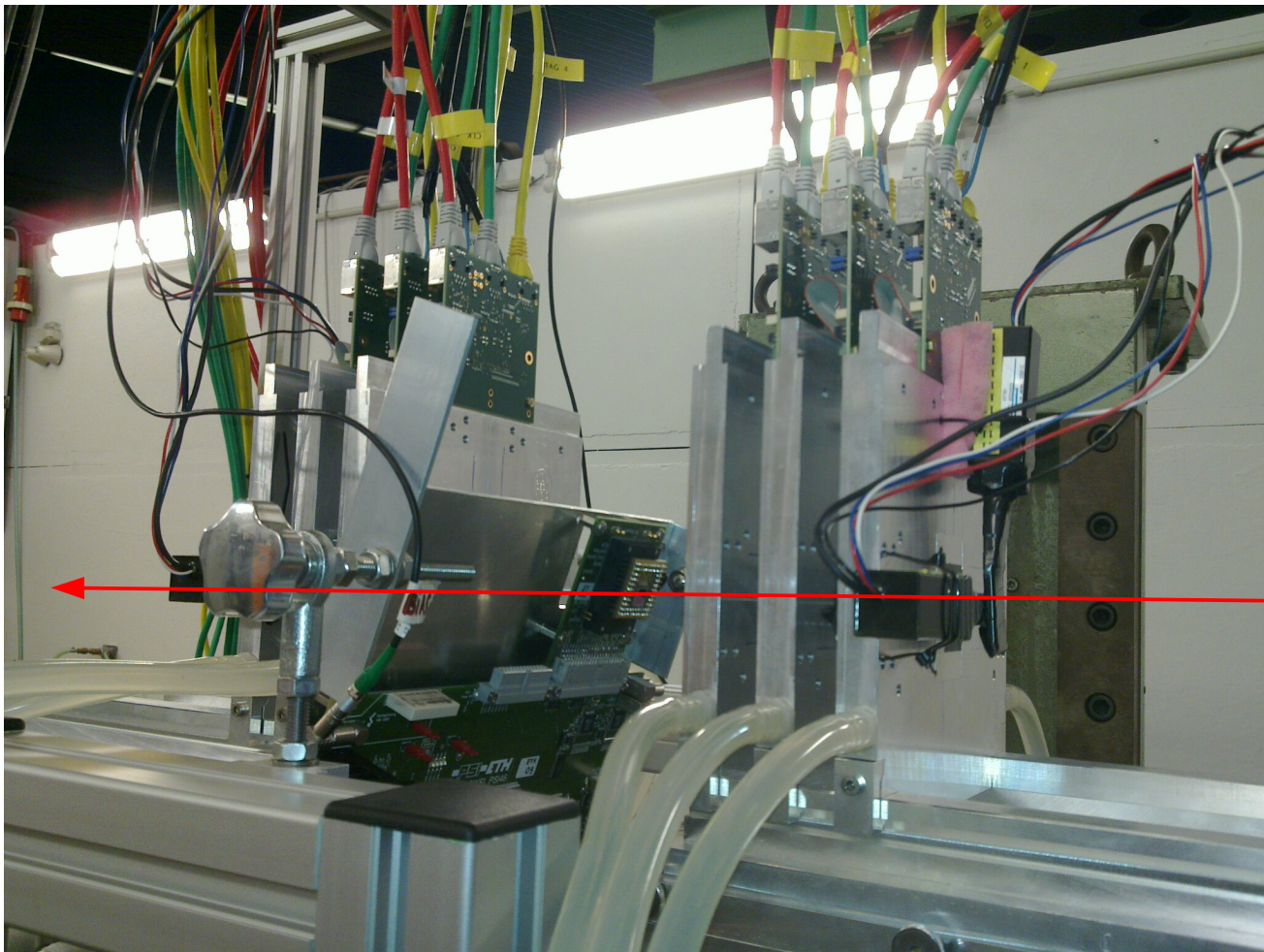


CMS pixel in the DESY test beam telescope

Daniel Pitzl, Alexey Petrukhin, Hanno Perrey,
Armin Burgmeier, Luigi Calligaris, Thomas Eichhorn
CMS upgrade, 20.12.2011

- EUDET telescope
- tilted pixels
- correlations
-



Test beam plans from Oct 2011

- this year: done by
 - software installed (ILCsoft: Marlin) Hanno, Daniel, Armin, Thomas
 - common scintillator trigger Hanno, Daniel
 - take data: pixel + telescope Daniel, Hanno, Alexey, Armin, Luigi, Thomas
 - analyse data Daniel, Armin
 - design and build tilting support Adam Zuber, Holger Maser
 - take data at various angle of incidence Daniel, Armin, Luigi
 - implement broken line track fit not yet
- 2012:
 - take more reference data, with 2 CMS stations all
 - prepare for new readout chip (PSI46xdb) Daniel, Alexey, Shiraz
 - take data with the new pixel readout chip all
 - study efficiency
 - study resolution

CMS Pixel with EuTelescope

**common
scintillator
trigger**

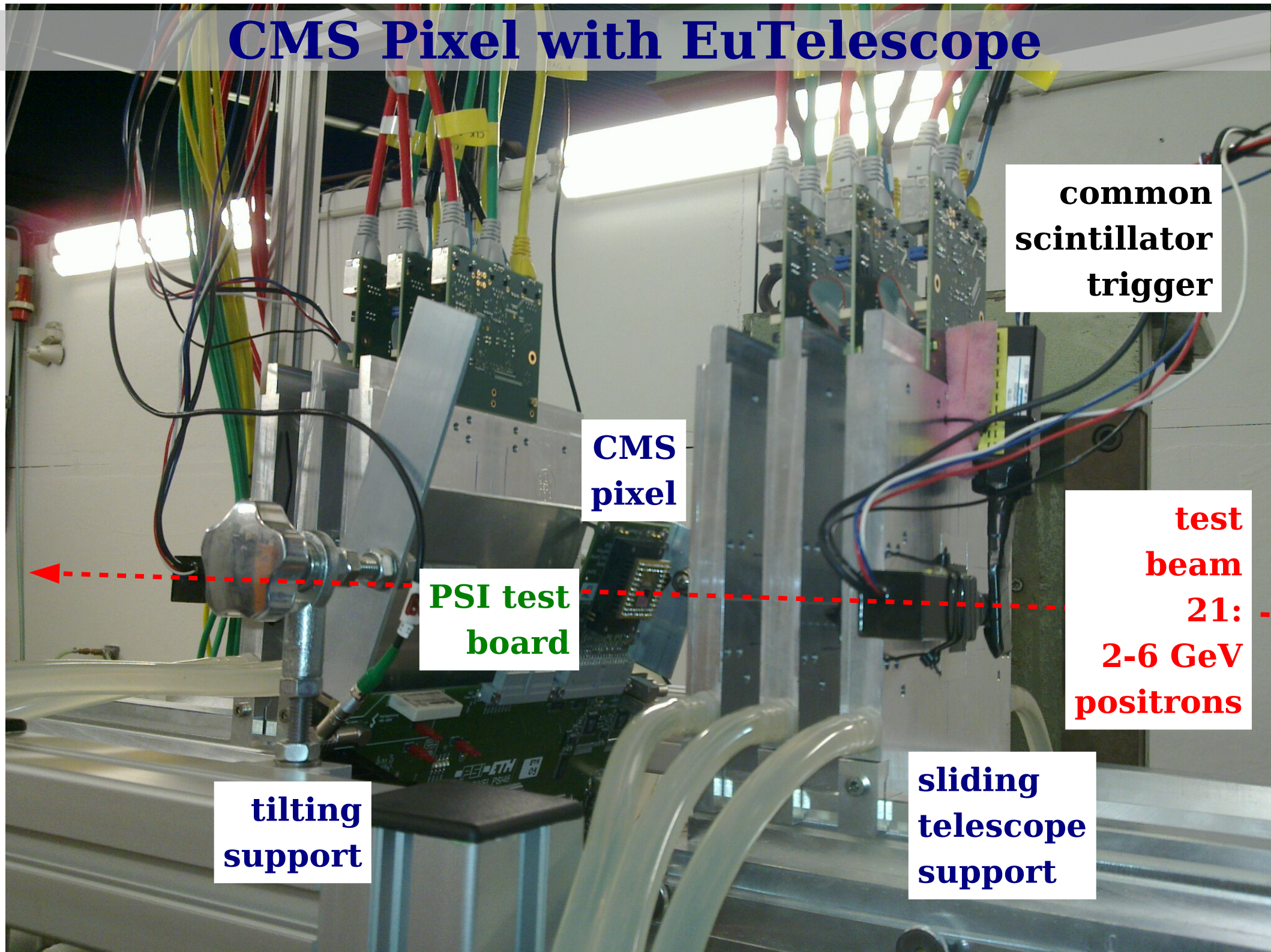
**CMS
pixel**

**PSI test
board**

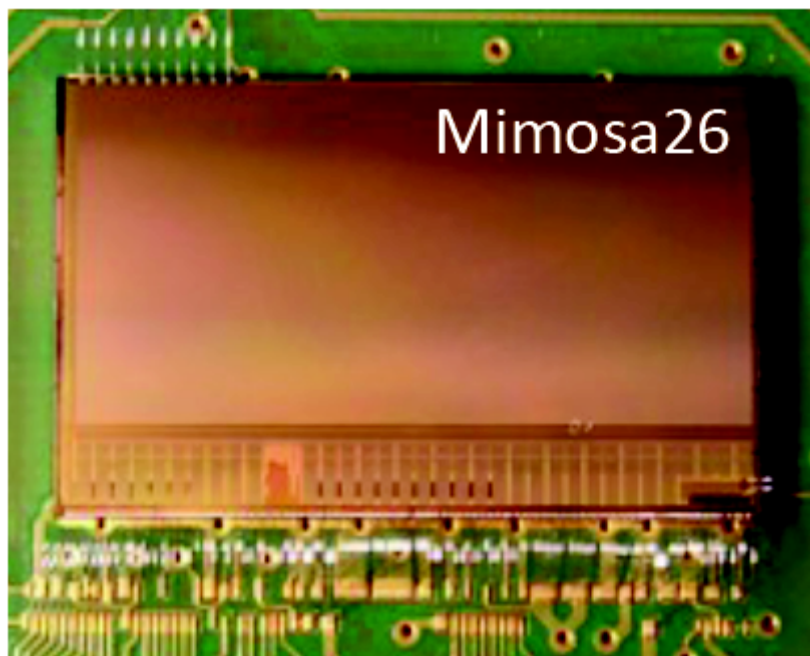
**test
beam
21:
2-6 GeV
positrons**

**tilting
support**

**sliding
telescope
support**



Mimosa26 ILC pixel chip



- Mimosa26 monolithic active pixel sensors (Strasbourg, 2009):
- thinned to 50 μm ,
- $18.4 \times 18.4 \mu\text{m}^2$ pixel size,
- $1152 \times 576 = 663\text{k}$ pixels,
- $10.6 \times 21.2 \text{ mm}^2$ active area,
- binary readout,
- integration time 115 μs .

EuTelescope software

step	data.format	constants
0. EUDAQ data taking: 900s	native.bin , e.g. 200 MB 500k triggers	
1. convert, find hot pixels: 70s	raw.lcio , e.g. 200 MB	hotpixel.db
2. clustering: 240s	clusters.lcio , e.g. 400 MB	offset.db
3. hits, coarse align: 250s	hits.lcio , e.g. 600 MB	pre-align.db
4. Millepede alignment: 12s	pede.bin , e.g. 120 MB	align.db
5. track fitting: 270s	tracks.lcio , e.g. 25 MB	

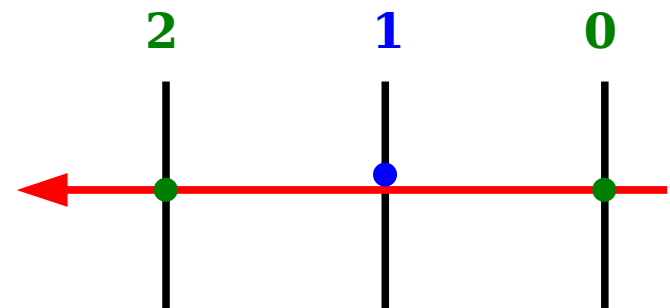
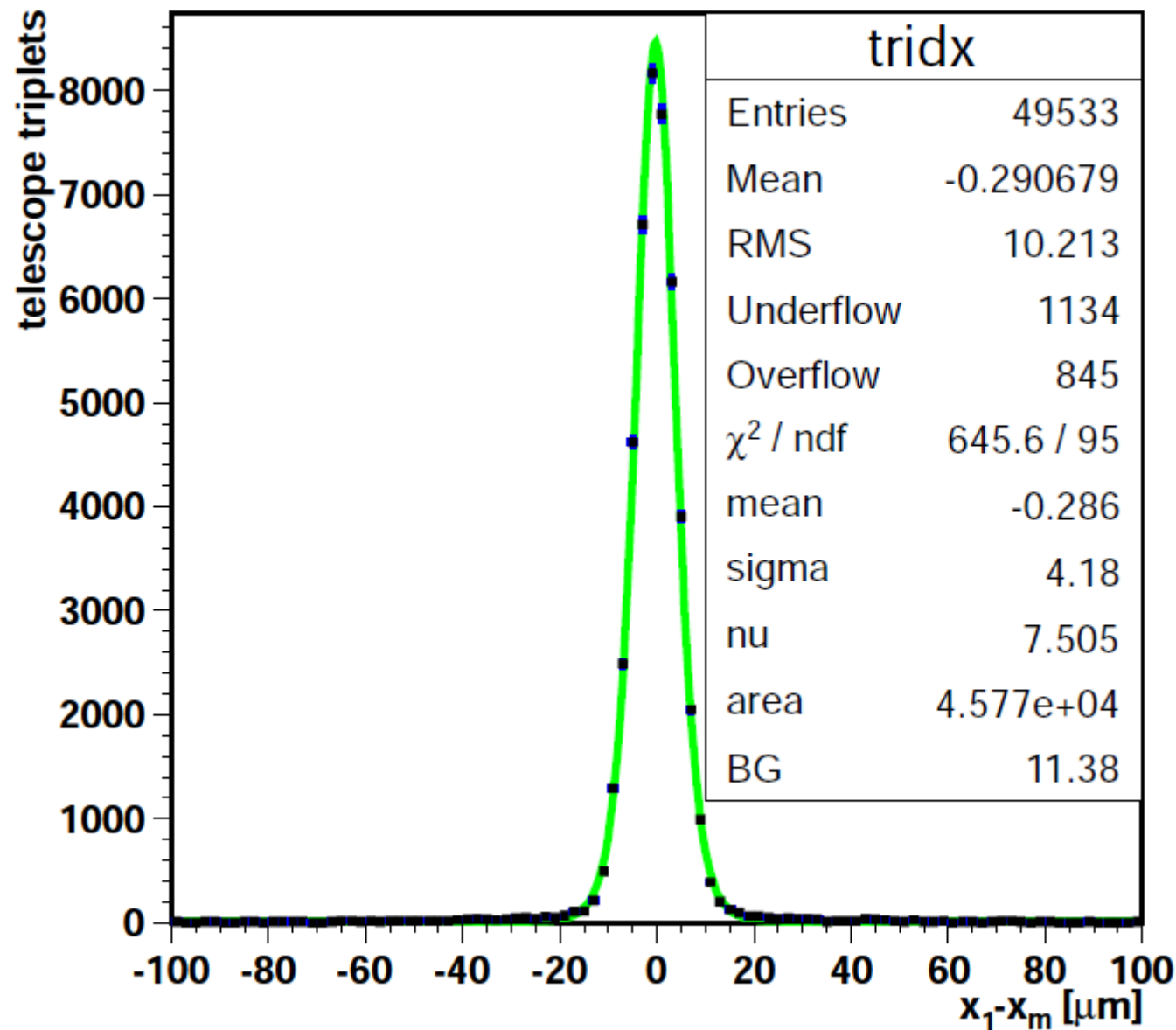
script `submit-all.sh` run energy by Armin Burgmeier

All steps produce ROOT histograms for monitoring.

Steps 1-5 require a geometry file defining the telescope.

Parameters are passed from xml files. Code in `svnsrv cmspixelupgrade`.

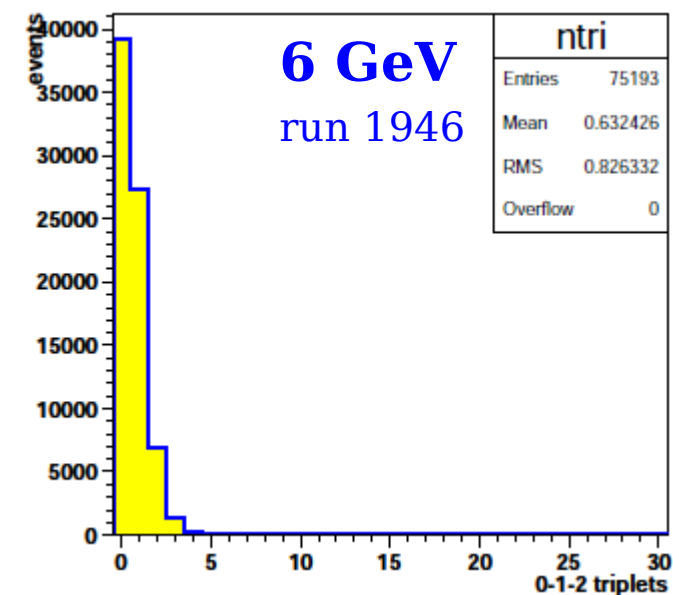
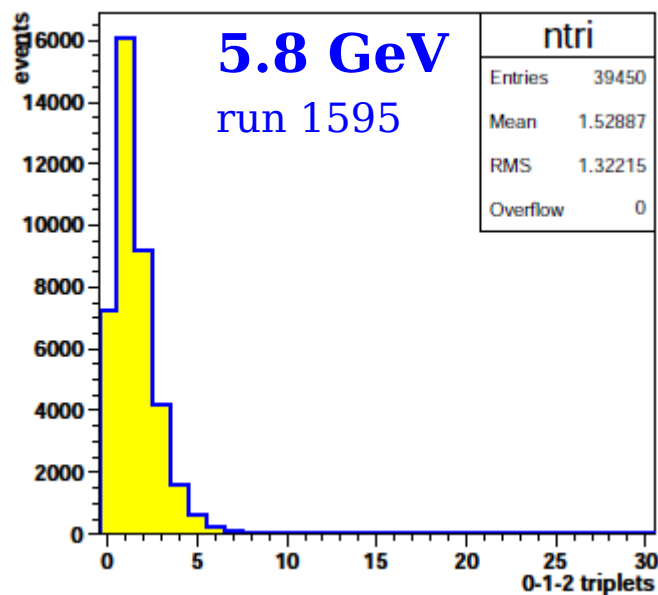
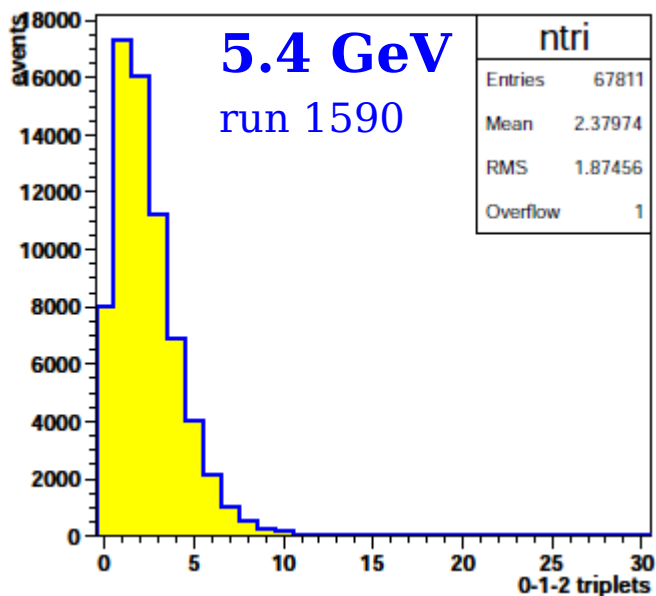
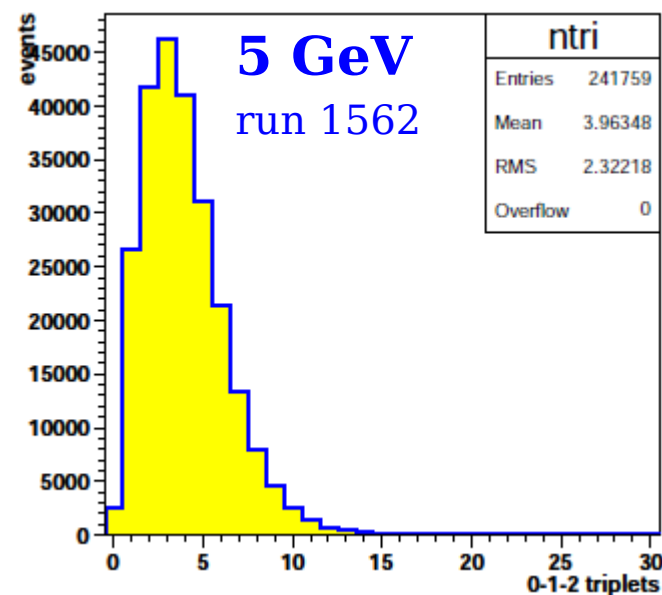
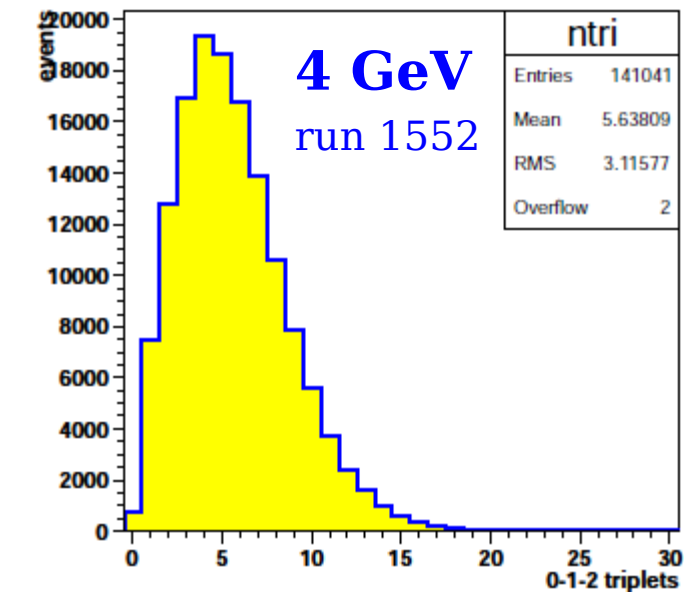
Telescope point resolution



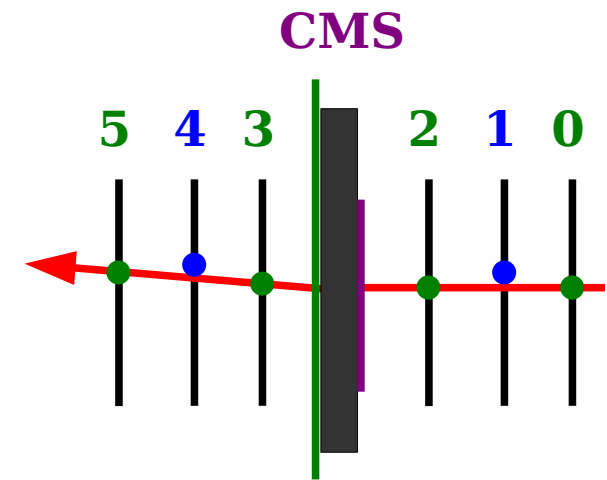
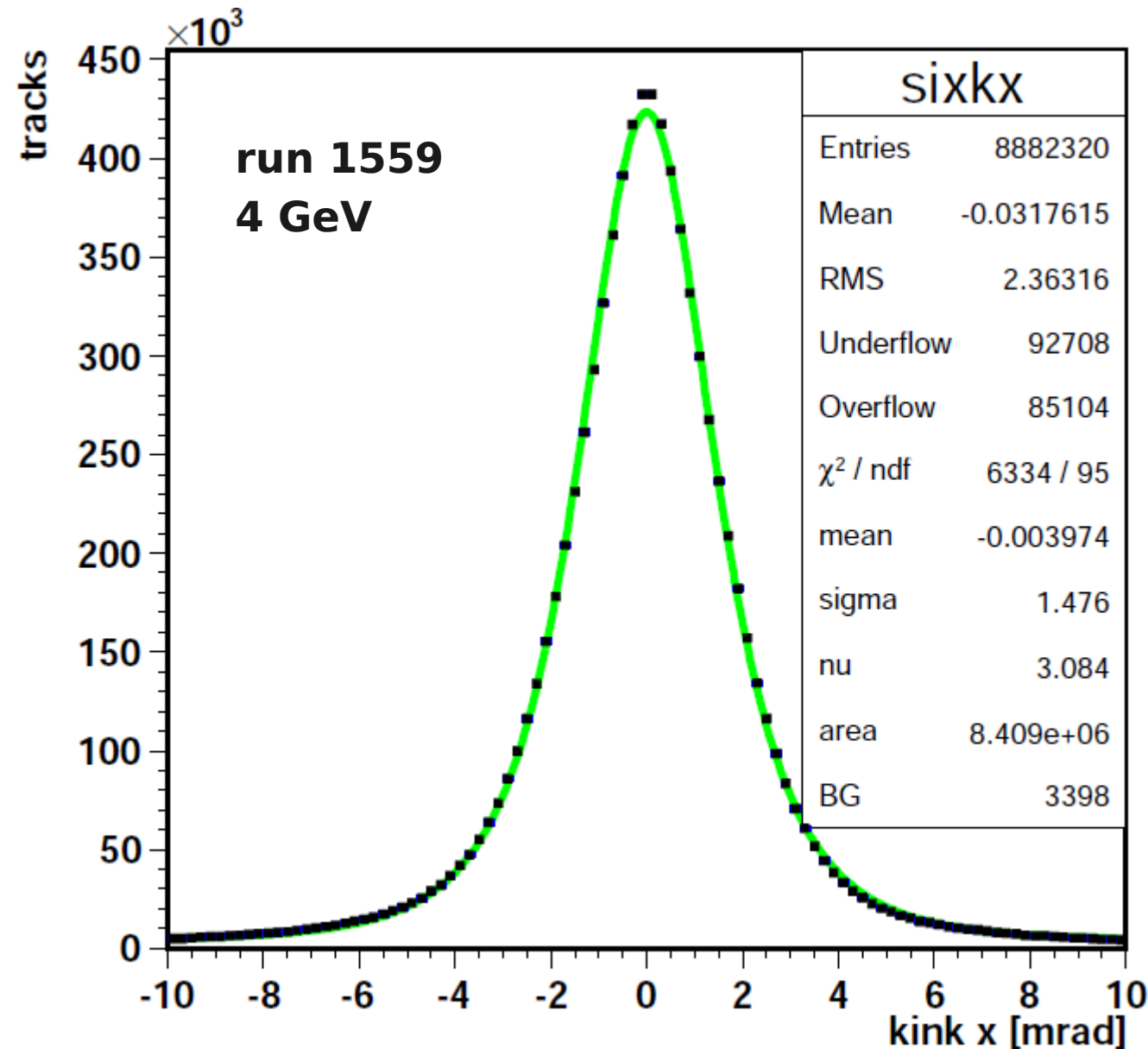
- 6 GeV e^+ beam.
- Triplet residuals:
 - 3 upstream planes,
 - hits in plane 0 and 2 form vector,
 - residual to hit in middle plane 1,
 - $\sigma_r = 4.2 \mu\text{m} = \sqrt{3/2} \sigma_i$
 - $\sigma_i = 3.4 \mu\text{m}$

telescope pile up

- Mimosa chips integrate over $115 \mu\text{s}$ = 115 DESY turns.
- We observe pile up
 - depending on DESY current, beam energy, and collimator opening.



scattering

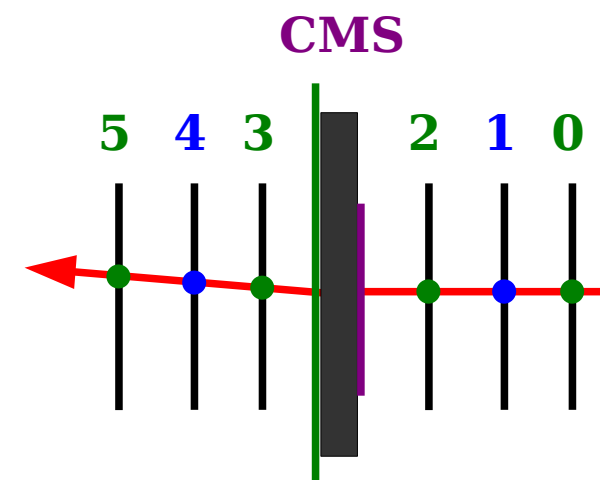
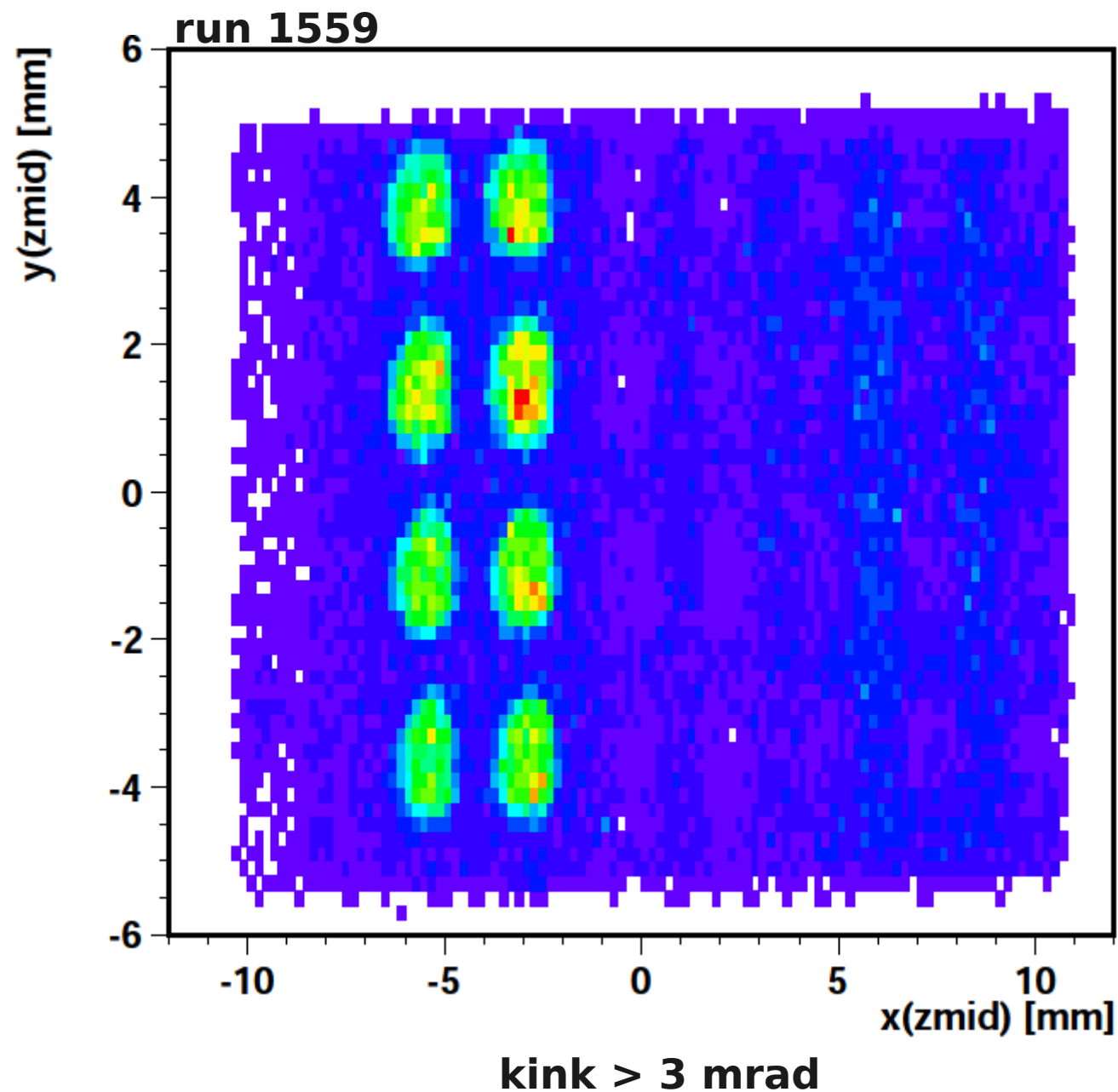


- 4 GeV e^+ beam.
- Kink angle between upstream and downstream triplets:
 ▶ 1.5 mrad

$$\theta_{MS} \approx \frac{0.0136}{p[\text{GeV}]} \sqrt{d/X_0}$$

$$\Rightarrow d \approx 0.19 X_0.$$

scattering centers

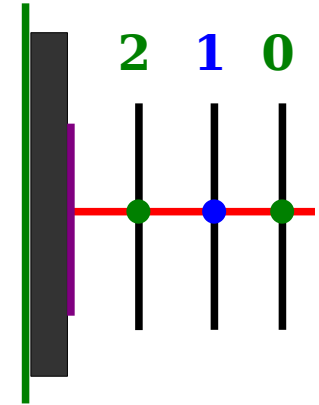


- 4 GeV e^+ beam.
- tracks with > 3 mrad kink angle:
 - metal pins of the PSI chip adapter visible

correlation with CMS pixel

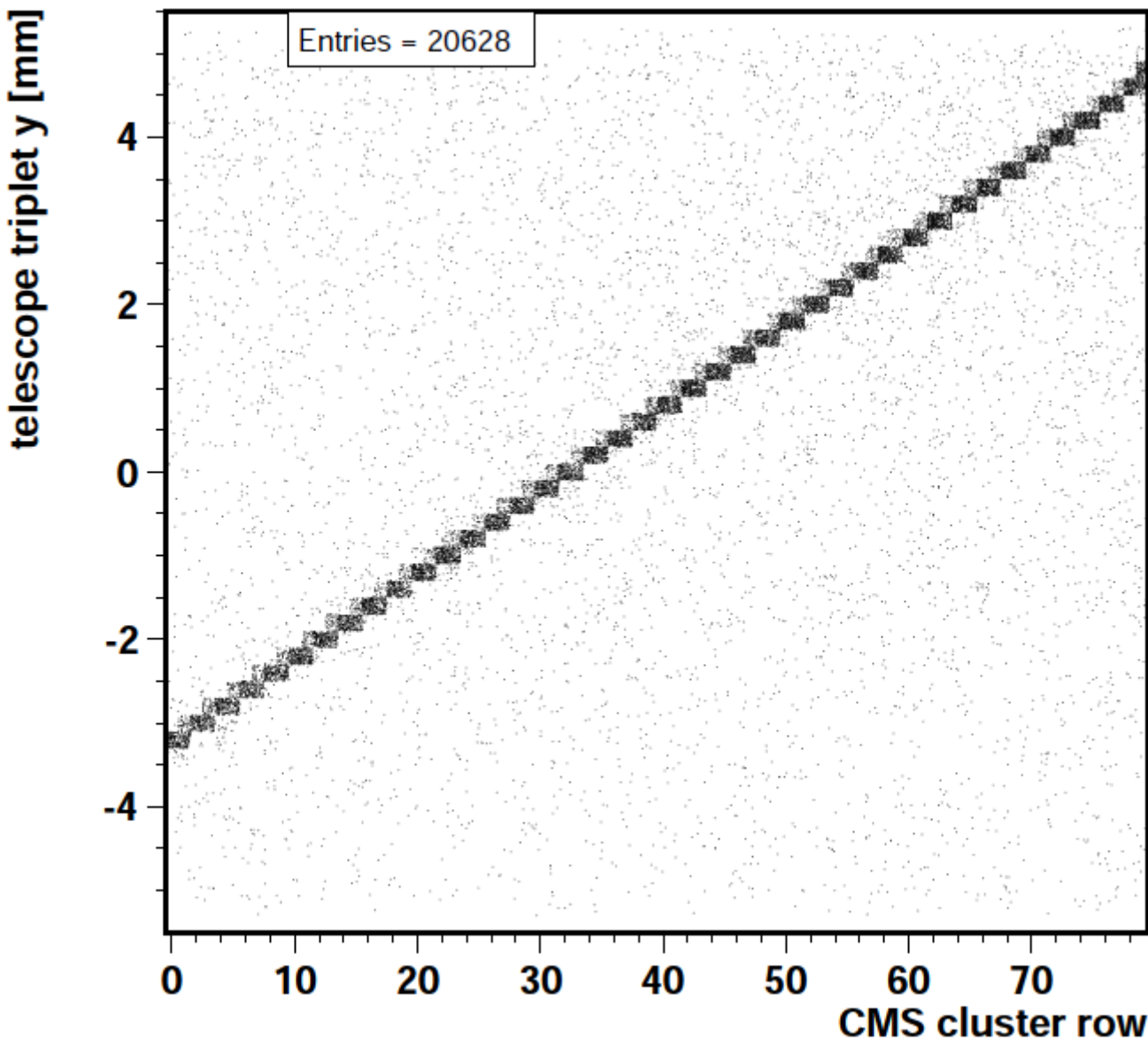
CMS

2 1 0



run 1946, 6 GeV

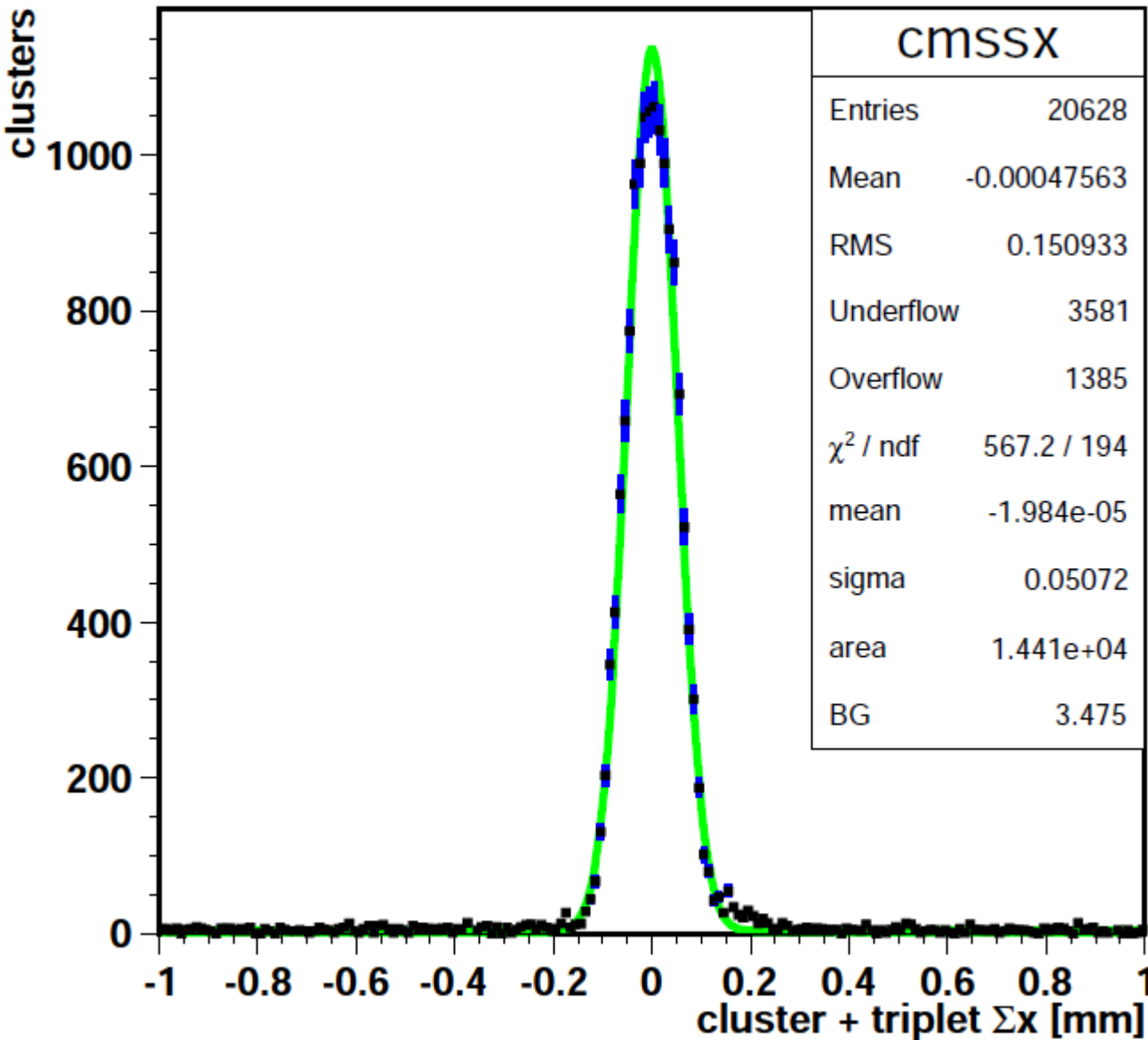
Entries = 20628



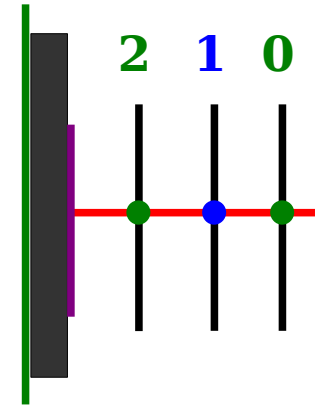
- Read CMS pixel data in parallel with telescope aligned hits
 - skip first 70 CMS events to synchronize (Armin Burgmeier).
- Nice correlation
 - ~1 mm vertical misalignment,
 - pixel binning.

CMS column pixel resolution

run 1946, 6 GeV



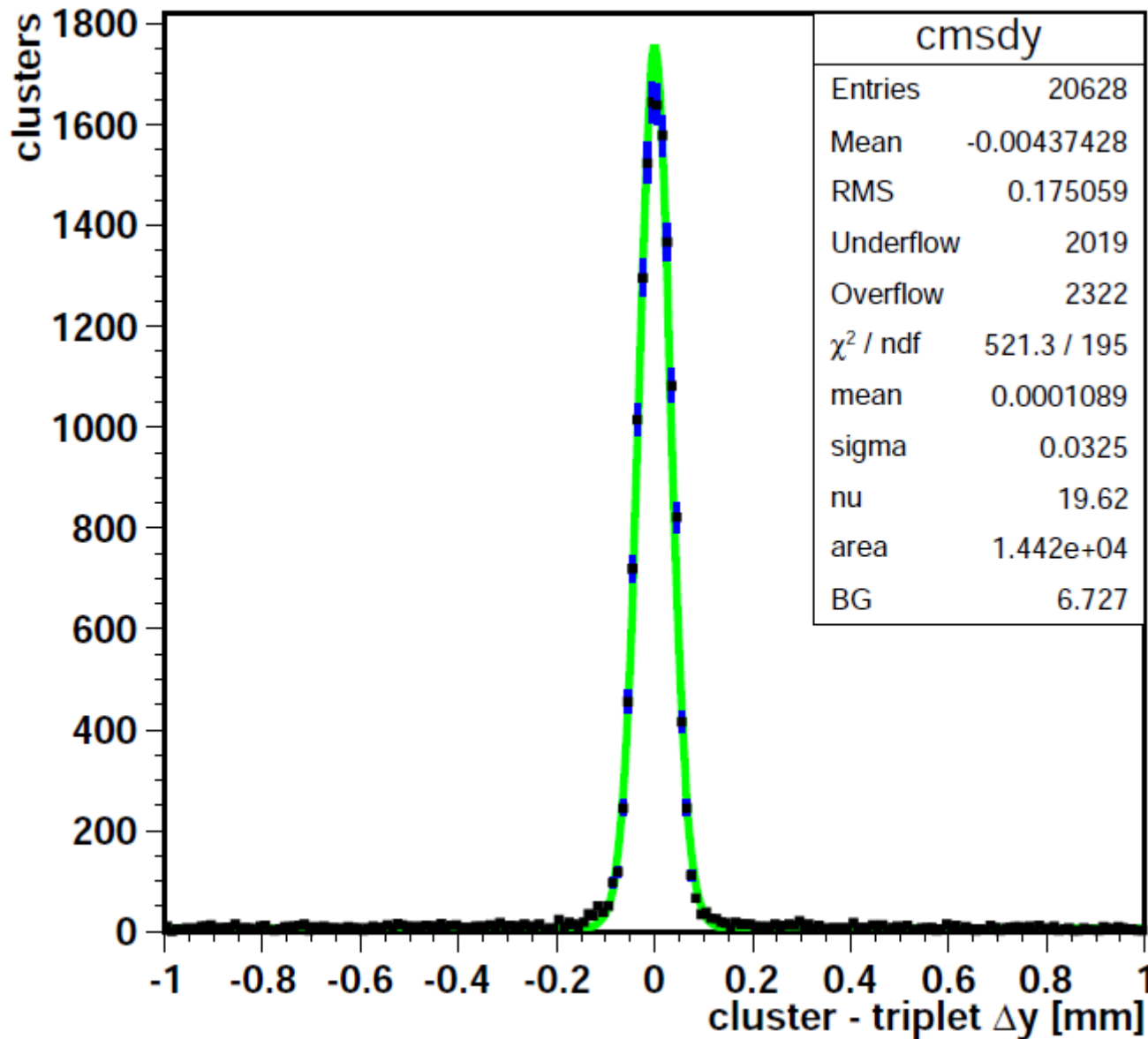
CMS



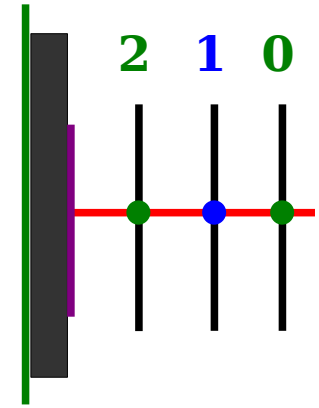
- Horizontal = columns
 - CMS pixel = 150 μm .
- Residual:
 - $\sigma = 51 \mu\text{m}$

CMS pixel row resolution

run 1946, 6 GeV, 0° tilt

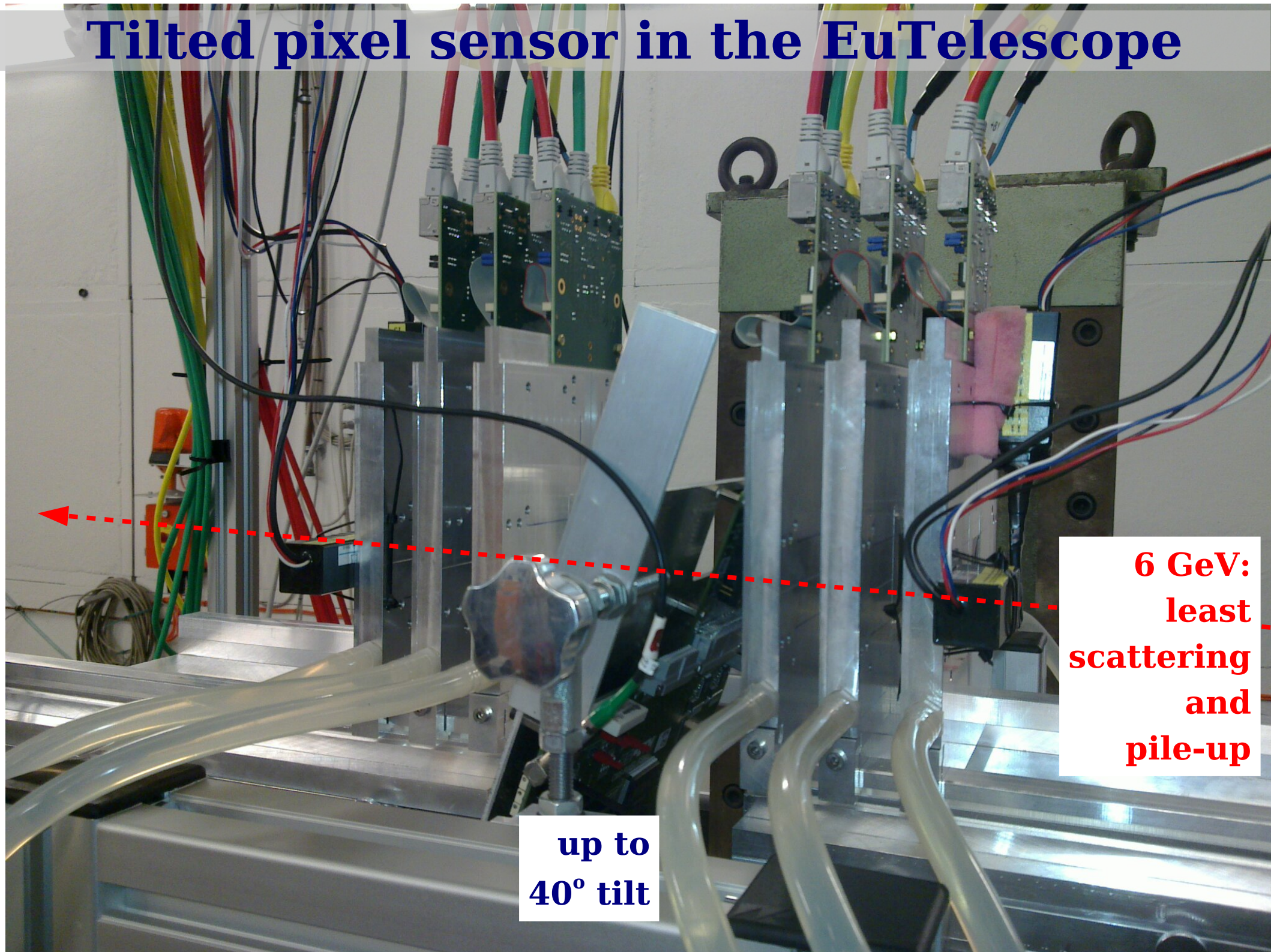


CMS



- Vertical = rows
 - CMS pixel = 100 μm .
- Residual:
 - $\sigma = 32.5 \mu\text{m}$.
 - mostly 1-pixel clusters, no interpolation possible.

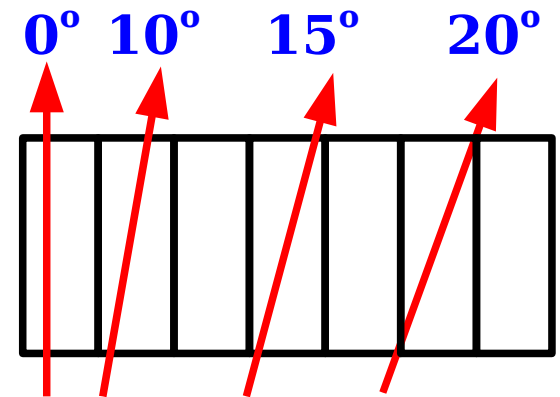
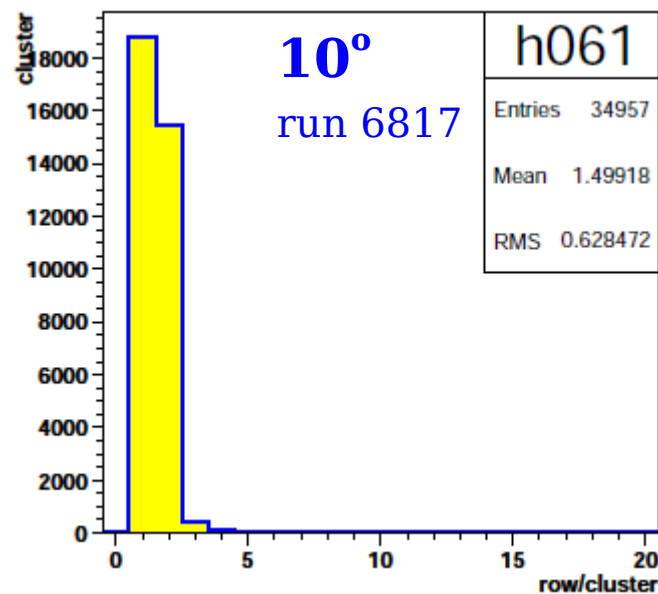
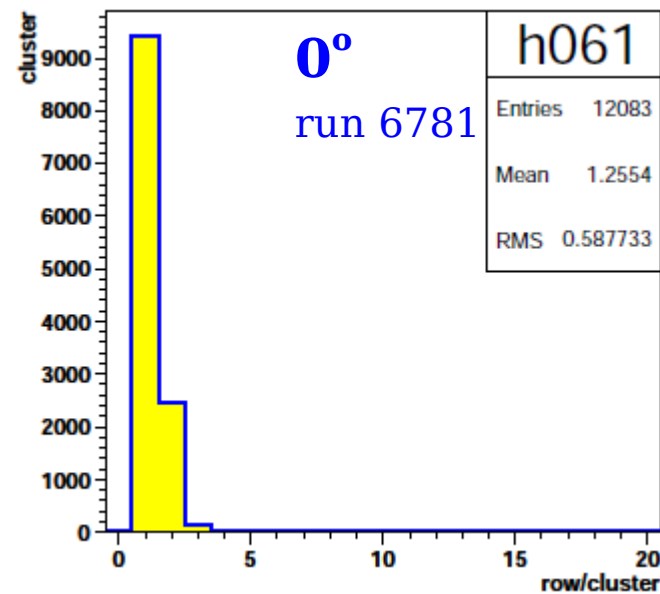
Tilted pixel sensor in the EuTelescope



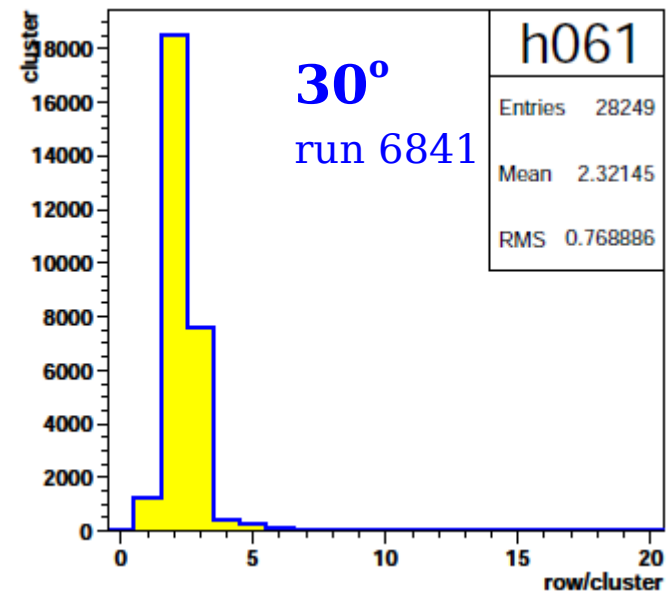
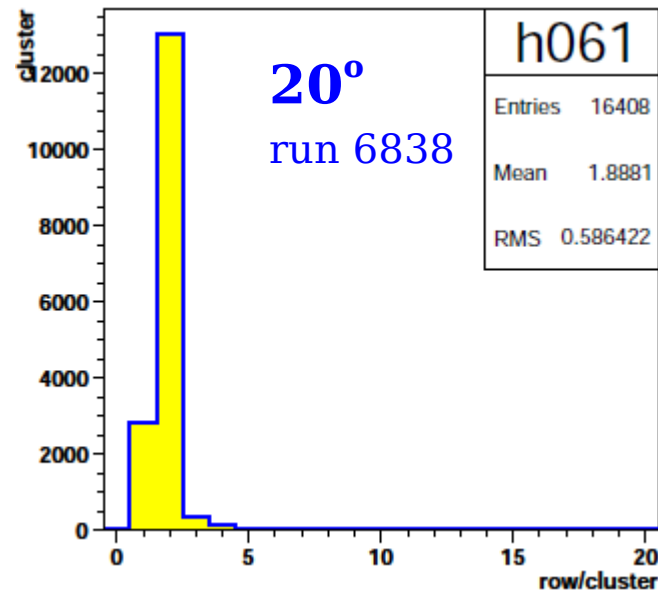
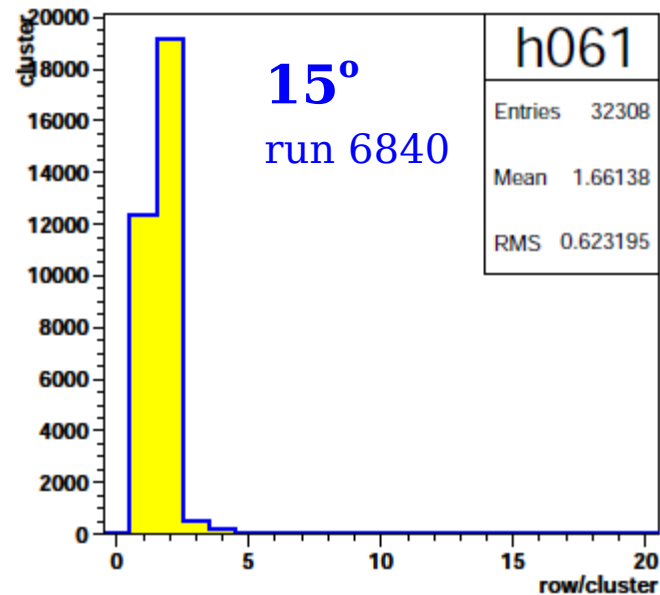
**6 GeV:
least
scattering
and
pile-up**

**up to
40° tilt**

tilting the CMS pixel detector

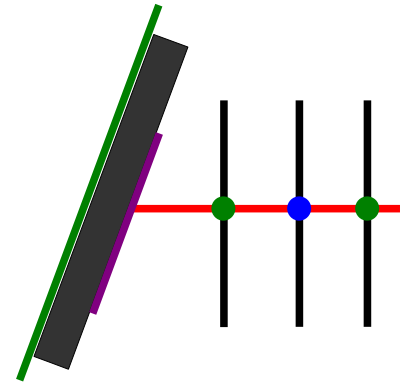
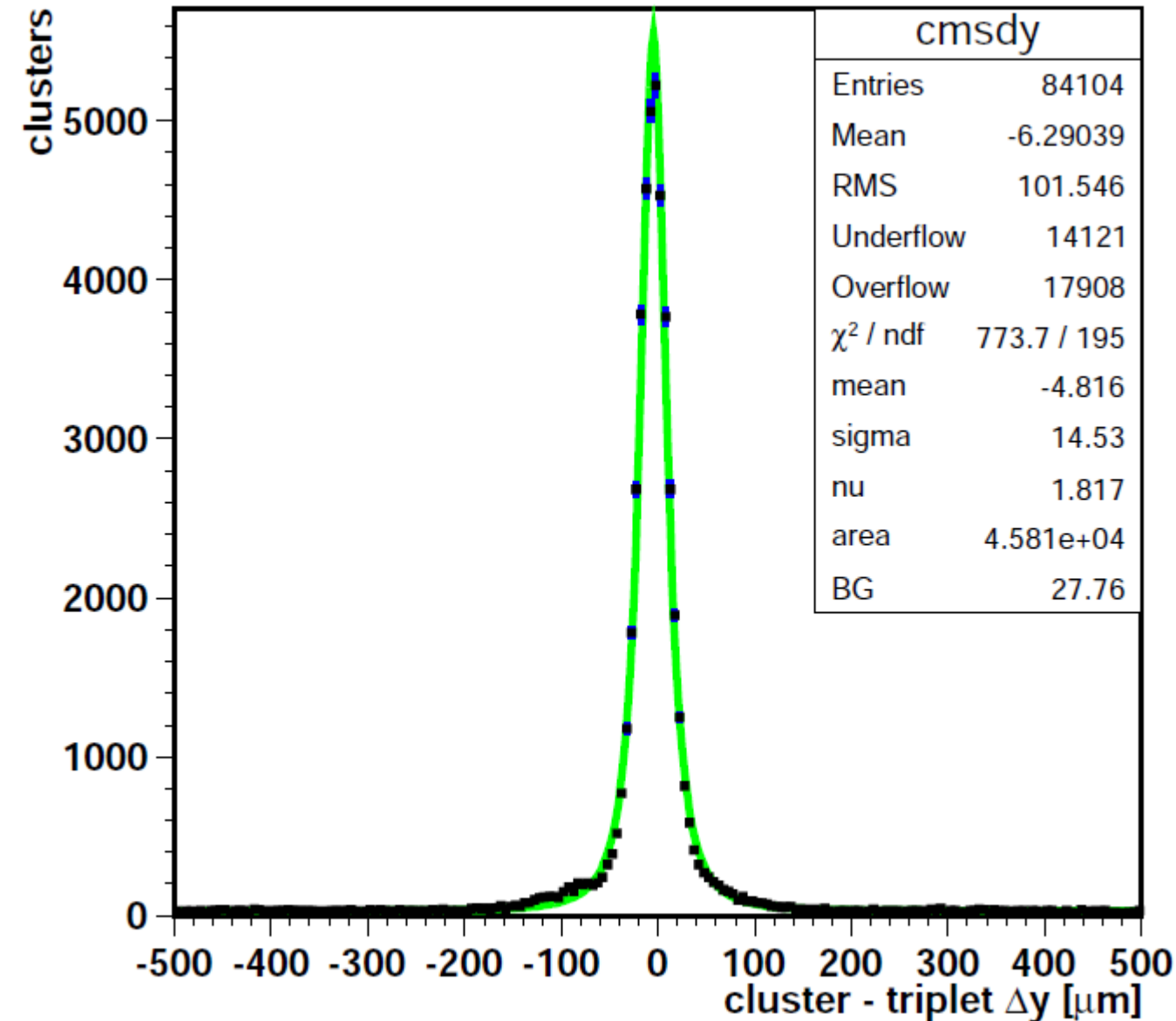


$$\text{atan}(100/285) = 19^\circ$$



CMS pixel row resolution

run 2322, 6 GeV, 20° tilt



- Vertical = rows
 - CMS pixel = 100 μm .
- Residual:
 - $\sigma = 14.5 \mu\text{m}$.
- Future improvement:
 - η -algorithm instead of center-of-gravity for cluster reconstruction.

Summary

- Data taking with the EUDET test beam telescope established:
 - common scintillator trigger
 - parallel readout, merged offline (data offset to be understood...)
 - up to 1.4 kHz at 4 GeV, 400 Hz at 6 GeV.
- results:
 - telescope point resolution 3.4 μm (Mimosa26)
 - pixel chip adapter with ZIF socket amounts to 0.2 X_0 .
 - pixel resolution measured, as function of tilt angle.
- problems:
 - chip 8 died, probably electrostatic discharge: always power (and ground) the test board before inserting a chip!
 - Mimosa integrates for 115 us: pile up. Need 2nd CMS chip as timing reference for efficiency studies: February 2012.

Acknowledgements

- Ingrid Gregor, Marcel Stanitzki, Artem Kravchenko, Igor Rubinskiy (all DESY ATLAS):
 - telescope hardware, DAQ, software, advice.
- Adam Zuber, Holger Maser (DESY CMS):
 - designing and building the tilting support frame for the test board.
- Michael Bieler, Heiko Ehrlichmann, Gunnar Priebe (machine group):
 - changing the target wire.
- Mark Terwort (DESY Calice):
 - tolerating us in the test beam.
- DESY operators:
 - steady beam production, friendly communication.