Measurements with a Si-strip telescope

Simone Bianco, Max Becker, Kai-Thomas Brinkmann,
Ralf Kliemt, Karsten Koop, Robert Schnell,
Thomas Würschig, Hans Georg Zaunick

Bundesministerium für Bildung und Forschung

Bonn-Cologne Graduate School
of Physics and Astronomy

Outline

- Telescope layout:
  - Setup
  - DAQ
  - DAQ to analysis interface
- Setup optimization:
  - Alignment
  - Calibration
  - Rotation of one sensor
  - Longitudinal shift of one sensor
  - Positioning and resolution
- Scattering measurements:
  - Setups
  - Measurements results
  - Comparison with simulations

Telescope setup

The telescope in its operational setup at COSY (Jülich)

Four boxes:

→2 double sided Si-strip sensors
→4 single sided Si-strip sensors

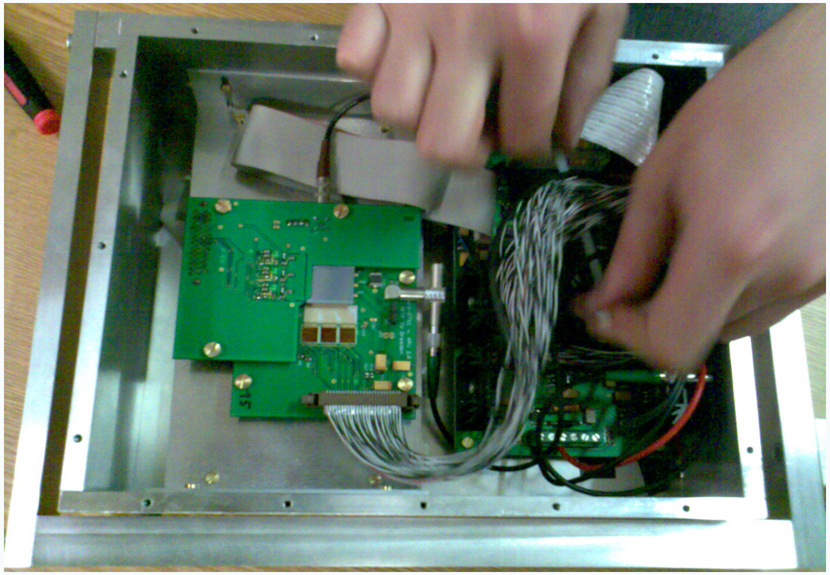
Sensors:

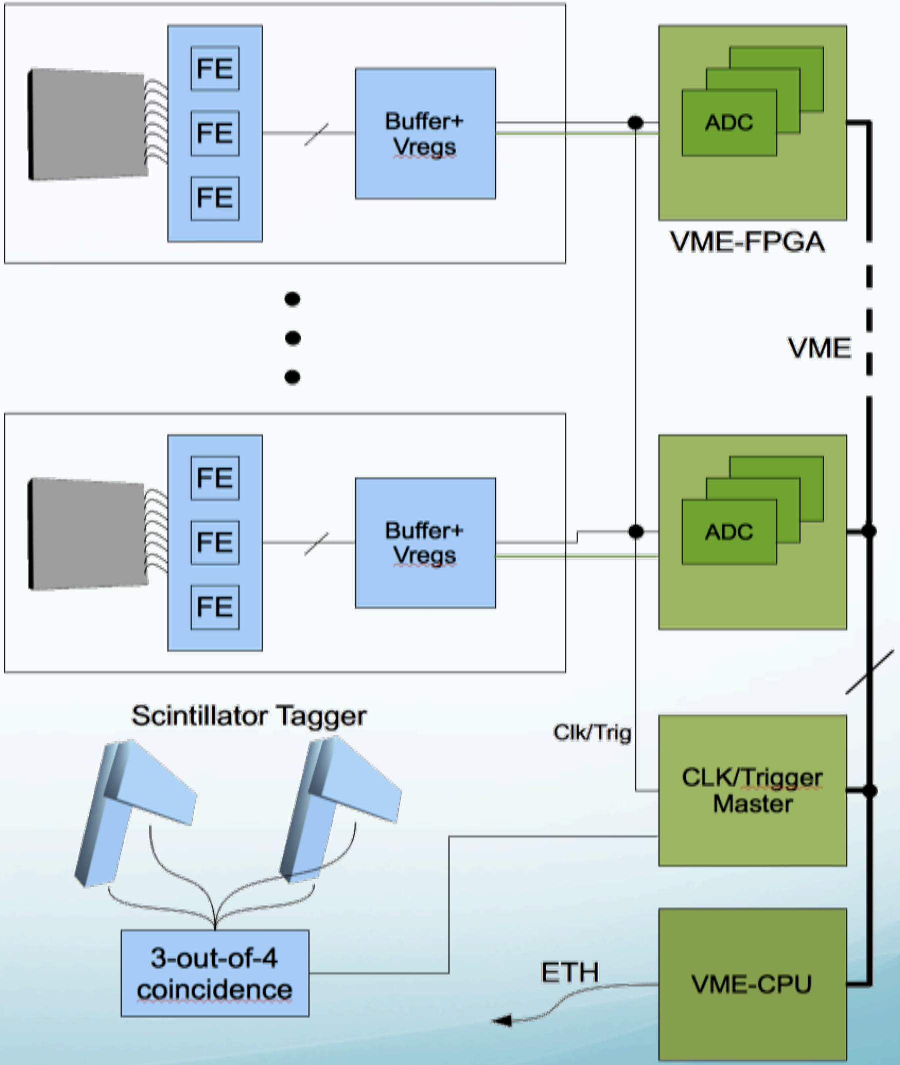
1.92cm x 1.92cm active area
300 μm thick
50 μm pitch
90° stereo angle (for double sided ones)

Trigger:

→4 scintillators (2 before and 2 downstream from the telescope) - 3/4 coinc.

Telescope - DAQ



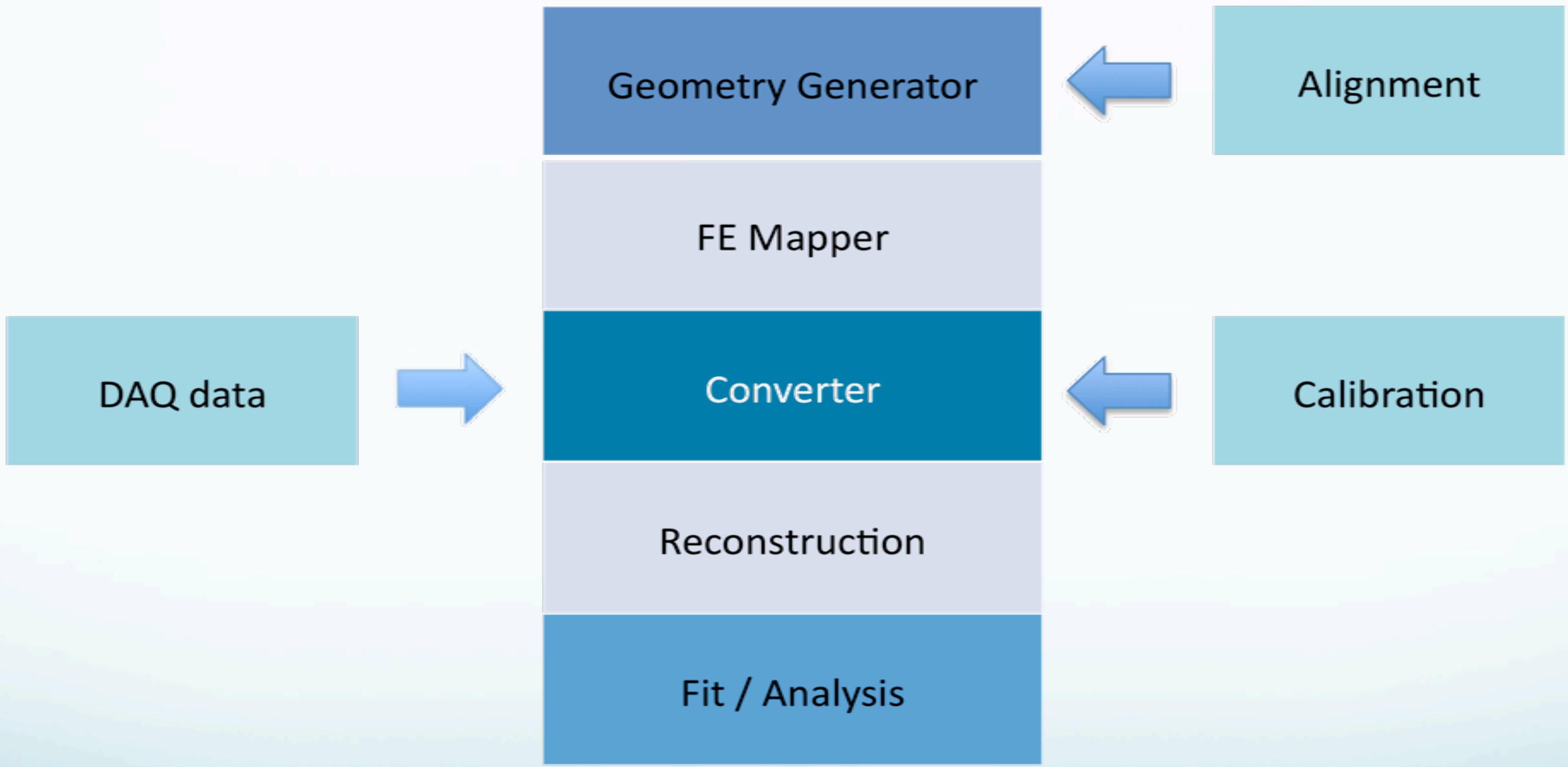


FEE: APV25-S1

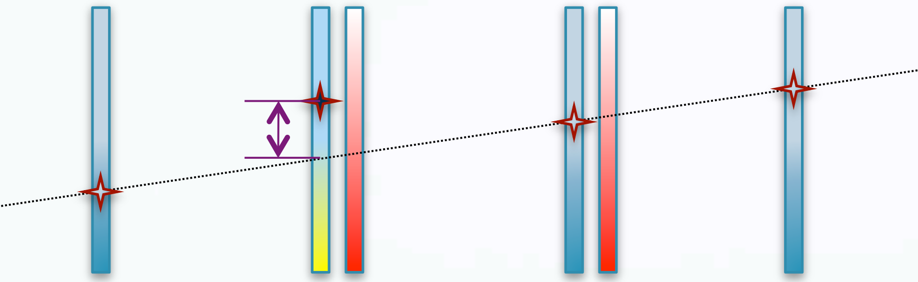
Depletion voltage: ~60 V
p in n⁻ bulk
(n in n on the other side)

Readout AC coupled
Punch through bias
Max DAQ rates ~ 1-2 k evts/s

Telescope: from DAQ to analysis



Alignment



Iterative procedure to align sensors:

1. Measure residual on the 1st sensor
2. Correct the position of the 1st sensor
3. 2nd sensor… 6th sensor
4. Reiterate the whole loop

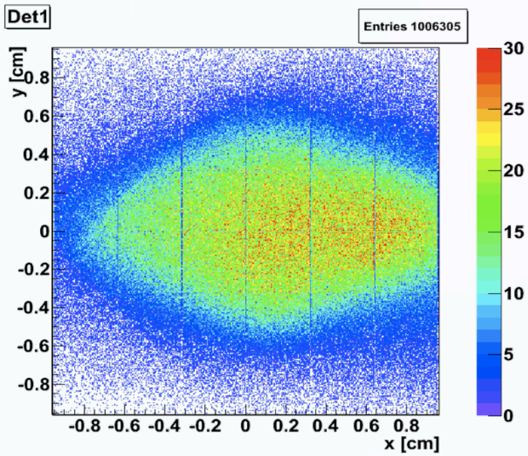
Energy Calibration

Realized in two steps:

- ✓ Same charge injected on each of the FE channels
  → to resolve differences in the response

- ✓ MIP hypothesis
  → to set an absolute ADC counts-to-energy-loss scale

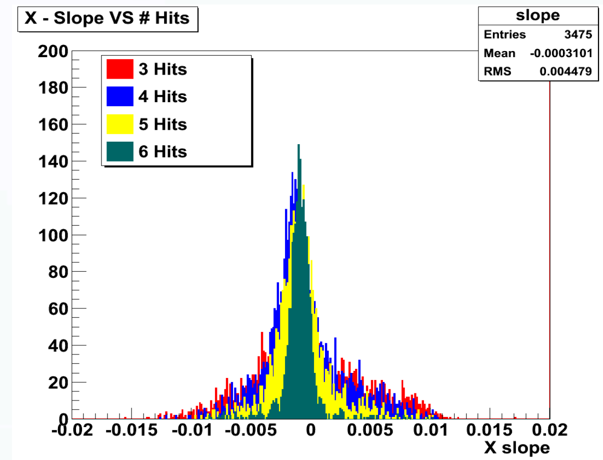
First measurements



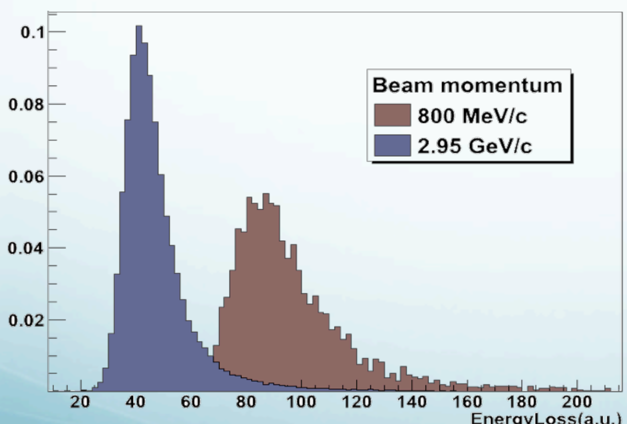
Beam profile: scint. overlap

First measurements:

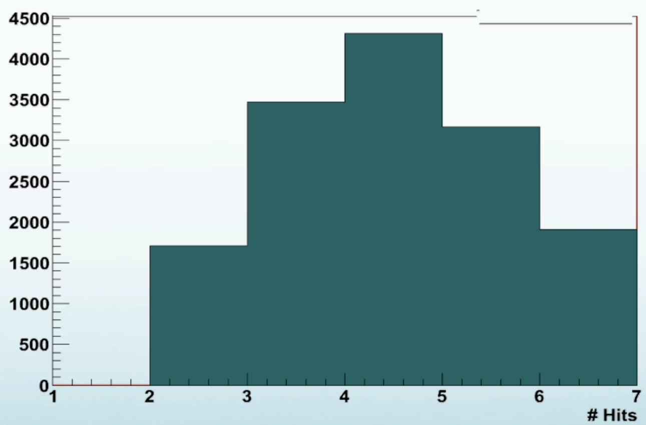
- ✓ behavior of the sensors
- ✓ experimental conditions
- ✓ benchmark of the tools



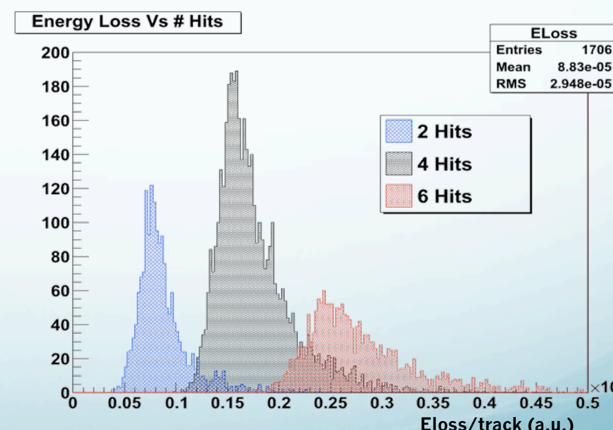
Slopes of fitted tracks



Eloss in a sensor with different beams



 # Hits / event

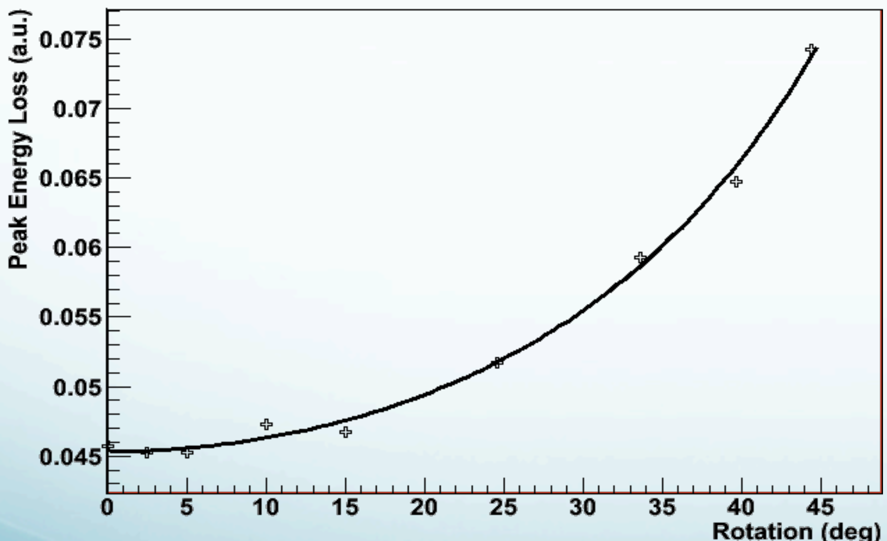


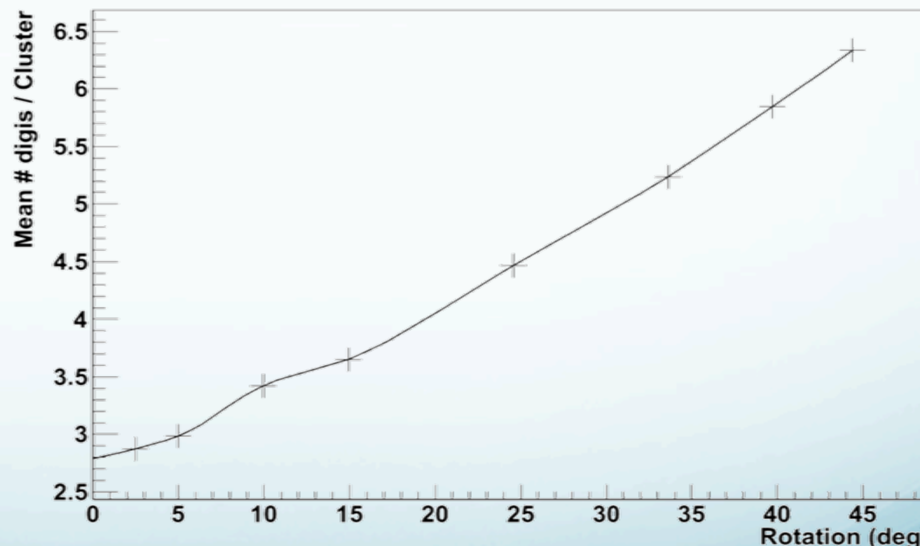
Eloss for tracks with different # of hits

Rotation of a sensor

The second box was rotated:
Different beam incident angles

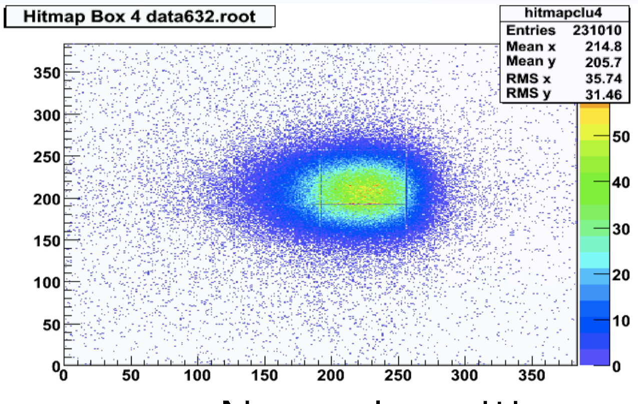
Effect of the rotation on energy loss and cluster size



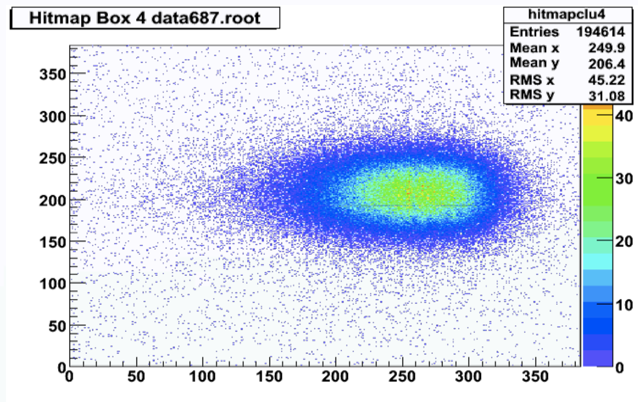


Measurements performed with 4 GeV electrons at DESY

Rotation - II

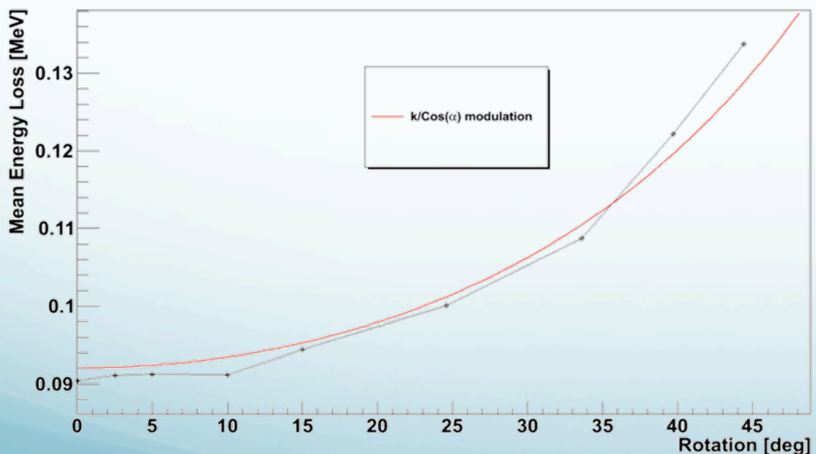


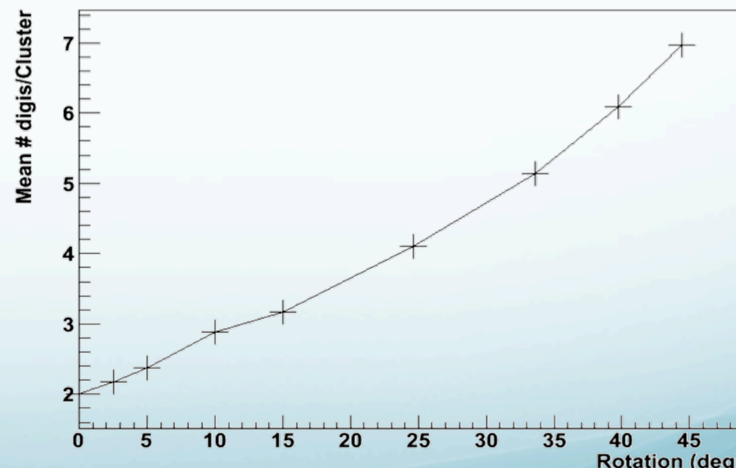
Normal position



Box rotated of 40°

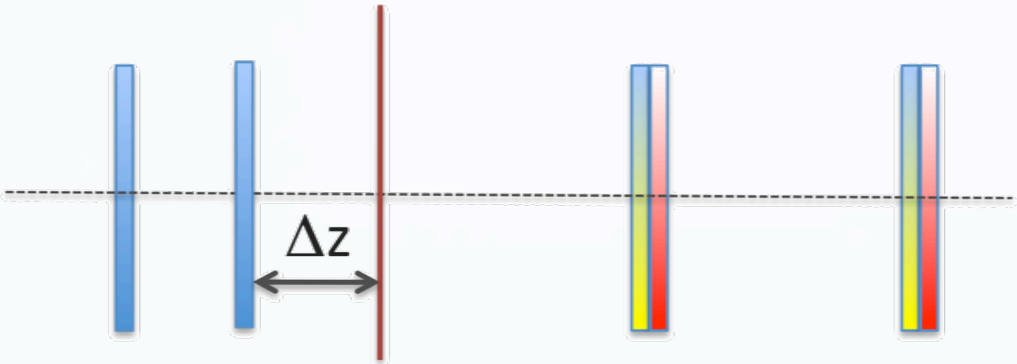
Hit distribution on the rotated box
2.95 GeV/c protons





Simulations of the previous setups, 4 GeV electrons

Translation of one sensor

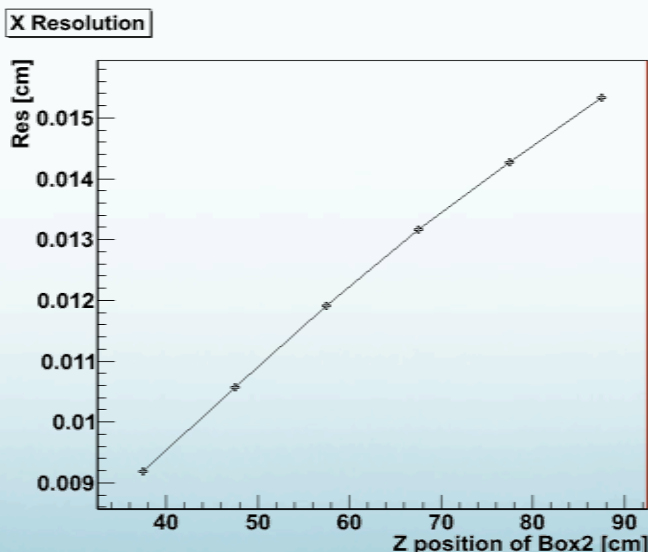


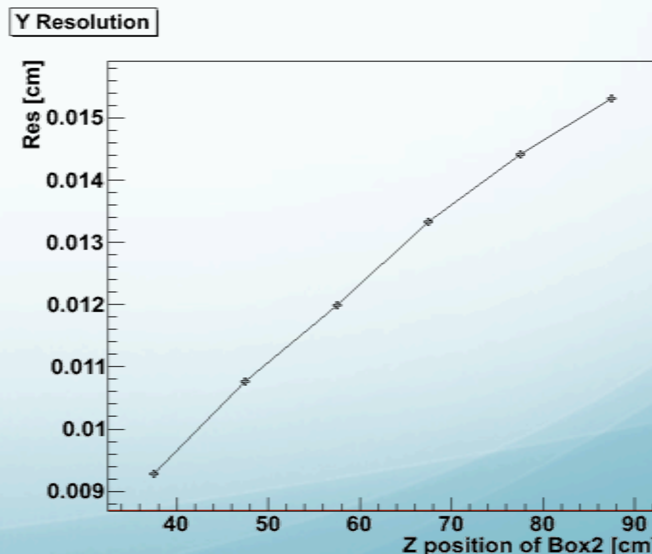
Longitudinal scan:

One sensor moved along the beam direction

$$RES = \sqrt[4]{\sigma_1 * \sigma_2 * \sigma_3 * \sigma_4}$$

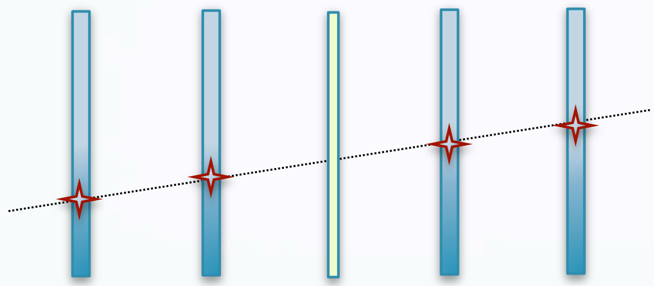
where σ_i is the width of the residuals distribution obtained on sensors *i*





Measurements with 3 GeV electrons at DESY

Positioning optimization



Simulations with 5 GeV e^-
and a 300 µm Si device

Setup	σ_x	σ_y
	µm	µm
A	56	53
B	16	16
C	34	34

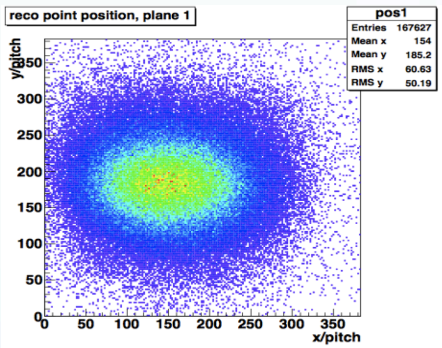
	B1	B2	Device	B3	B4
	z(cm)	z(cm)	z(cm)	z(cm)	z(cm)
A	16.	86.	110.	145.	185.5
B	90.	100.	110.	120.	130.
C	65.	85.	110.	139.	159.

Photon tests

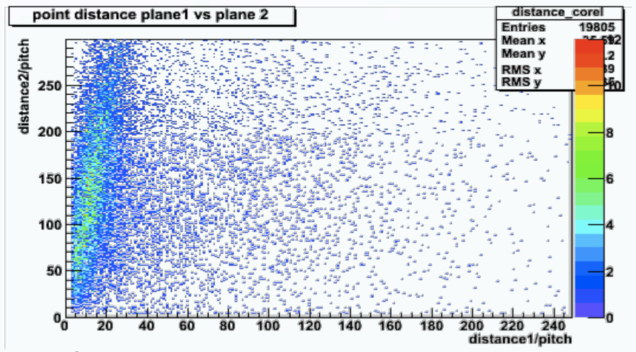
Electron ring → Bremsstrahlung photons (up to 3 GeV) → PP in a converter

2 Boxes equipped with double sided sensors

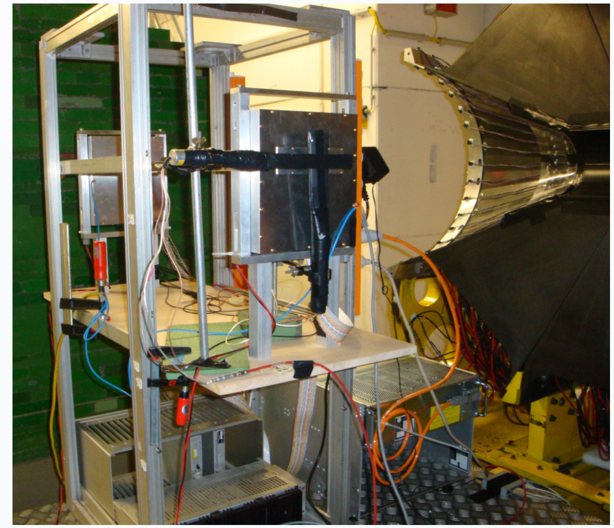
Scintillator as a converter

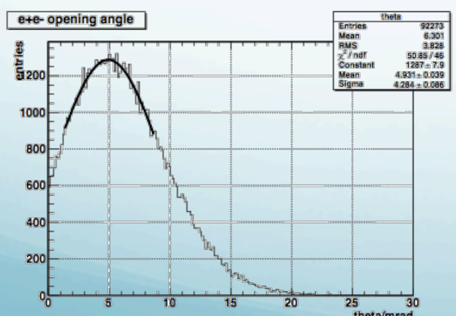


Hits on the 1st sensor (2 hits/sensor events)



Correlation of the distance between two hits on the two sensors

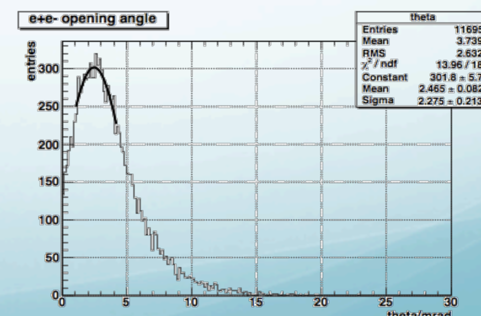




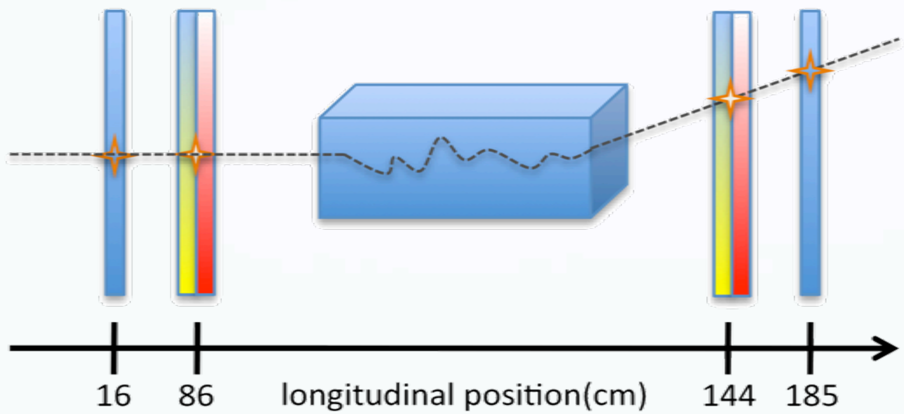
Distribution of the opening angle of the e^+e^- pair

←Low E (~400 MeV)

Higher energies →



Scattering measurements

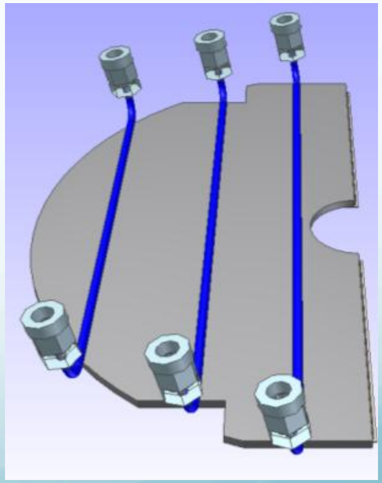


Beams:

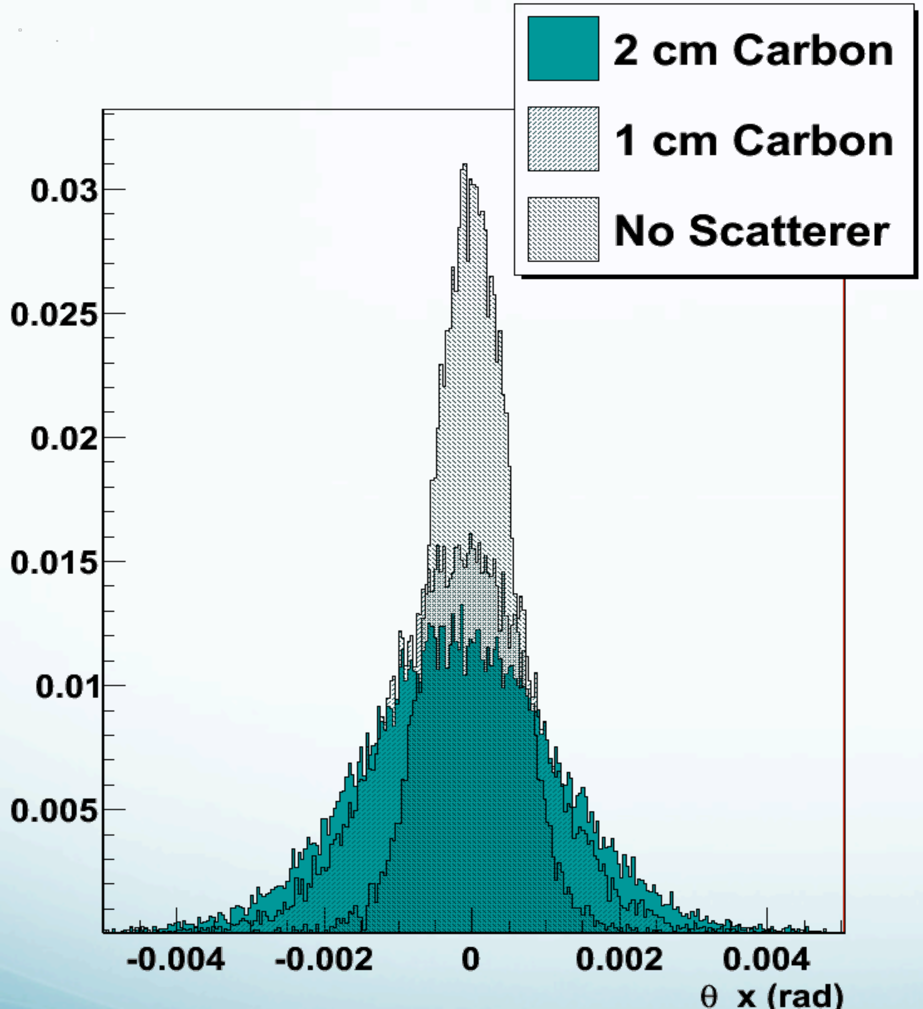
COSY	Protons of 2.95 GeV/c
DESY	Electrons of 1-5 GeV

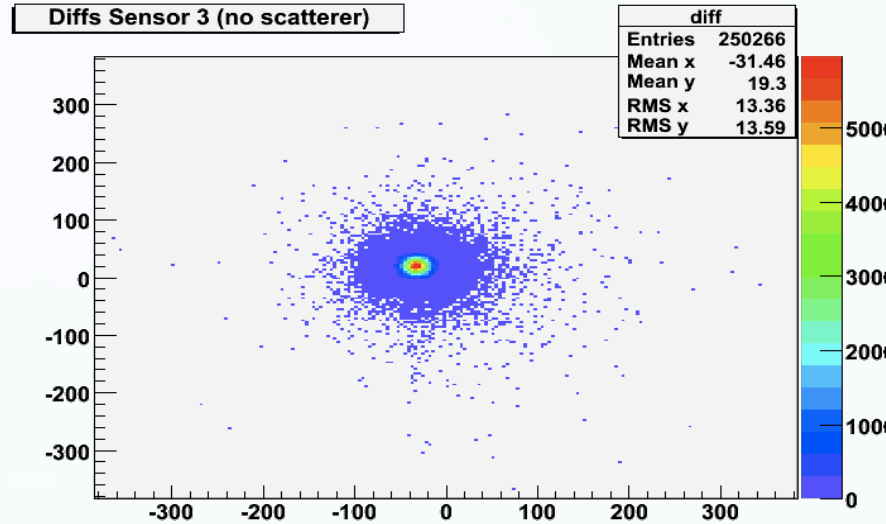
Scatterers:

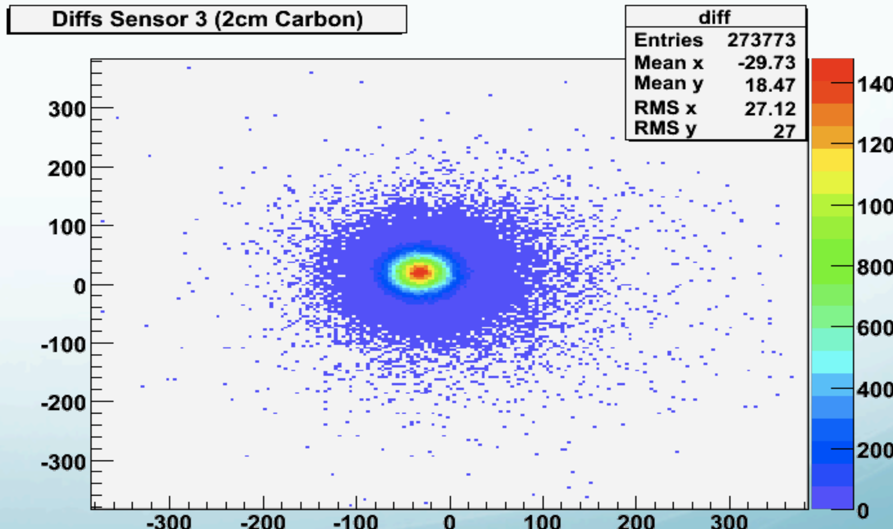
- 1 cm of C (ρ ~1.79 g/cm^3)
- 2 cm of C (ρ ~1.69 g/cm^3)
- 2.5 cm of carbon foam (ρ ~0.52 g/cm^3)
- Carbon foils
- a prototype for support structures
  (4mm C-foam with embedded cooling pipes)
  (ρ ~1.1 g/cm^3)



Scattering mesurements - II







Measurements with
2.95 GeV/c protons at COSY

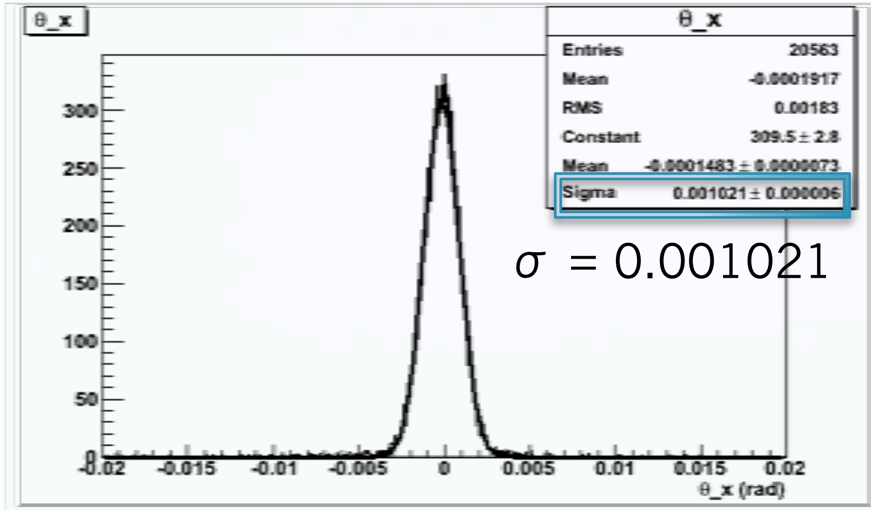
Simulations

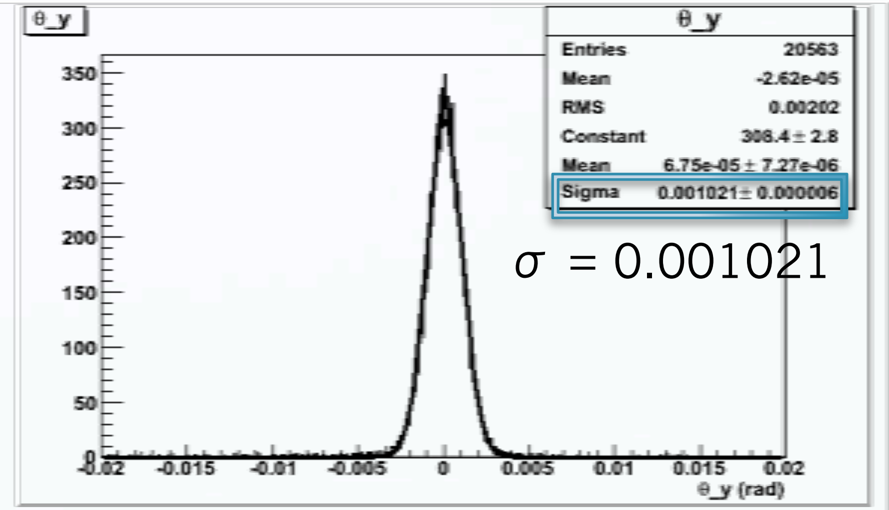
- The setup used for simulations was the same as the one of the measurements
- Geo definition:
  - 6 silicon parallelepipeds with sizes 1.92cmx1.92cmx300μm
- Beam definition: “single-particle” events, particles propagated from a few cm upstream the telescope
- No beam divergence (small effect due to geometry restrictions)
- Beam shot toward the center of the first box, parallel to the longitudinal axis
- Propagation realized with Geant3 (tested several scattering models without experiencing severe differences)

Results with protons

GEANT3 → Sigma 0.001011

1 cm of C-based material

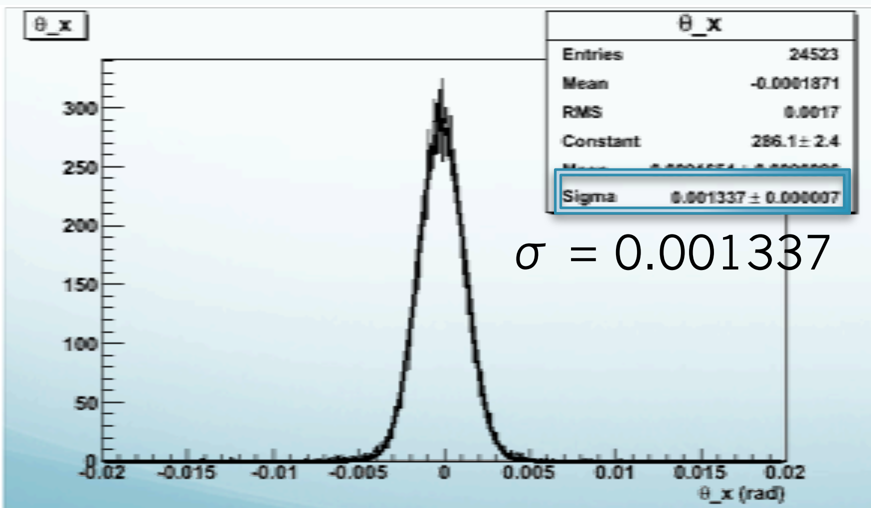


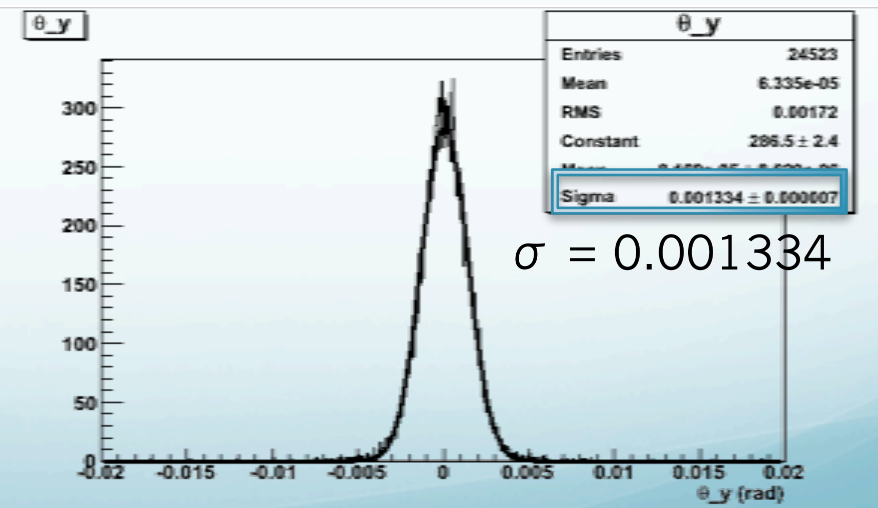


2.95 GeV/c protons scattering in:

GEANT3 → Sigma 0.001334

2 cm of C-based material





Results with electrons

Scatterer	e^- Mom.	Sigma Meas. (mrad)	Sigma Sim (mrad)
air	1 GeV/c	1.24	1.40
air	3 GeV/c	0.423	0.476
air	5.4 GeV/c	0.243	0.284
2.5 cm C-Foam	1 GeV/c	2.18	2.54
2.5 cm C-Foam	3 GeV/c	0.746	0.887
2.5 cm C-Foam	4 GeV/c	0.588	0.645
1 Cm C	1 GeV/c	2.48	2.89
1 Cm C	5.4 GeV/c	0.511	0.599
2 Cm C	1 GeV/c	3.15	3.82
2 Cm C	5 GeV/c	0.698	0.807
Foam Disk	1 GeV/c	1.76	1.87
Foam Disk	3 GeV/c	0.600	0.611
Foam Disk	4 GeV/c	0.471	0.483

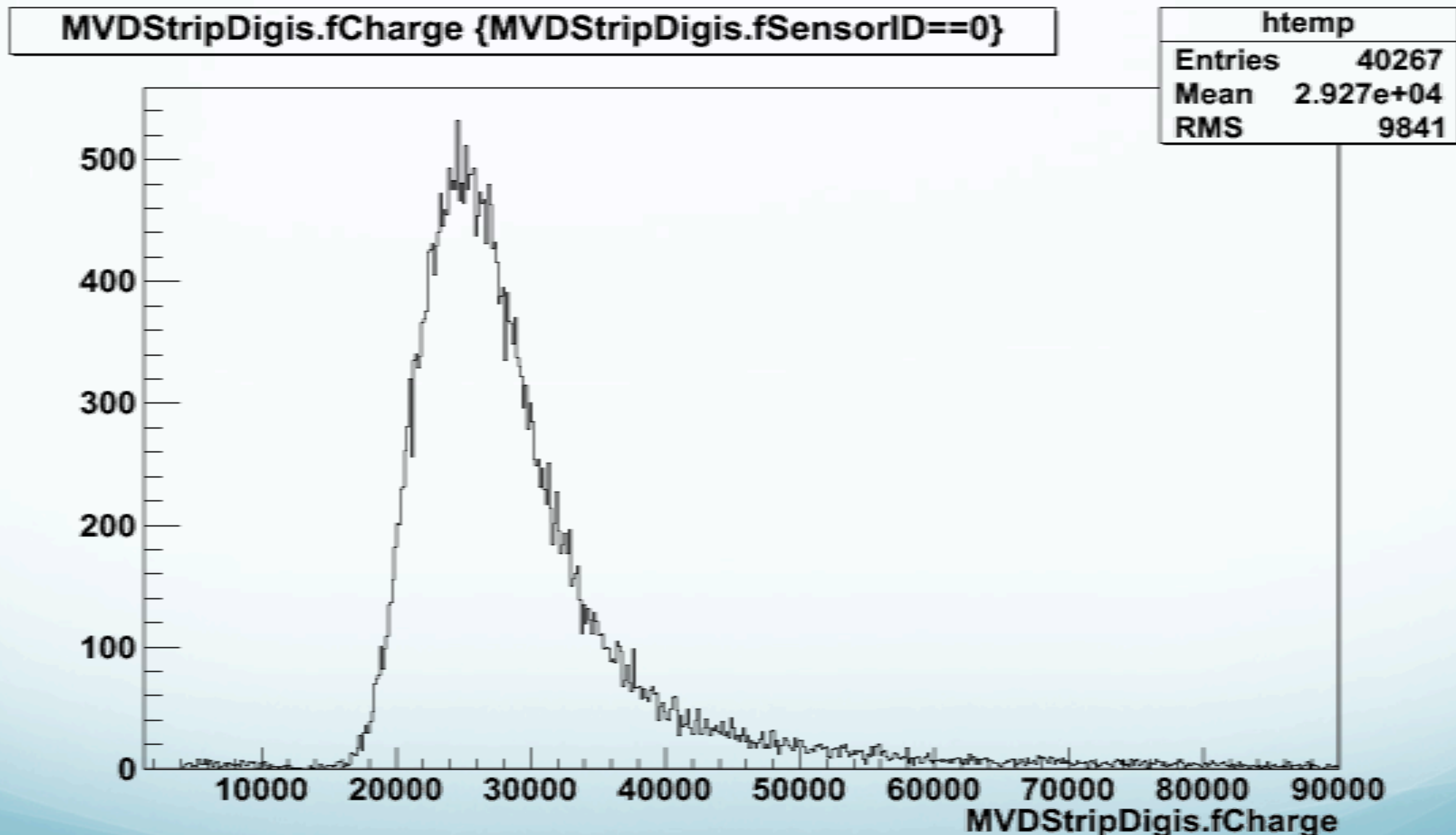
Conclusions

- The telescope was successfully operating in several beam conditions
- Different setups have been tested
- The effects of rotations and positioning of the sensors has been studied
- Scattering measurements were performed
- A direct comparison between analysis and simulations allowed to validate our framework

Thanks for your attention!

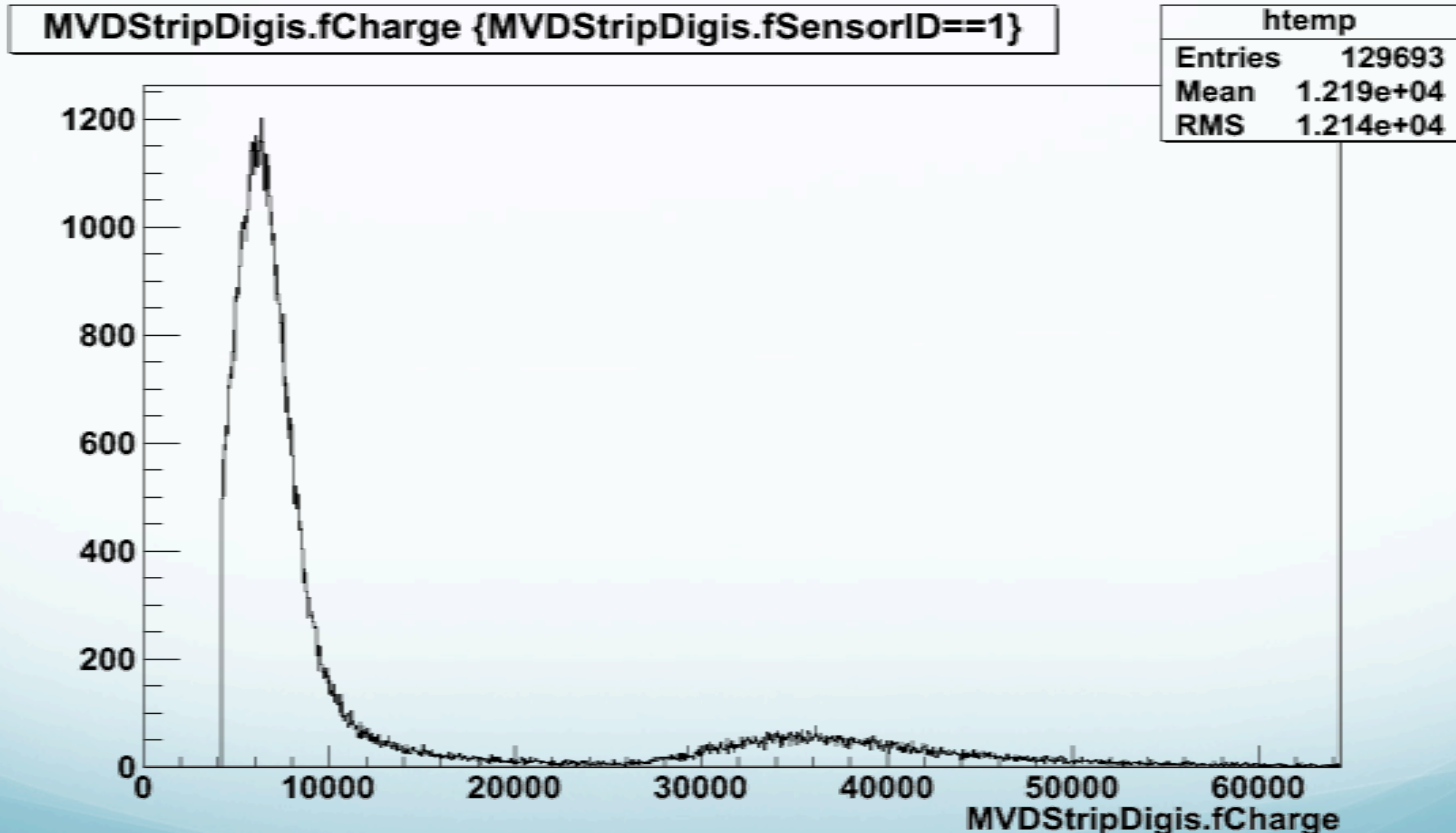
Backup slides

Rotation of One Sensor - Simulations



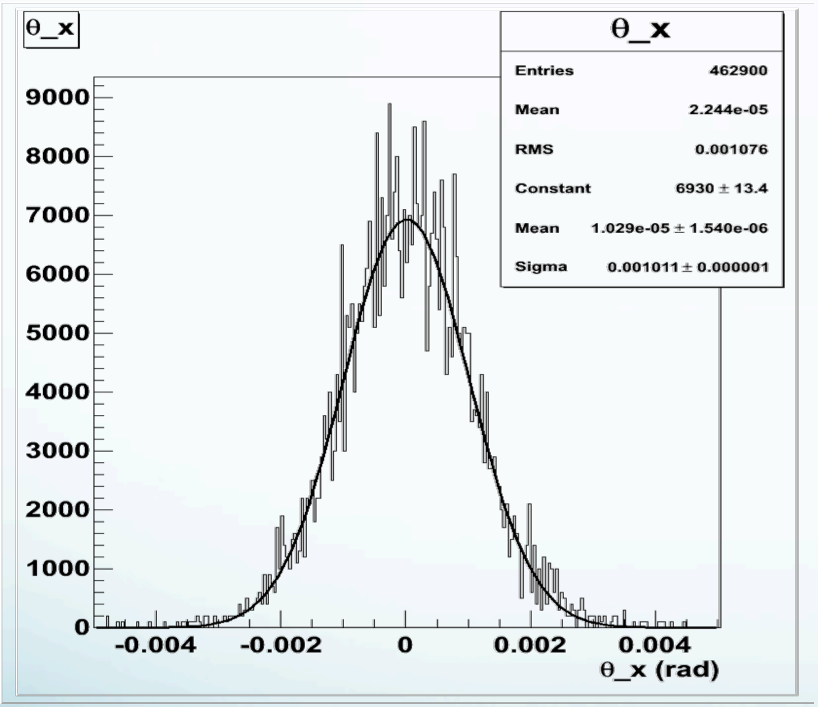
Electrons of 4 GeV - 0 deg rotation

Rotation of One Sensor - Simulations



Electrons of 4 GeV - 44.4 deg rotation

Scattering distributions



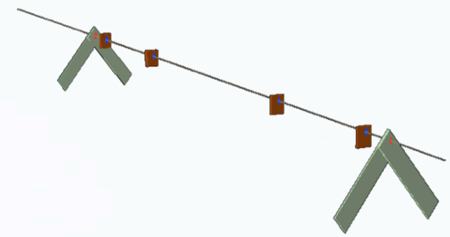
2.95 GeV/c protons scattering in 1 cm of C (density 1.79 g/cm3)

FEE to SIM maps

RW	SW	Detector Name
0	0	/TS_1/TTVol_0/TTDouble_0/StripActiveTD1_0
1	1	/TS_1/TTVol_0/TTDouble_0/StripActiveTD1_0
2	2	/TS_1/TTVol_0/TTDouble_0/StripActiveTD1_0
3	3	/TS_1/TTVol_0/TTDouble_0/StripActiveTD1_0
4	4	/TS_1/TTVol_0/TTDouble_0/StripActiveTD1_0
5	5	/TS_1/TTVol_0/TTDouble_0/StripActiveTD1_0
6	0	/TS_1/TTVol_0/TTSingle_0/StripActiveTS3a_0
7	1	/TS_1/TTVol_0/TTSingle_0/StripActiveTS3a_0
8	2	/TS_1/TTVol_0/TTSingle_0/StripActiveTS3a_0
-1	3	/TS_1/TTVol_0/TTSingle_0/StripActiveTS3a_0
9	0	/TS_1/TTVol_0/TTSingle_0/StripActiveTS3b_0
10	1	/TS_1/TTVol_0/TTSingle_0/StripActiveTS3b_0
11	2	/TS_1/TTVol_0/TTSingle_0/StripActiveTS3b_0
-2	3	/TS_1/TTVol_0/TTSingle_0/StripActiveTS3b_0
12	0	/TS_1/TTVol_0/TTSingle_0/StripActiveTS4a_0
13	1	/TS_1/TTVol_0/TTSingle_0/StripActiveTS4a_0
14	2	/TS_1/TTVol_0/TTSingle_0/StripActiveTS4a_0
-3	3	/TS_1/TTVol_0/TTSingle_0/StripActiveTS4a_0
15	0	/TS_1/TTVol_0/TTSingle_0/StripActiveTS4b_0
16	1	/TS_1/TTVol_0/TTSingle_0/StripActiveTS4b_0
17	2	/TS_1/TTVol_0/TTSingle_0/StripActiveTS4b_0
-4	3	/TS_1/TTVol_0/TTSingle_0/StripActiveTS4b_0
18	0	/TS_1/TTVol_0/TTDouble_0/StripActiveTD2_0
19	1	/TS_1/TTVol_0/TTDouble_0/StripActiveTD2_0
20	2	/TS_1/TTVol_0/TTDouble_0/StripActiveTD2_0
21	3	/TS_1/TTVol_0/TTDouble_0/StripActiveTD2_0
22	4	/TS_1/TTVol_0/TTDouble_0/StripActiveTD2_0
23	5	/TS_1/TTVol_0/TTDouble_0/StripActiveTD2_0

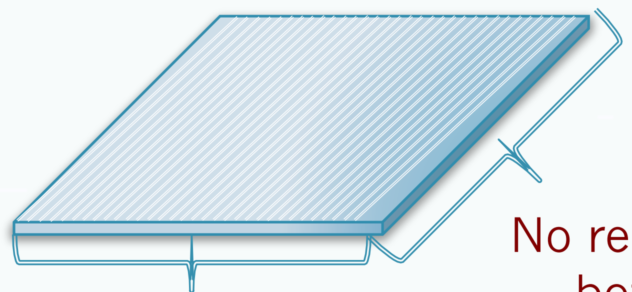
Template of a map

Converter – Single Sided Modules



The converter is creating PndMvdStripDigi objects.
The two single sided sensors (components of each of the single sided boxes) are treated independently.

The MVD strip reconstruction tools are designed to work with double sided sensors.

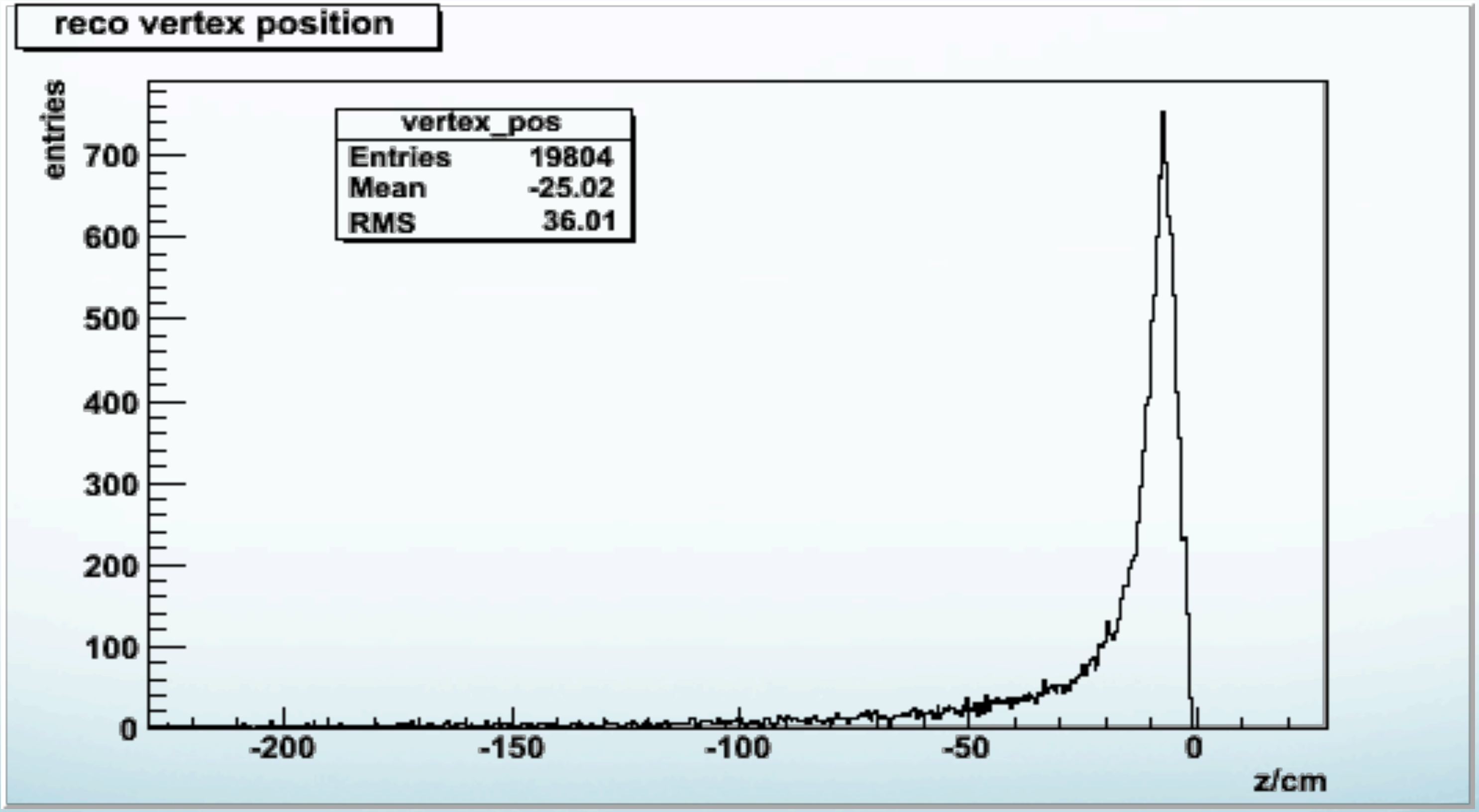


In the definition of the parameters we set one ideal strip on the bottom side, choosing as a pitch the width of the sensor.

When a single sided sensor is hit we fill the TClonesArray with one more digi on the bottom side:

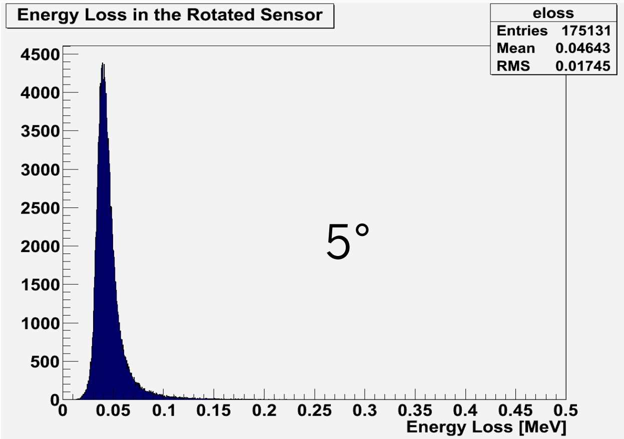
DetName, Index, ...	Like hits on the top side
Charge	Sum of the values on the top side
Channel	0
Frontend chip	4

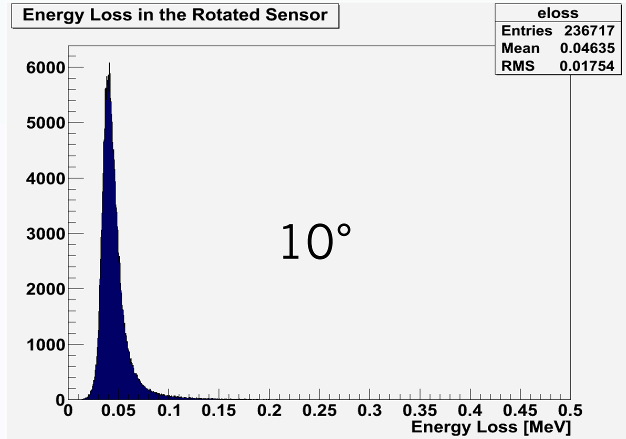
Z-reco @ ELSA

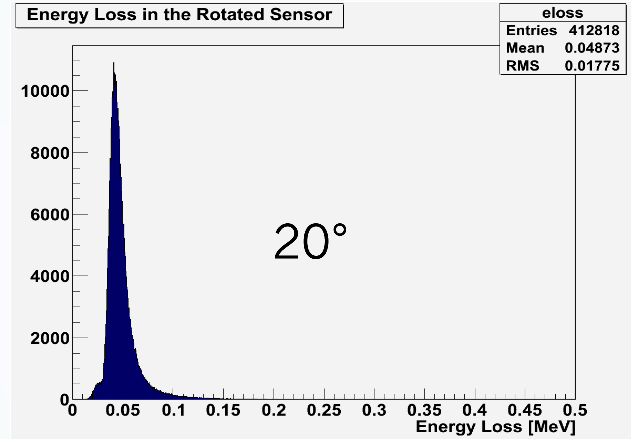


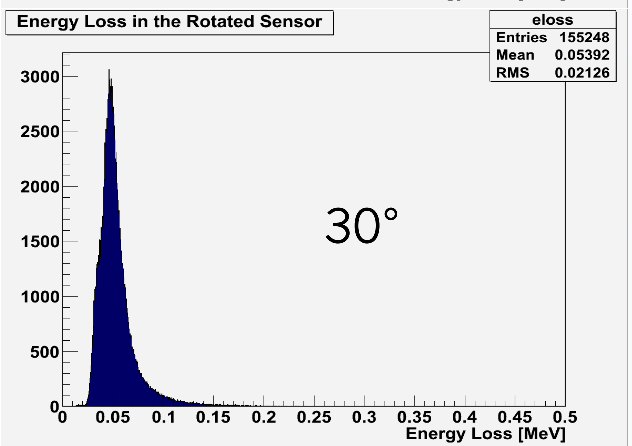
reco vertex position
entries
vertex_pos
Entries 19804
Mean -25.02
RMS 36.01
700
600
500
400
300
200
100
0
-200
-150
-100
-50
0
z/cm

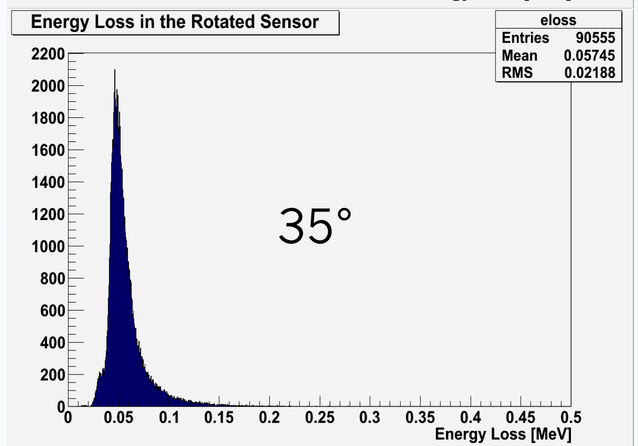
2.95 GeV/c protons @ COSY

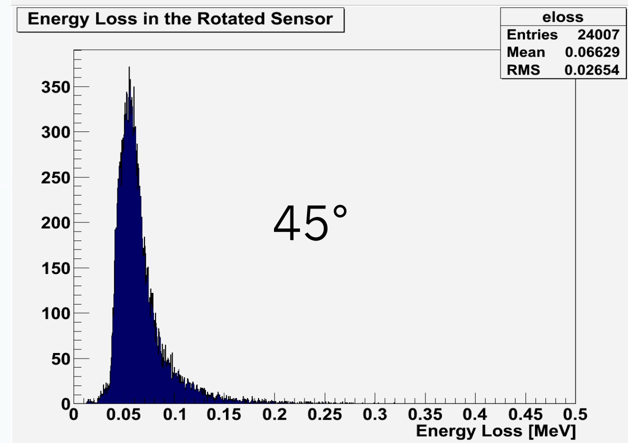

Energy Loss in the Rotated Sensor
eloss
Entries 175131
Mean 0.04643
RMS 0.01745
5°
Energy Loss [MeV]

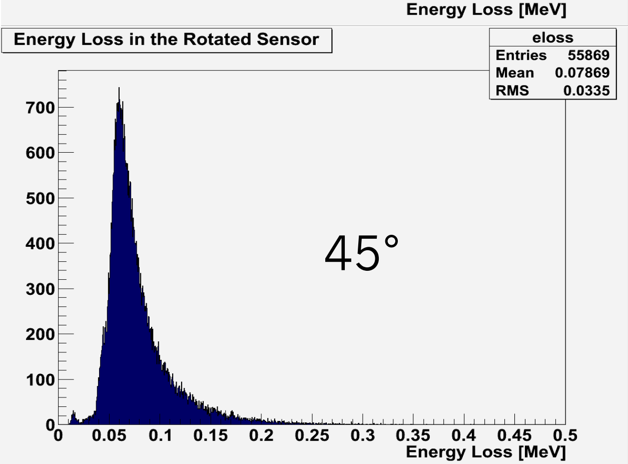

Energy Loss in the Rotated Sensor
eloss
Entries 236717
Mean 0.04635
RMS 0.01754
10°
Energy Loss [MeV]


Energy Loss in the Rotated Sensor
eloss
Entries 412818
Mean 0.04873
RMS 0.01775
20°
Energy Loss [MeV]


Energy Loss in the Rotated Sensor
eloss
Entries 155248
Mean 0.05392
RMS 0.02126
30°
Energy Loss [MeV]

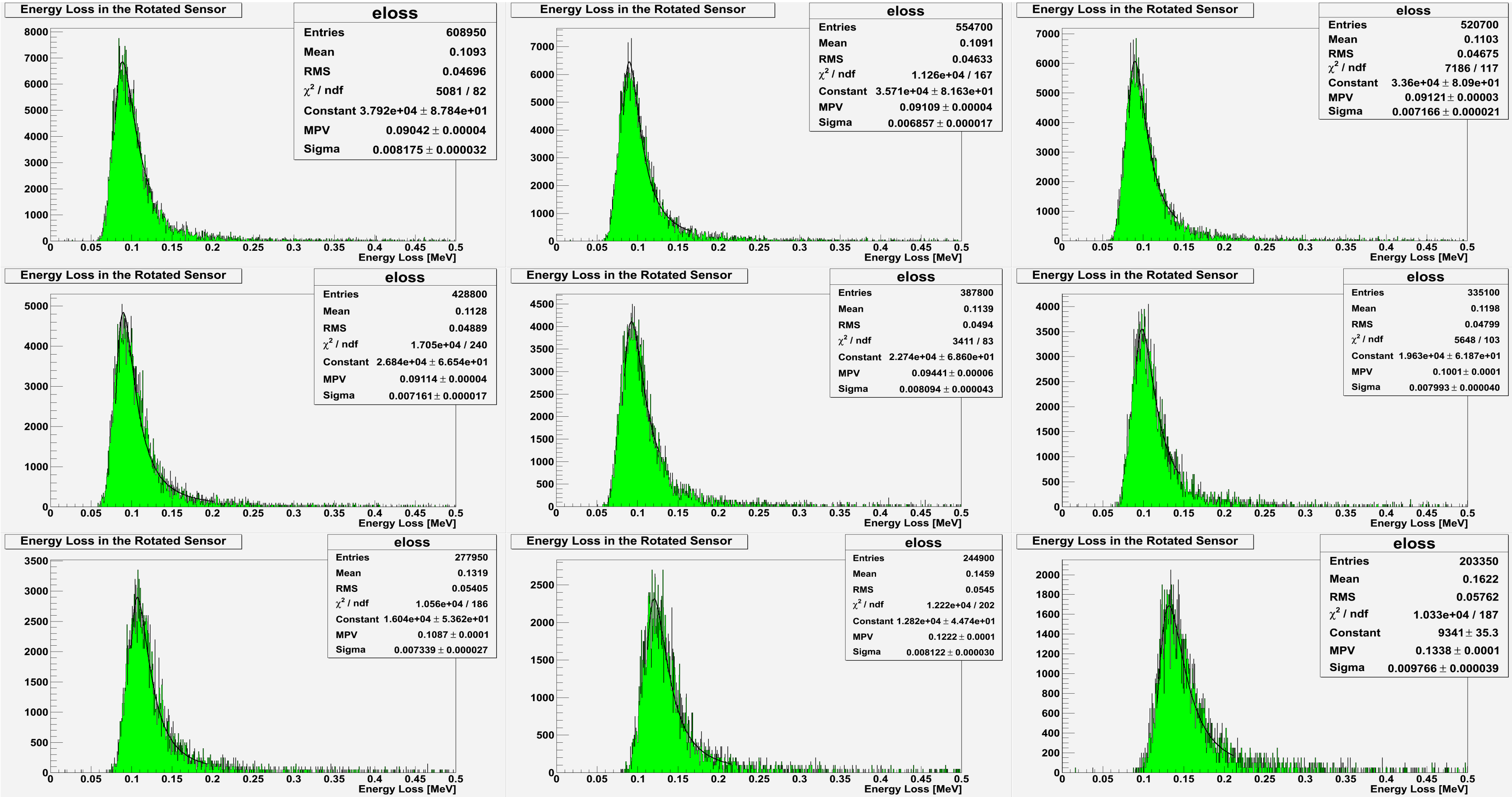

Energy Loss in the Rotated Sensor
eloss
Entries 90555
Mean 0.05745
RMS 0.02188
35°
Energy Loss [MeV]


Energy Loss in the Rotated Sensor
eloss
Entries 24007
Mean 0.06629
RMS 0.02654
45°
Energy Loss [MeV]

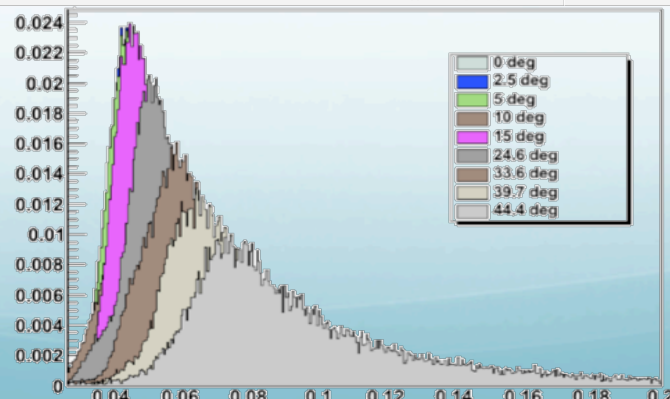

Energy Loss in the Rotated Sensor
eloss
Entries 55869
Mean 0.07869
RMS 0.0335
45°
Energy Loss [MeV]

DATA

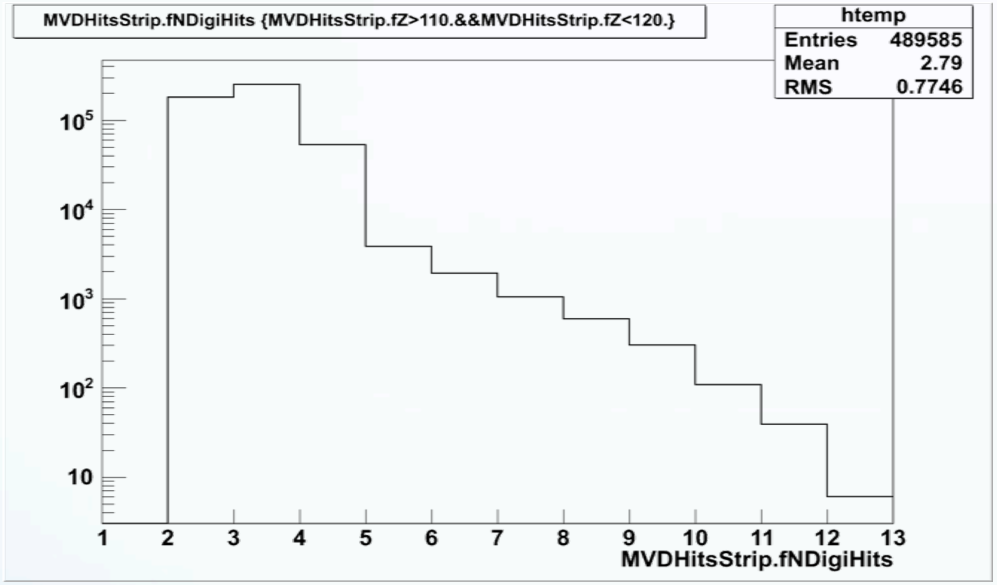
4 GeV electrons @ DESY



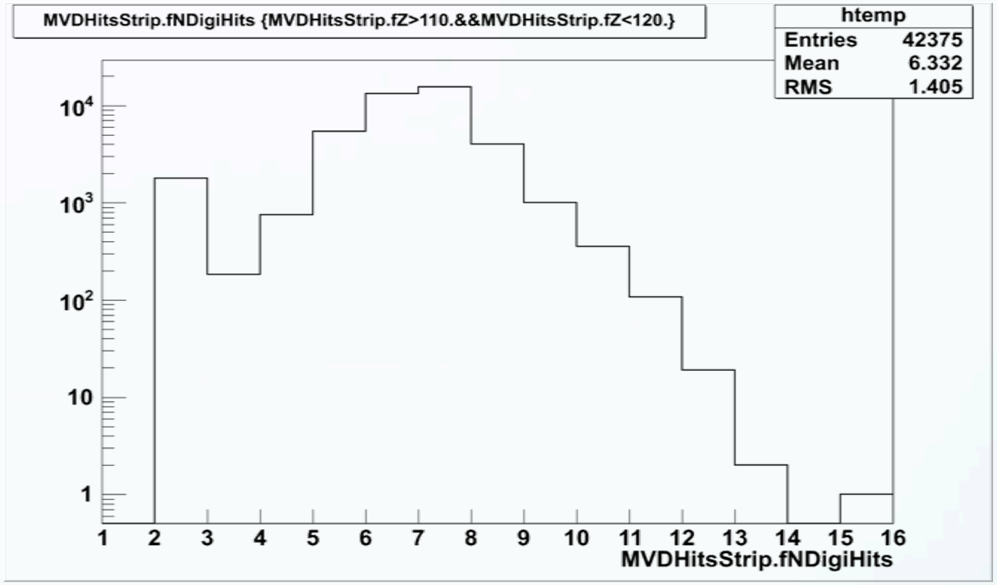
SIMULATIONS



Cluster size



0 deg rotation



45 deg rotation

Simulation Setup

G E A N T Version 3.2111   DATE/TIME 110601/1058   R U N 1   *
Data structure Date Time GVERSN ZVERSN   *
INIT 110601 1058 3.2111 3.77   *
KINE 110601 1058 3.2111 3.77   *
HITS 110601 1058 3.2111 3.77   *
DIGI 110601 1058 3.2111 3.77   *

Standard TPAR for this run are   *

CUTGAM= 1.00 MeV CUTELE= 1.00 MeV CUTNEU= 1.00 MeV
CUTHAD= 1.00 MeV CUTMUO= 1.00 MeV
BCUTE = 10.00 TeV BCUTM = 10.00 TeV DCUTE = 10.00 TeV
DCUTM = 10.00 TeV PPCUTM= 10.00 TeV

IPAIR= 0. ICOMP= 0. IPHOT= 0. IPFIS= 0. IDRAY= 0. IANNI= 0. IBREM= 1. IHADR= 0.
IMUNU= 0. IDCAY= 0. ILOSS= 4. IMULS= 1. IRAYL= 0. ILABS= 0. ISYNC= 0. ISTRA= 0.

Energy loss:no delta rays

Molière model