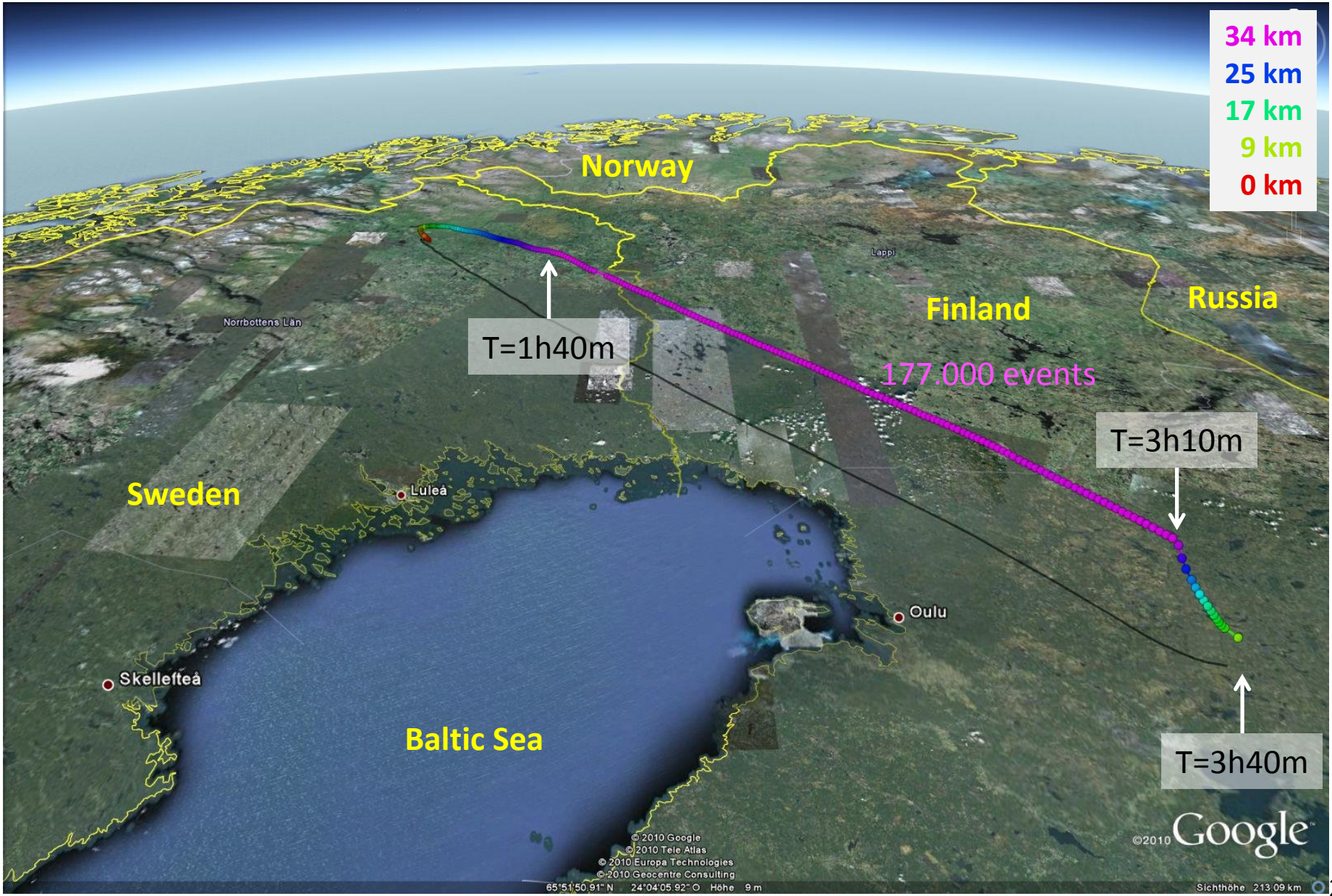
November 23rd, 2010 07:

T-0:40 Balloon Filling

09:18 Liftoff

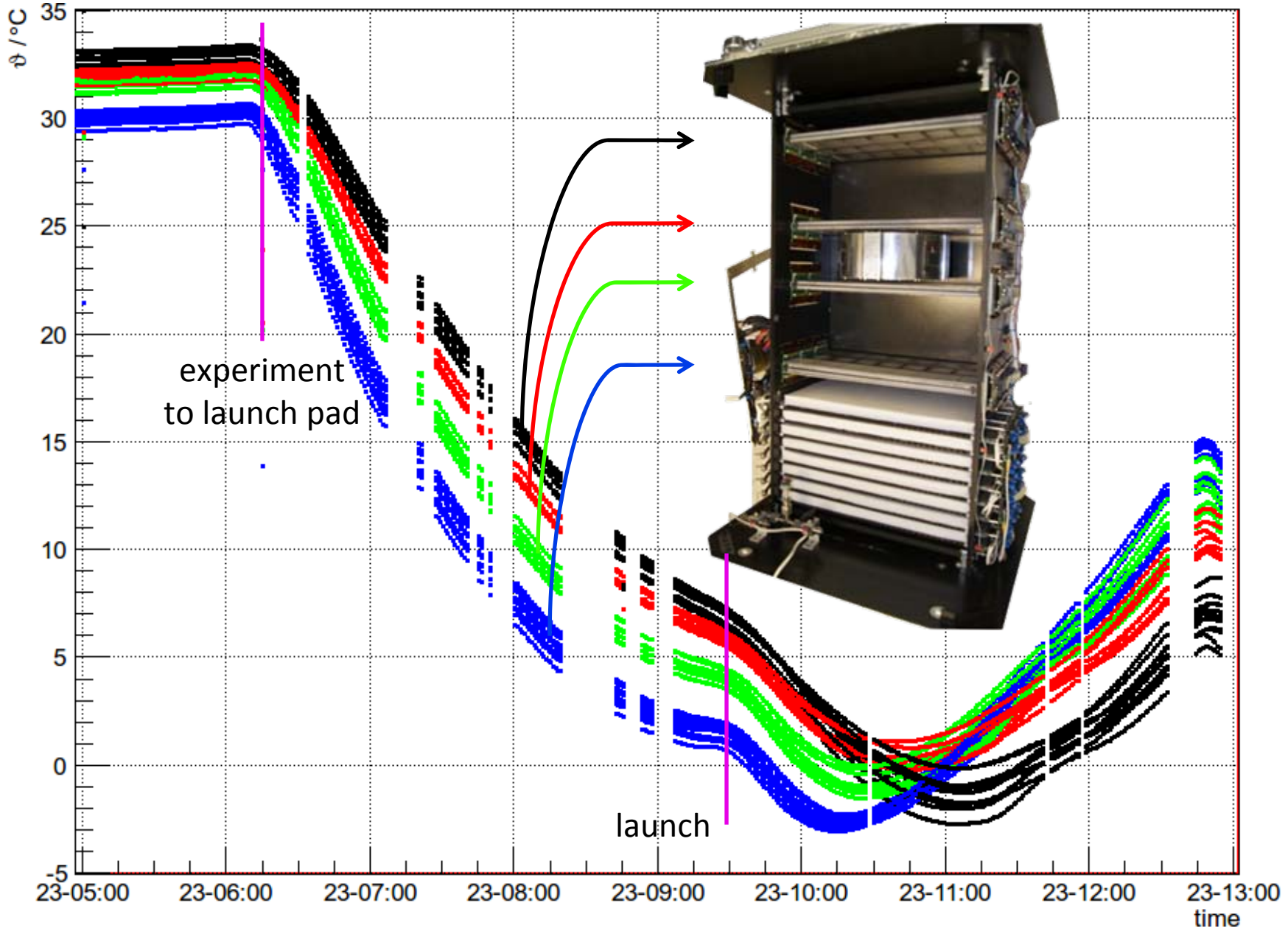


BEXUS-11 trajectoy

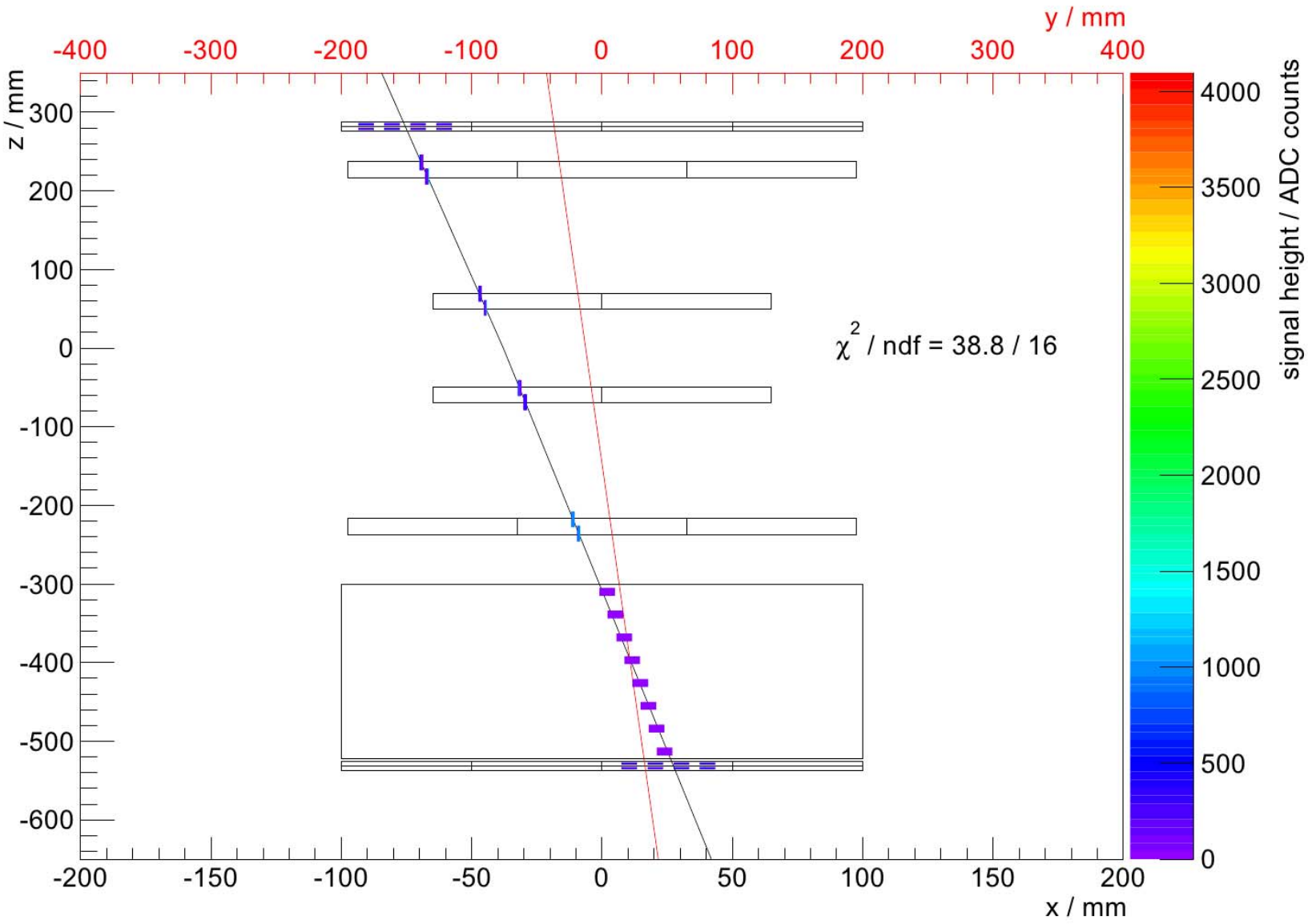


Bexus-11 environment

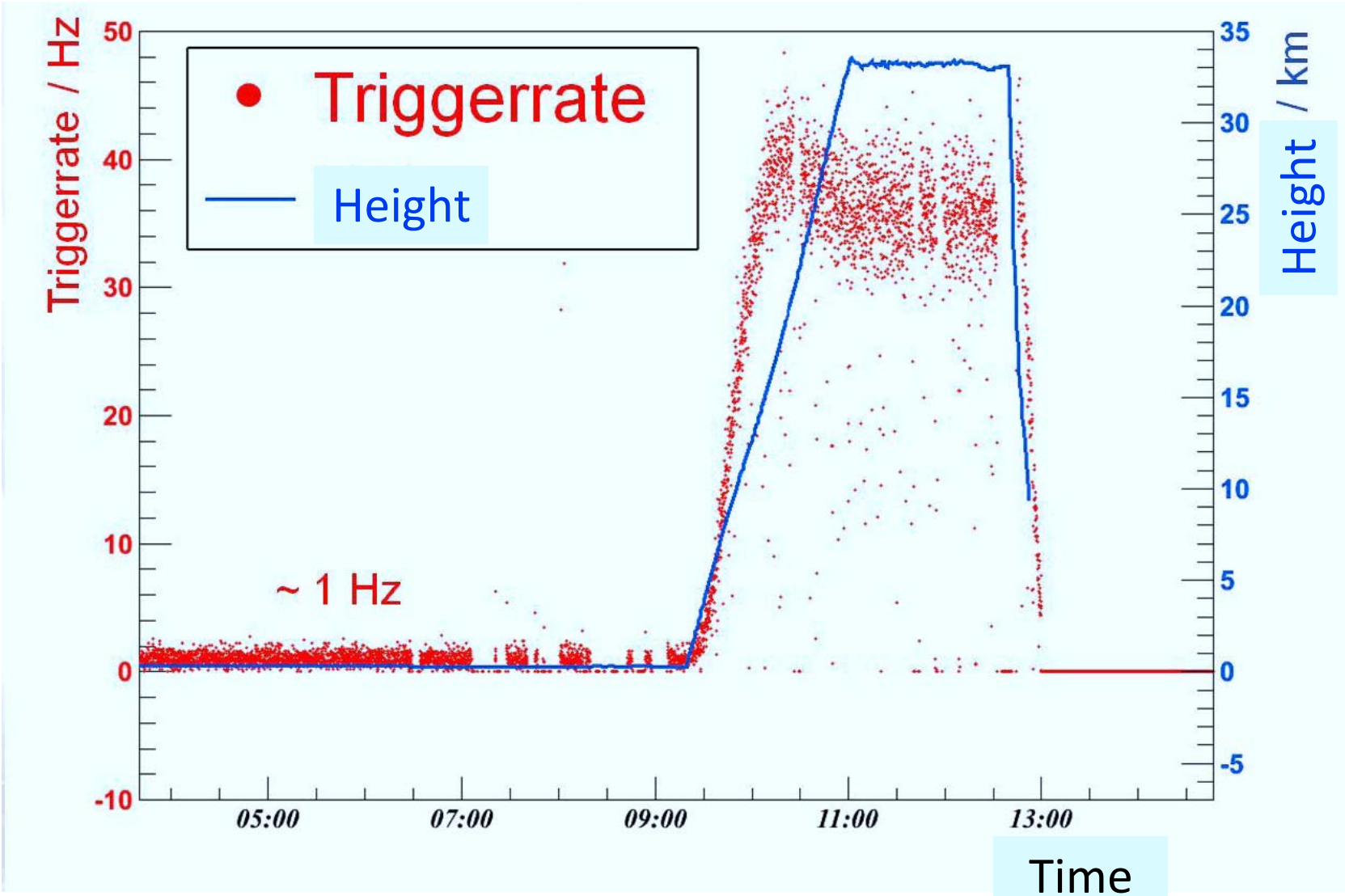
Tracker temperatures



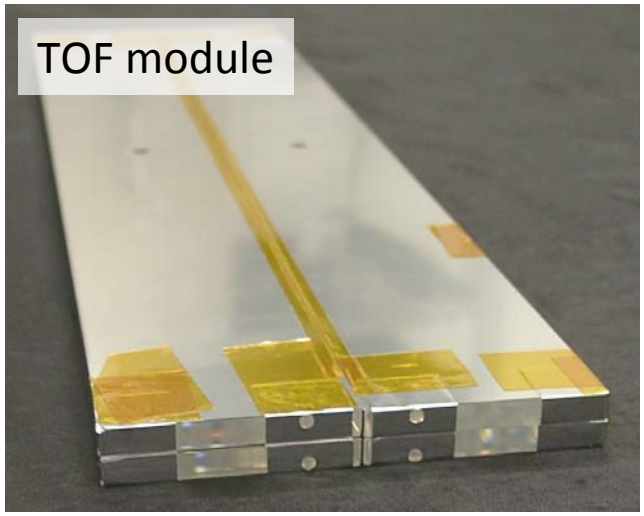
Online event display

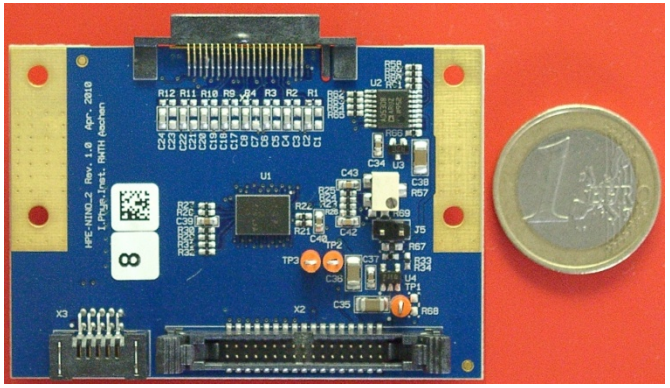


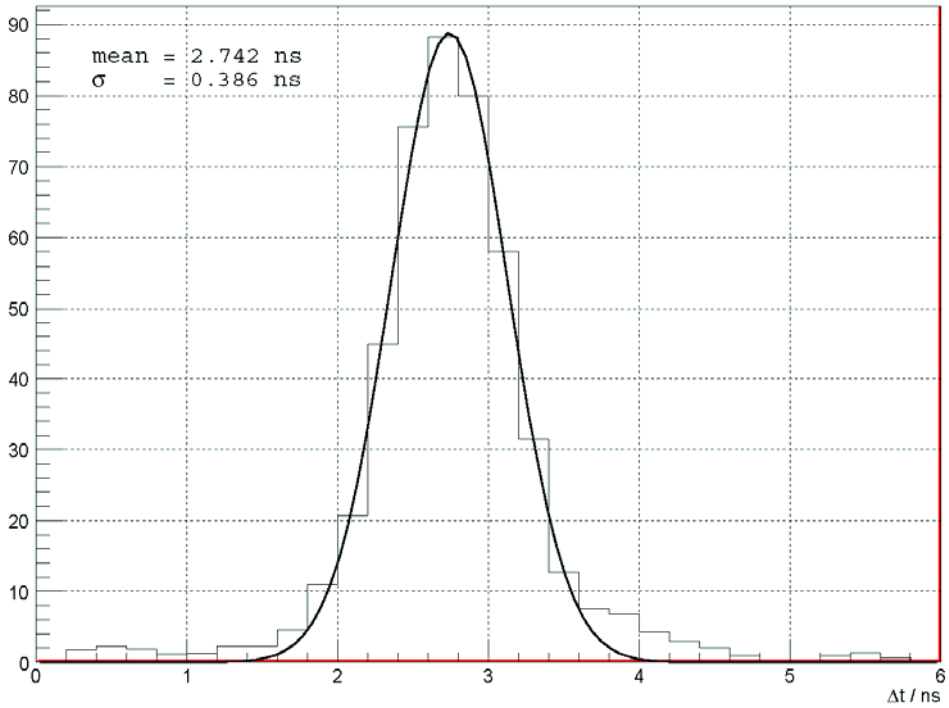
Trigger rate



Time-of-Flight System



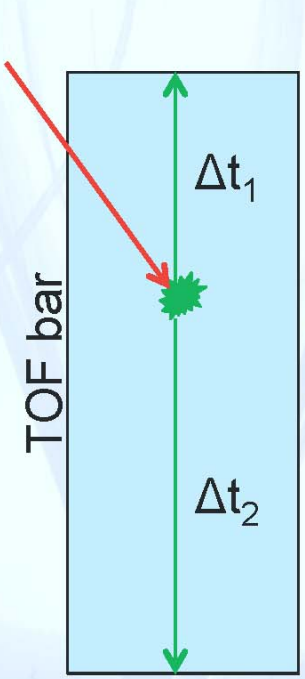


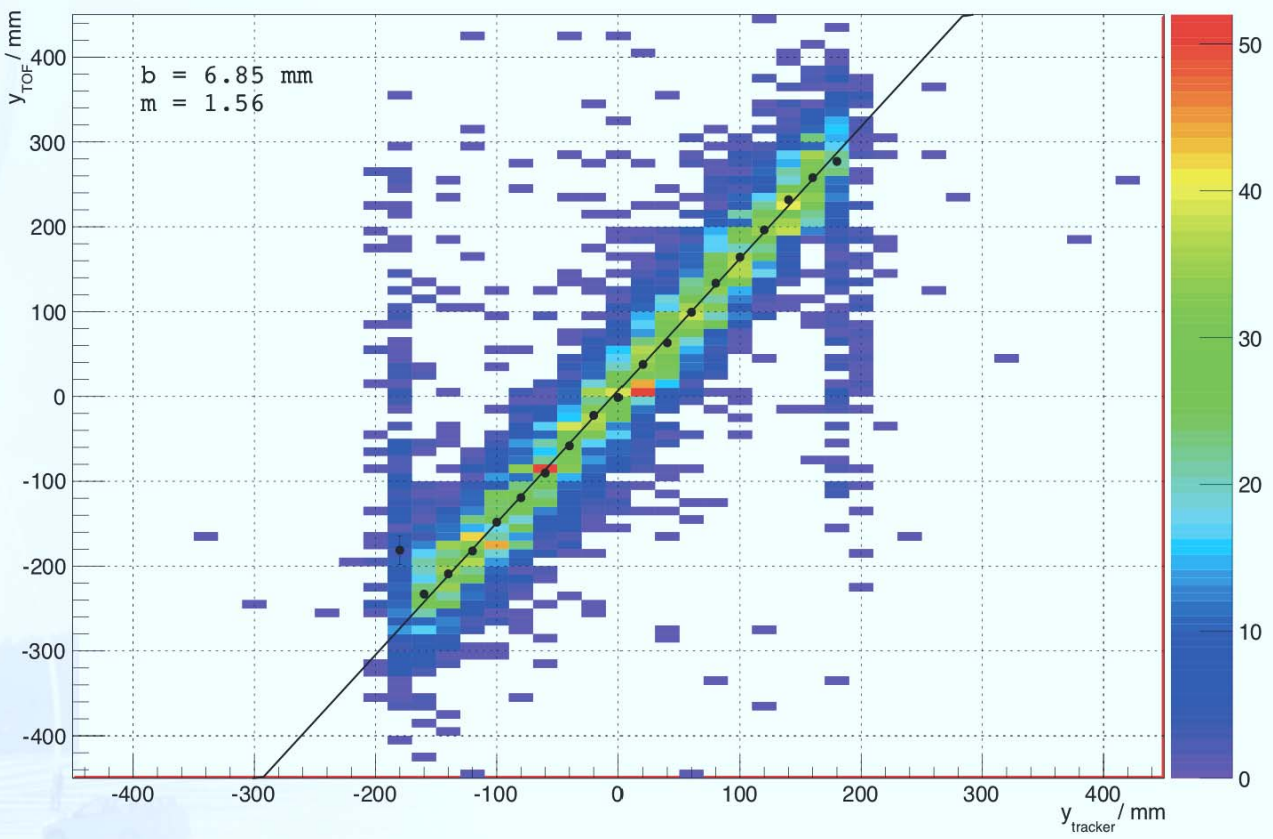


Time-of-Flight System

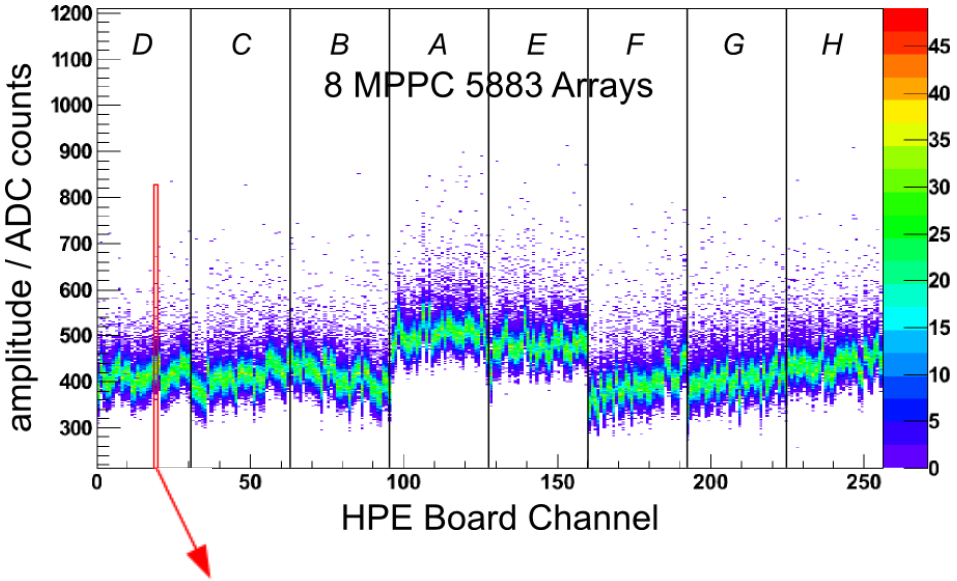
Correlation between y-coordinate measured by TOF and by Tracker

(Y-coordinate measured by difference in photon travel time to each side of the scintillator bar)

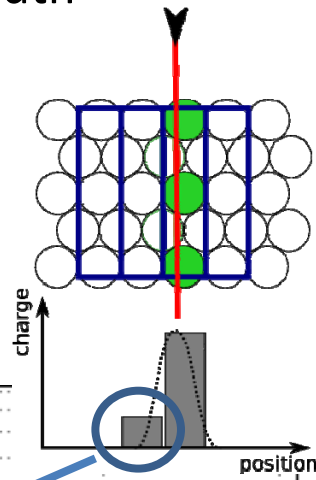


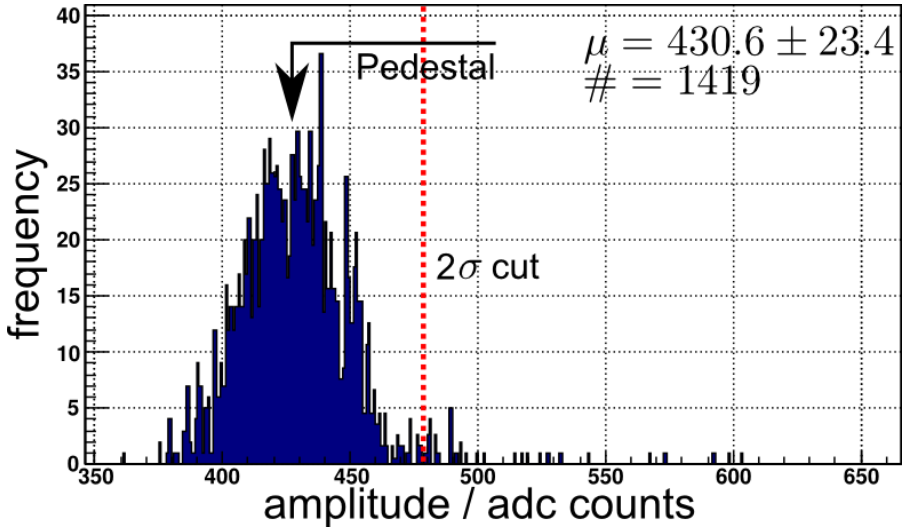


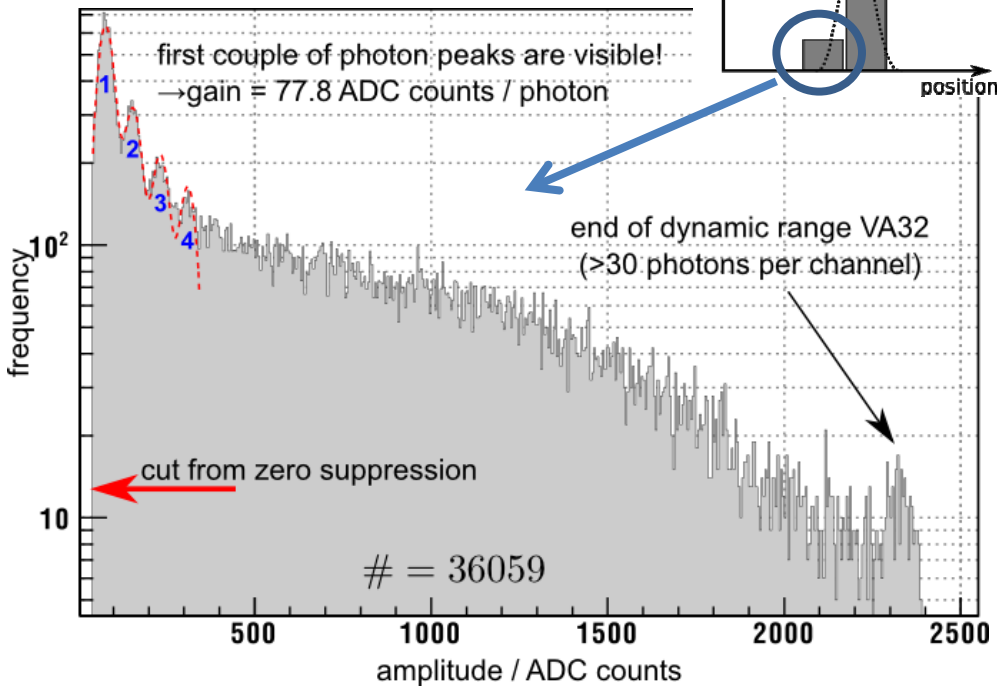
Tracker, Photon Yield



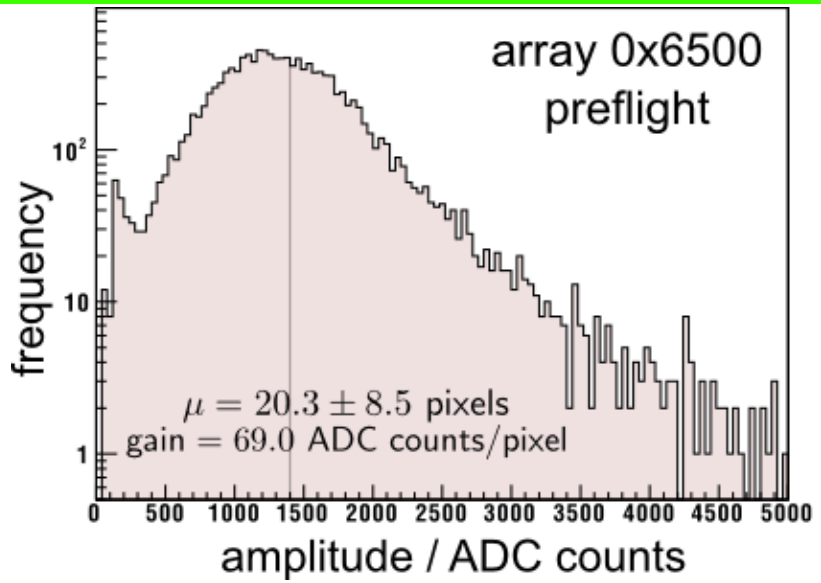
- **Random Trigger** → Dark Spectra
  - Pedestal position & width
- **Channels in signal clusters**
  - Gain calculation

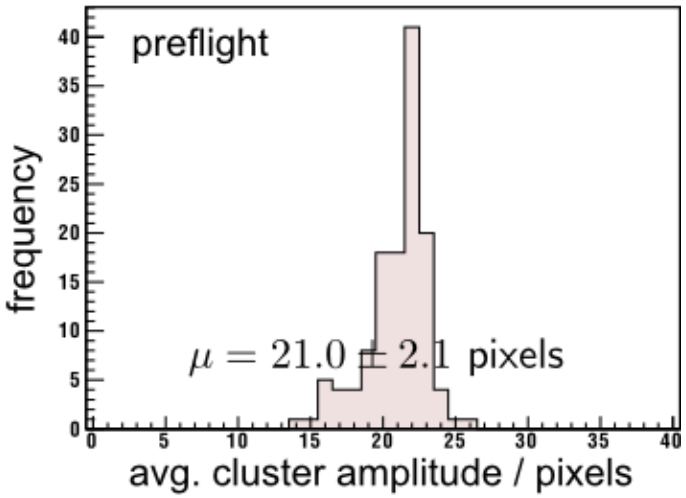


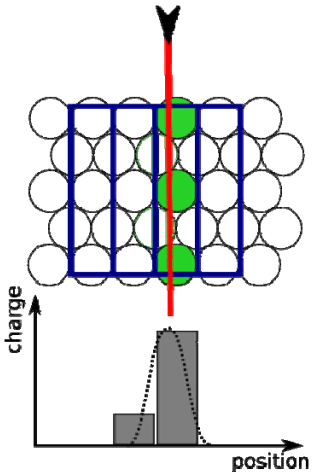


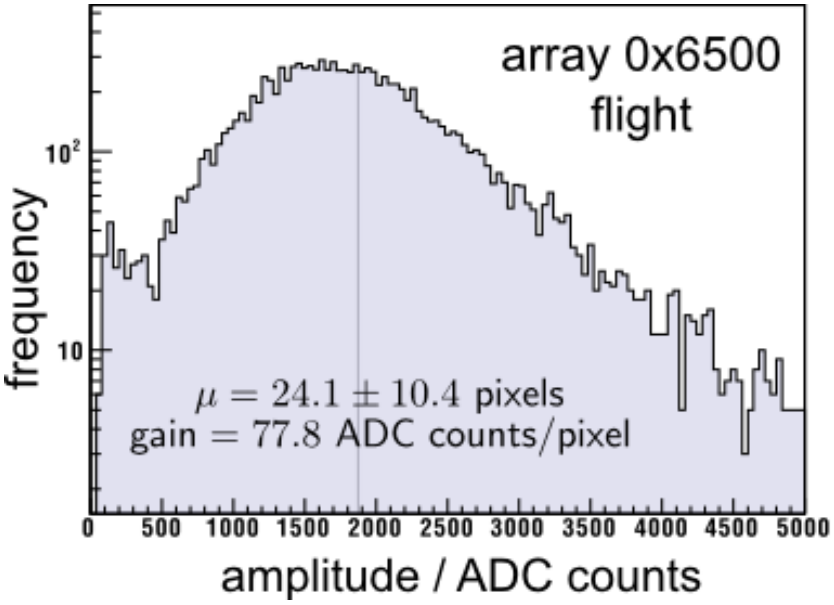


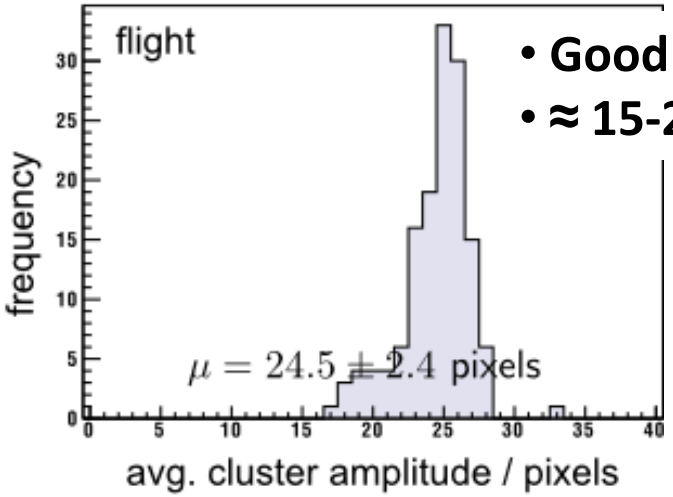
Tracker, Photon Yield





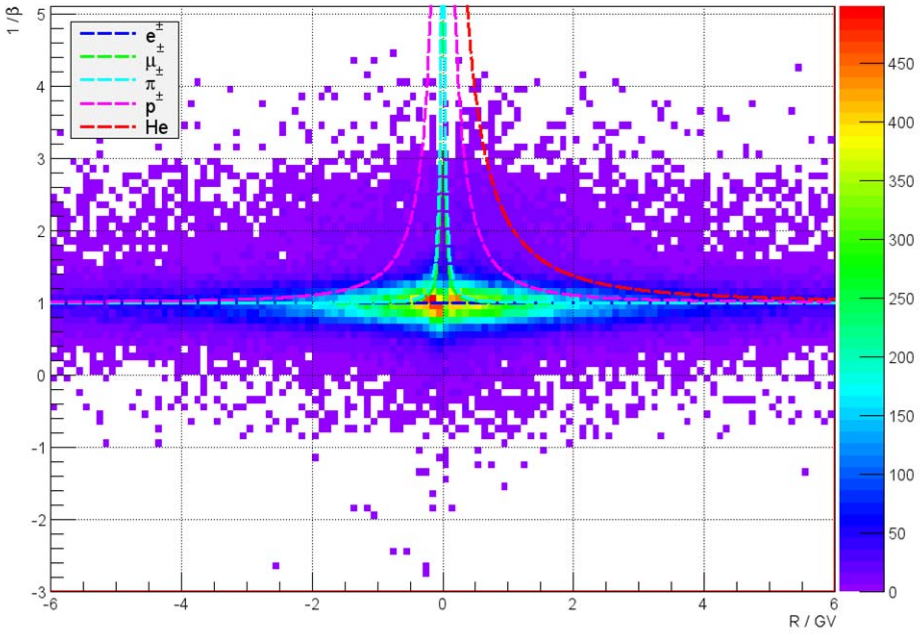




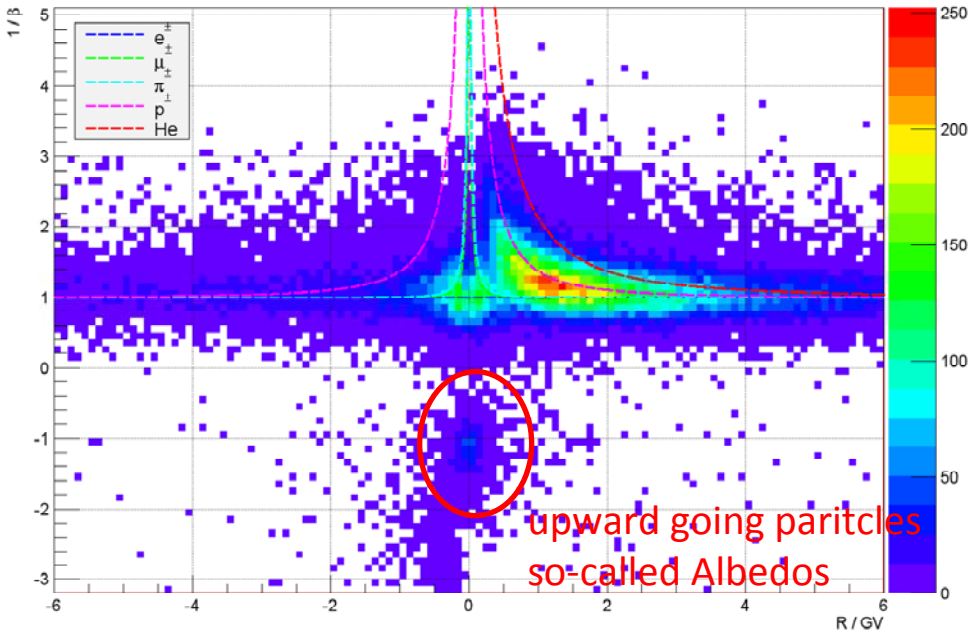


- **Good S/N**
- **≈ 15-20 Photons/MIP**

Comparison to muons



Cosmic data on ground before launch

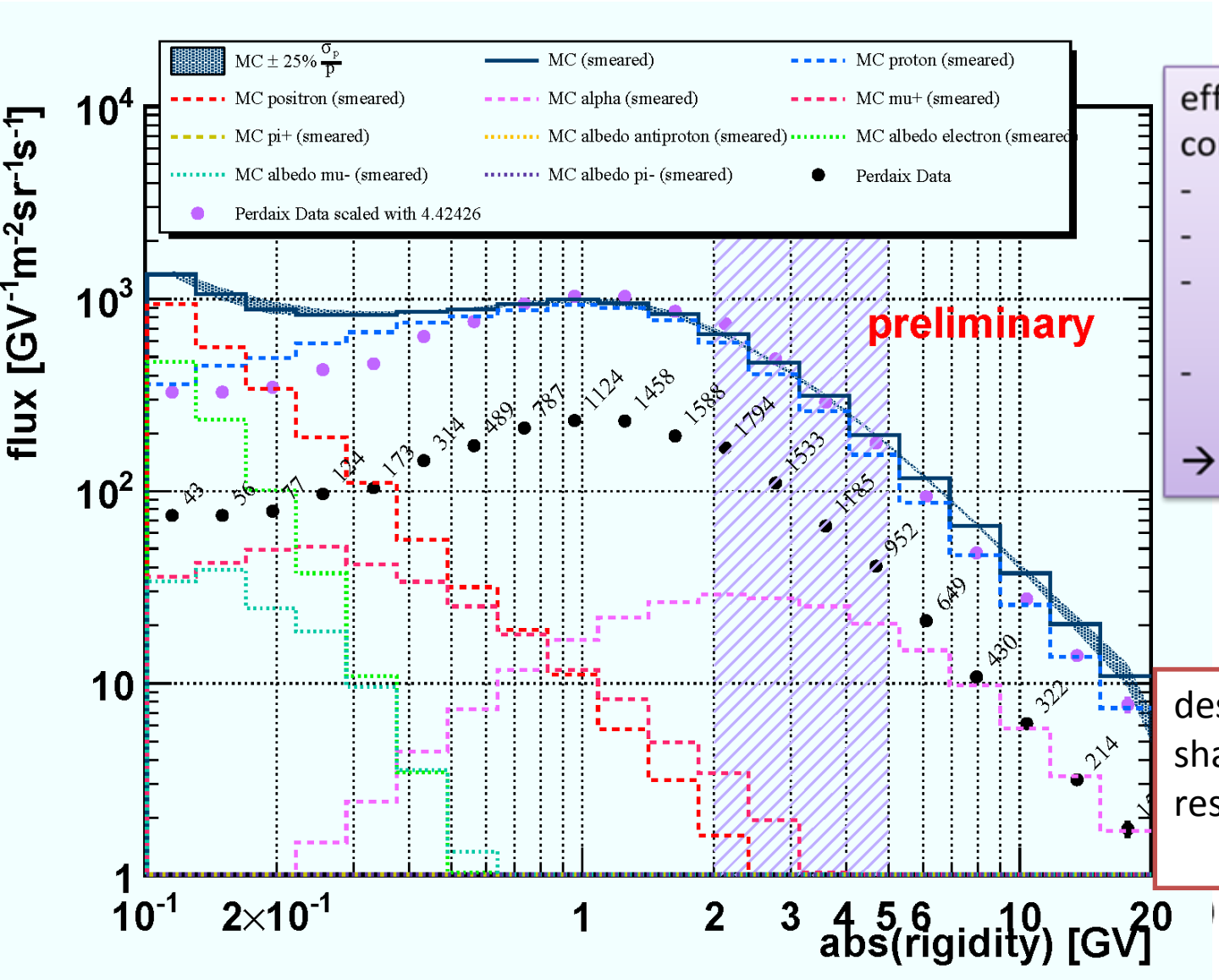


Flight data taken on Nov 23rd 2010

Preliminary Z^+ particle spectrum

Measured positive fluxes at 33 km, ϕ = 550MV

PRELIMINARY, WORK IN PROGRESS!



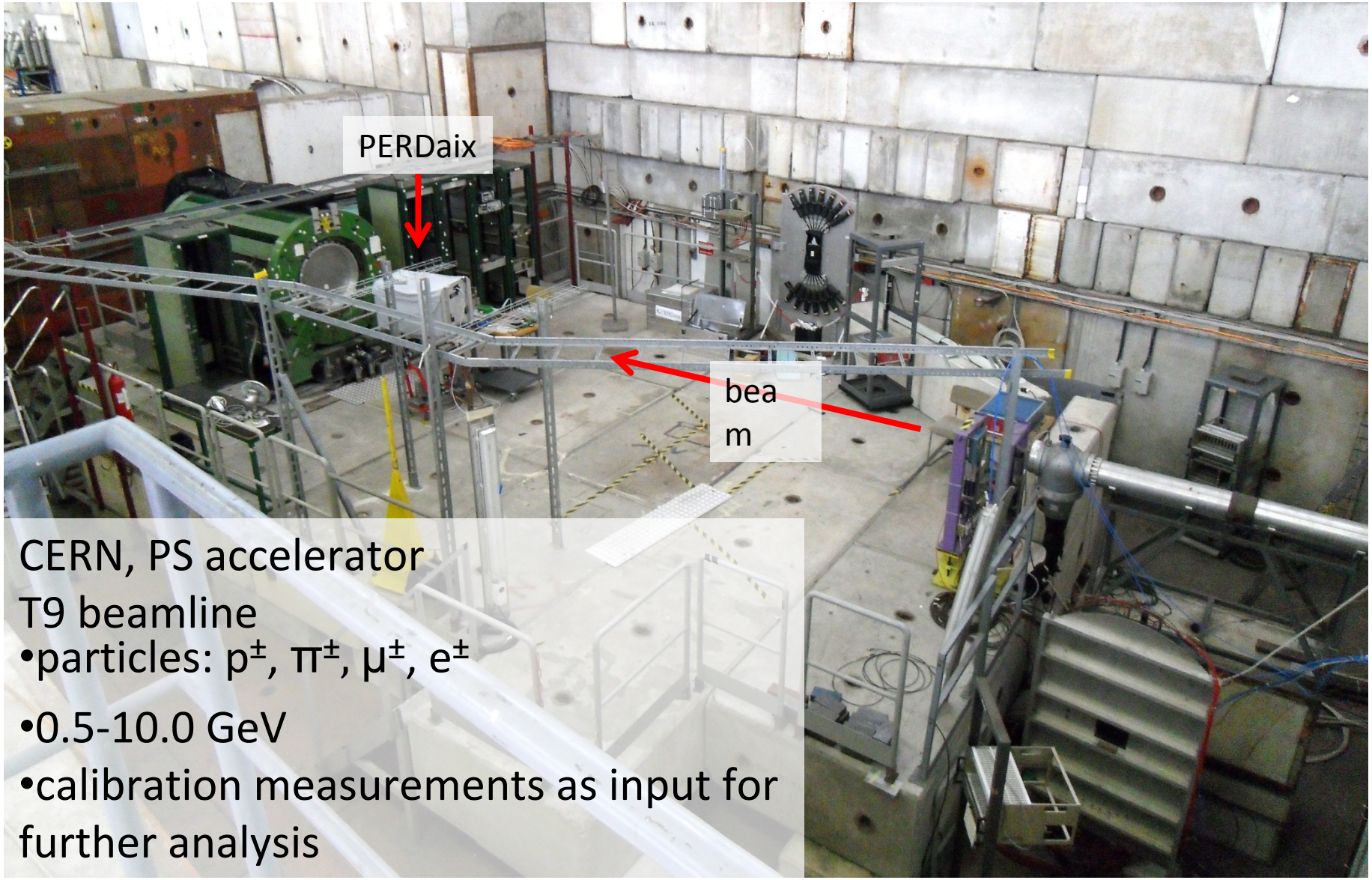
efficiency: ≈ 25%
contribution:
- trigger
- track finding
- reconstruction algorithm
- detector dead times

→ Monte Carlo studies

descrepancy in spectral shape due to detector resolutions

unfolding

Testbeam May 2011



CERN, PS accelerator

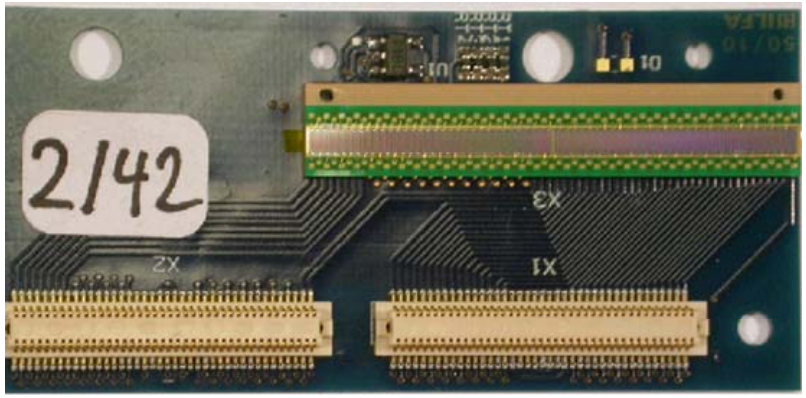
T9 beamline

- particles: $p^{\pm}$, $\pi^{\pm}$, $\mu^{\pm}$, $e^{\pm}$
- 0.5-10.0 GeV
- calibration measurements as input for further analysis

Summary & Outlook

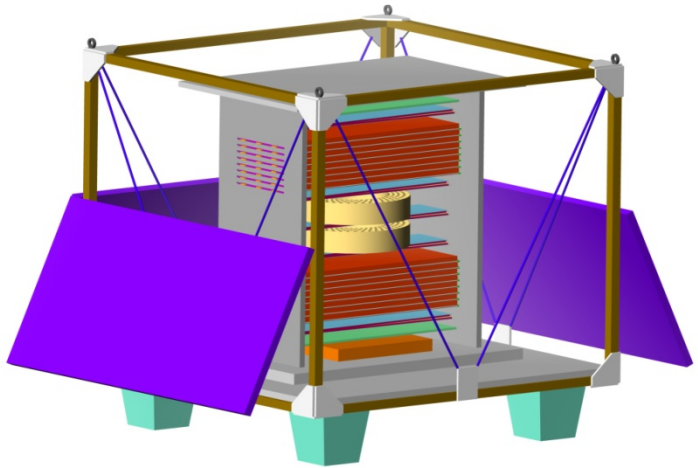
Summary

- Very successful balloon flight in November 2010
- 177.00 particle tracks recorded
- Spatial resolution of 50 µm
- Lightyield 15-20 Photons/MIP
- First preliminary estimation of proton spectrum



Outlook:

- Determination of efficiencies
- Unfolding of spectrum to account for detector resolution
- e^- - spectrum, He - spectrum
- further corrections (rest atmosphere, geomagnetic cutoff, etc.)



Next SiPM-generation (128 channels)
→ Next Ballon experiment