FoCal Test Beam Run

June 11-30, 2009 CERN PS and SPS facility

Participants: 23 total.

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Heonjoo Kim, Korea
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Terry Awes, our host from ALICE.

PHENIX Collaboration Meeting 08/06/09

Andrey Sukhanov for PHENIX FoCal group

FOCal 2009

4 mm W plates, ~21 X_0;

21 layer of ~500μ   Si pads 15x15 mm²

8 layers of ~300μ   0.5 mm wide Si strips (4 X + 4 Y)

PAD Sensors (micromodules)	3360	62x62 mm², 15x15 mm² pads
Subtowers (RO channels)	7680	960 octal preamps, 120 64ch. ADC
Strip Sensors (micromodules)	1280	62x62 mm², 0.5x62 mm² strips
SVX4 (128 channels)	1280	14 FEM stations
Bias	<200V	350 channels, 300 mka each

Goals of the test run

To set milestone and stop any further improvements;

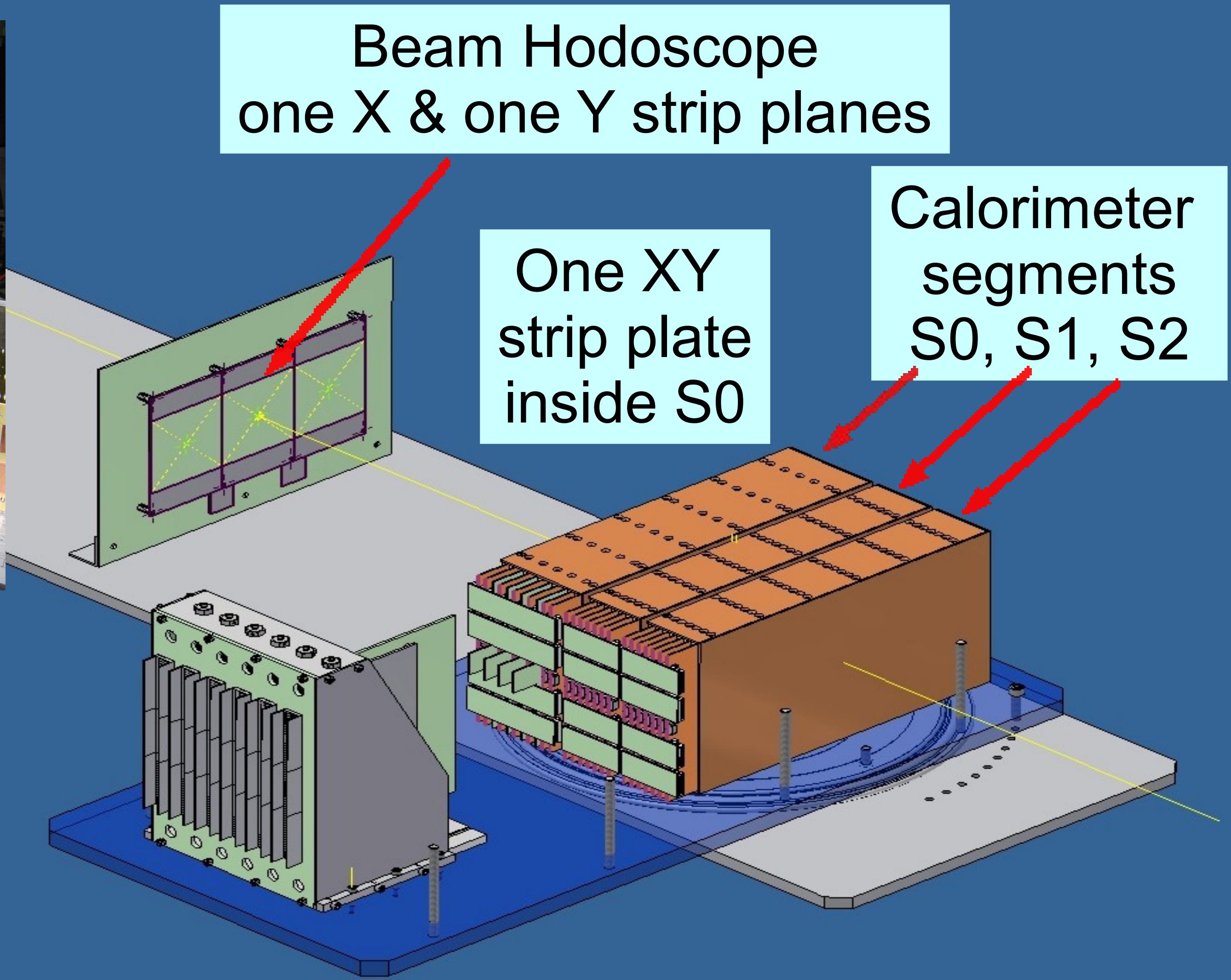
To get detector running in the field conditions;

To study detector performance and response to em-particles. To write NIM paper;

To identify shortcomings and set the project on a path to completion;

To confirm that we the PHENIX can still do great things in instrumentation as well as in physics.

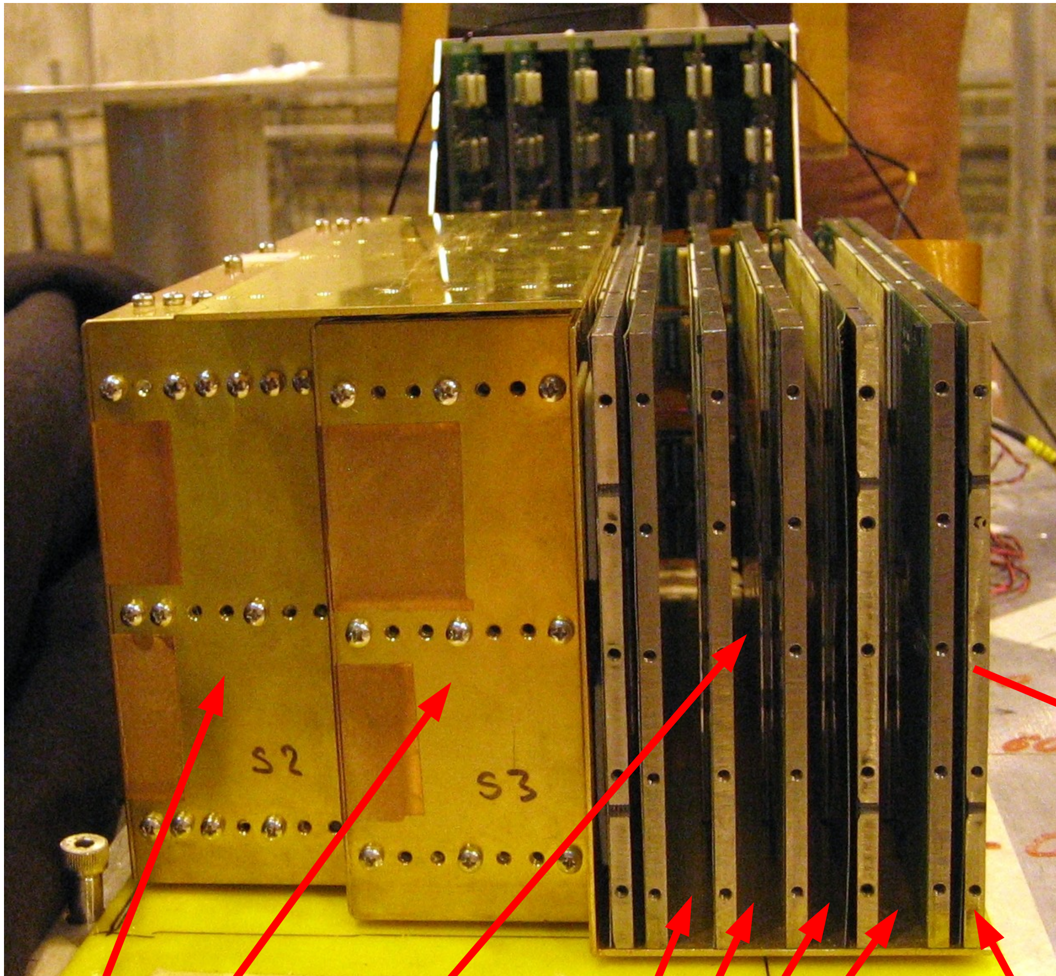
Test Beam Setup



What actually happened

- At Cern on June 11th (planned for run start on June 19th);
- Pad detector was well tested in all aspects except bias power (delivered to CERN from Dubna on June 14th);
- Strip micromodules (except few built at BNL) were almost ready for bonding. By June 25, 15 of strip micromodules were assembled, wire bonded, fully commissioned
- SPS was down till 22nd;
- Found PS (below 6 GeV/c) slot for June 14-19;
- Bias from Dubna was noisy, switching to backup at night (without Mike) resulted in a few summing cables damaged;
- Two nearly perfect days of data taking with pads only and a lot of data from PS.
- SPS run began on June 22nd and ended on June 29th;
- Teaching two DAQ's (pads and strips) to run in synchronized mode was pain ….;
- First data which included strip taken on June 27th and seriously digested through only at BNL;
- Analysis still ongoing. Detector as expected, readout needs bugs fixed, ranges tuned to physics and one more beam test (FNAL) before the prototype is ready for prime time in PHENIX.

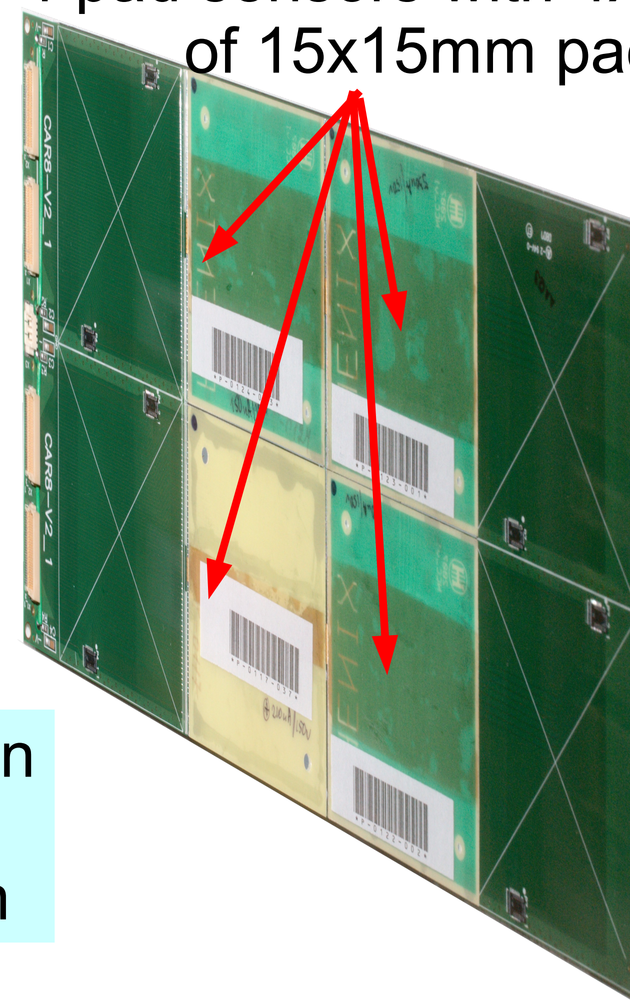
FoCal Brick



BEAM

Pad Carrier Board

4 pad sensors with 4x4 of 15x15mm pads



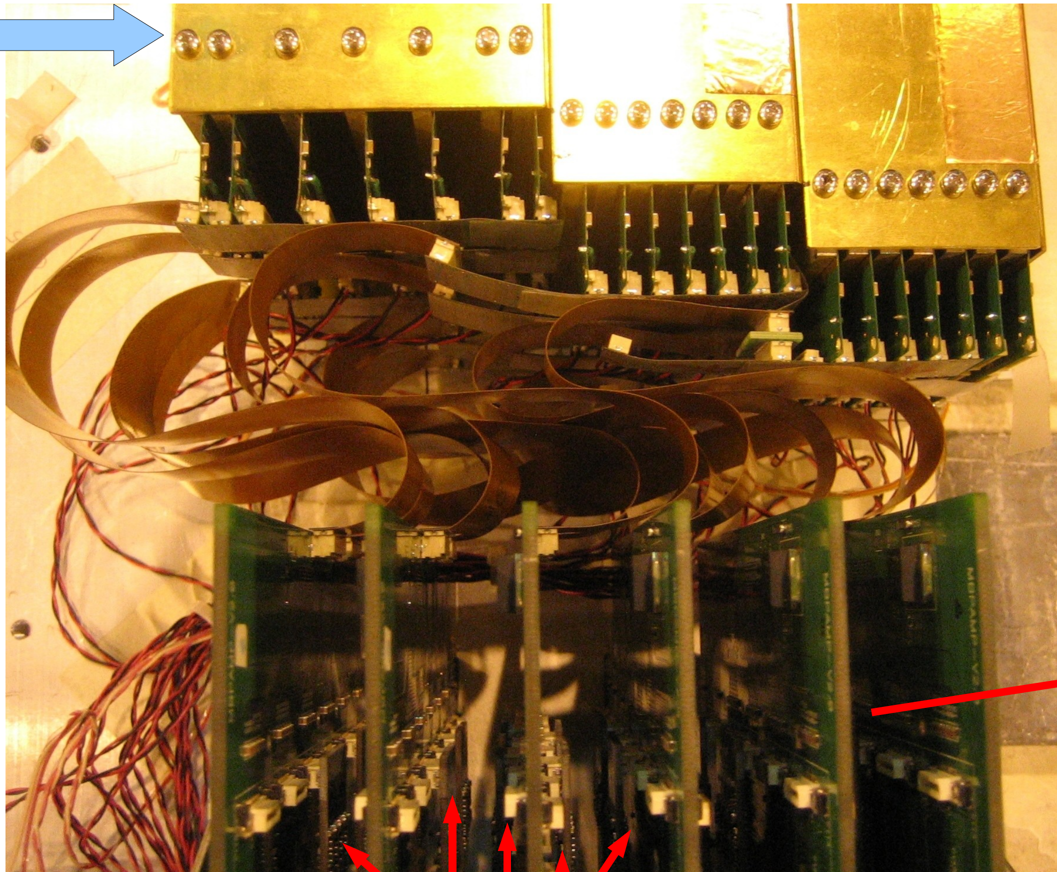
S2, S1, S0 Segments

Gaps 4,3,2,1 For strip layers

Tungsten plates 4.2 mm

Longitudinal Summing of Pads

BEAM

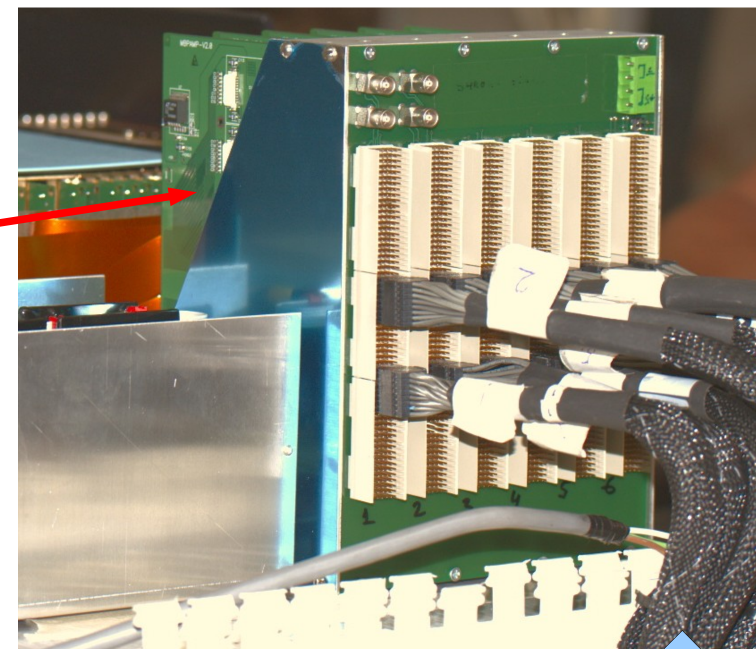


Home-made hybrid current preamps, gain 4 KOhm.

Each of 3 segments provides signals of 8x8 sub-towers, 15x15mm, 7 layers of W+Si.

Total in pads: 84 sensors -> 192 towers

Motherboards in crate

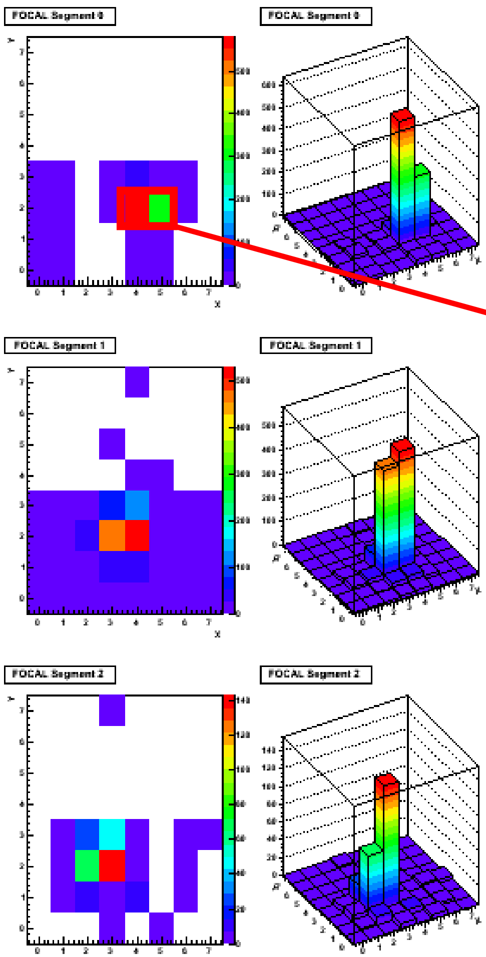


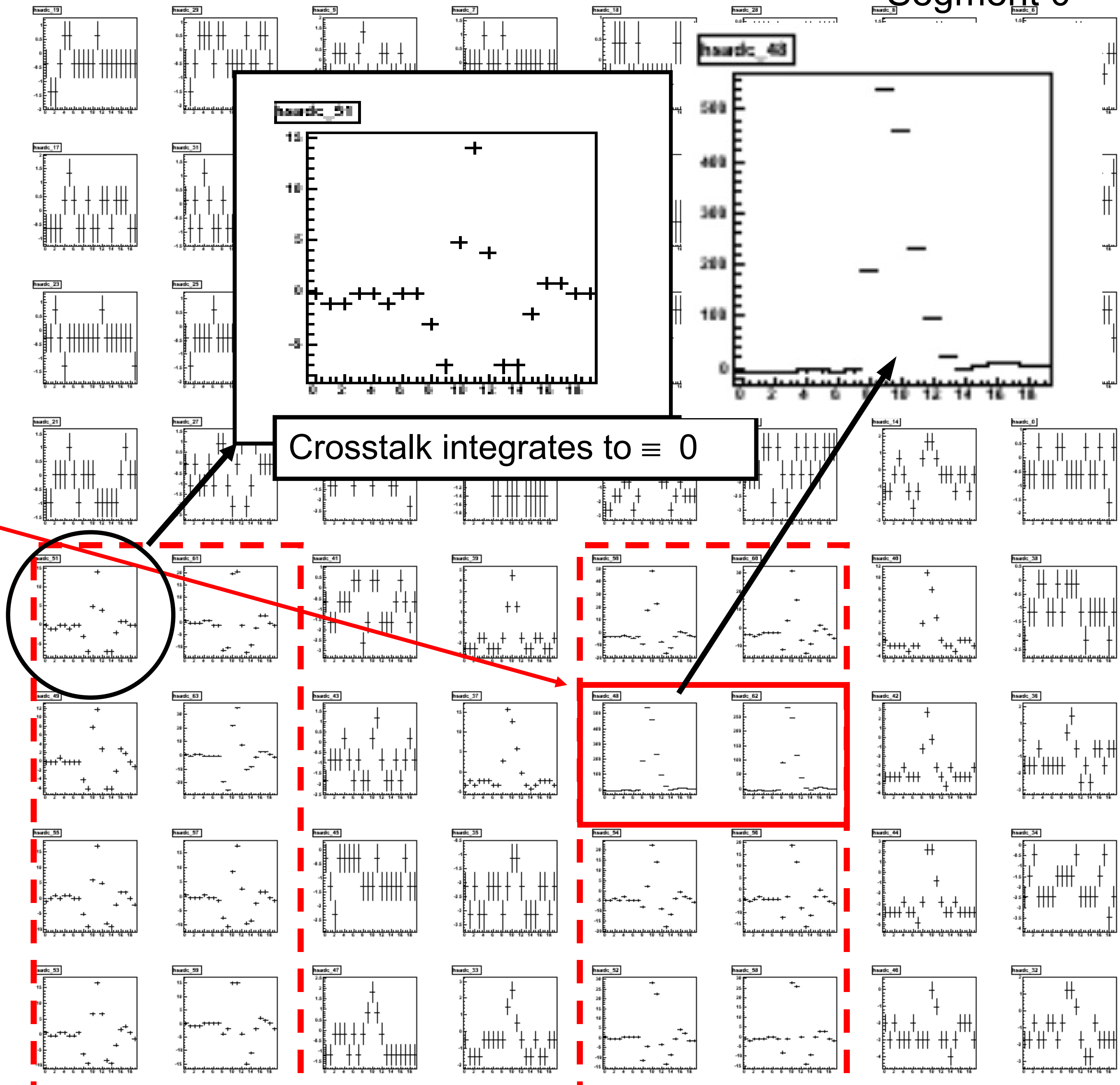
10m differential cables to HBD ADC 12bit 65 MHz

Crosstalk

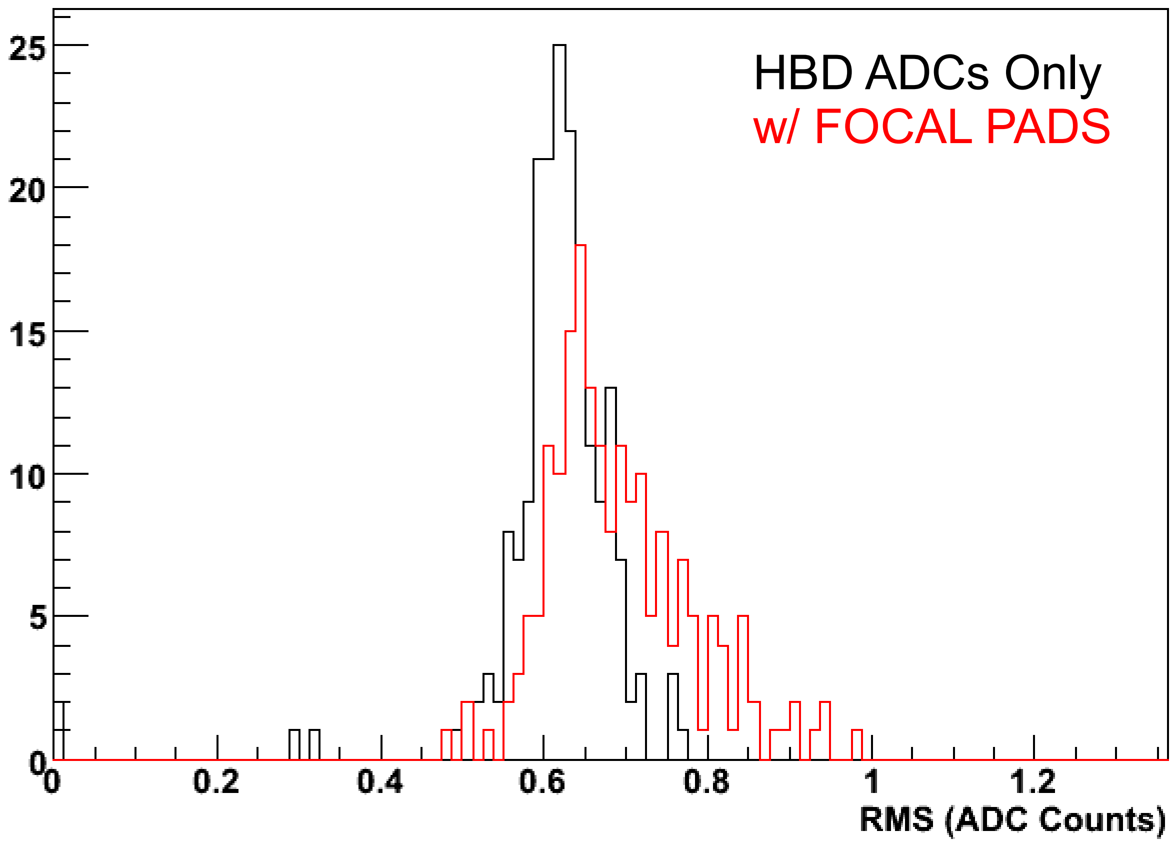
Run 341
50 GeV e+

Segment 0



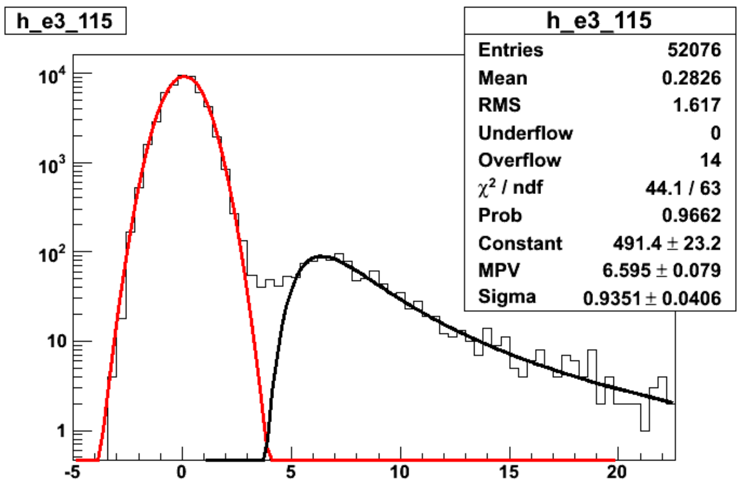


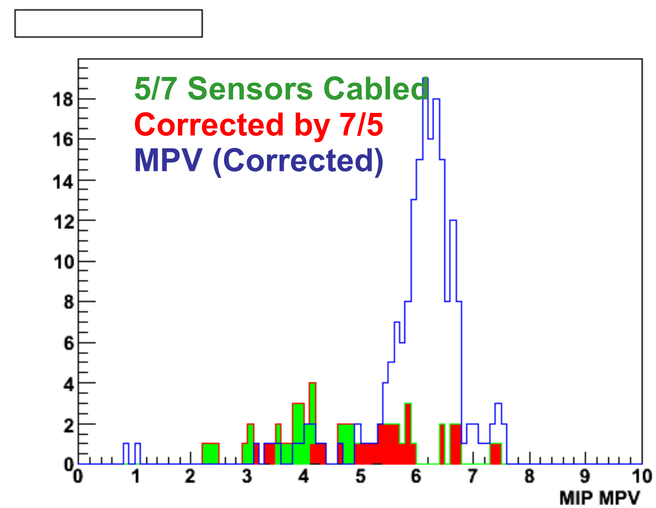
Pad System Pedestals

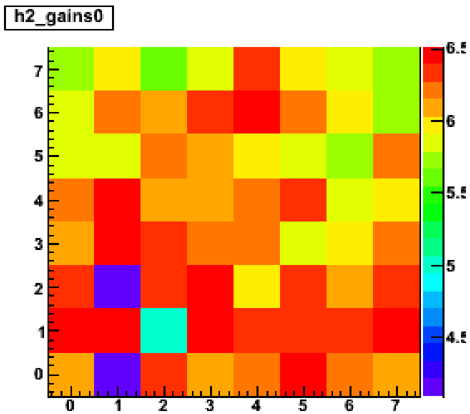


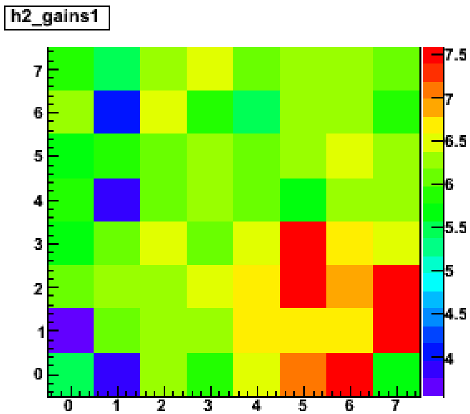
System is extremely quiet
With PADS connected, get only 0.2 ADC increase in RMS

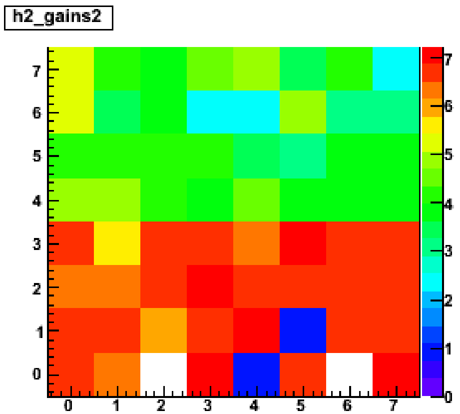
Muon Response





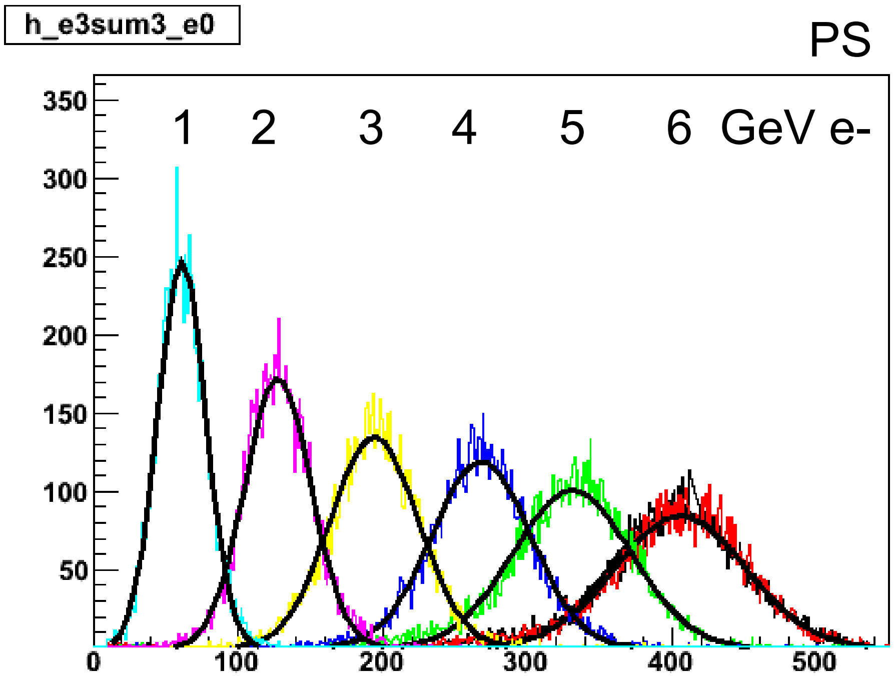


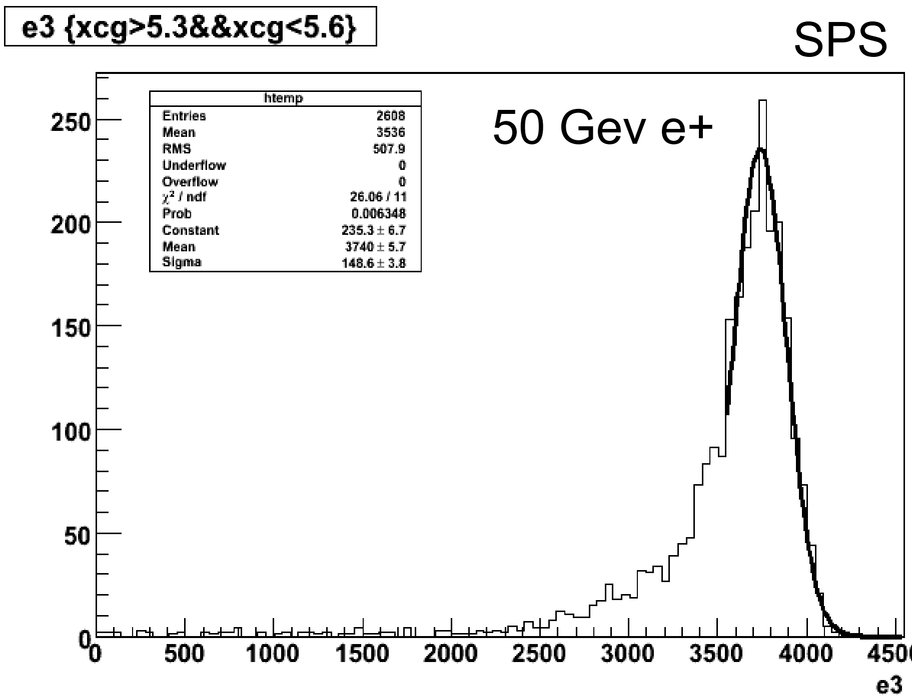




Excellent response to MIP, with amplitude consistent with expectations
Fits very well to gaussian pedestal plus landau
Excess between them comes from muons which cross more than one pad
Should be able to use to calibrate gains. Currently still under study.
S/N (MIP/RMS) is more than 10 (noise is too low to measure)

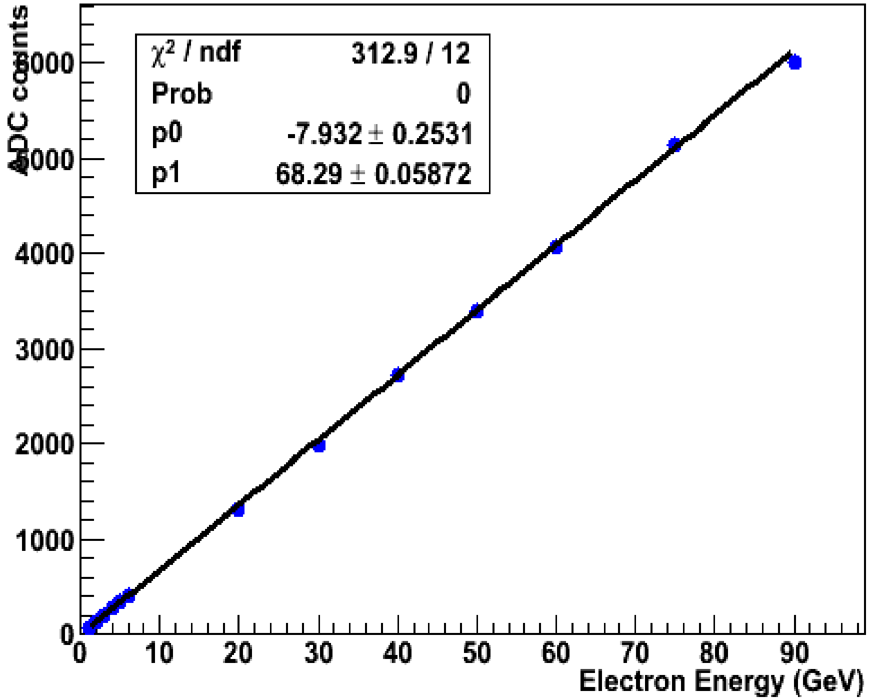
Electron Response

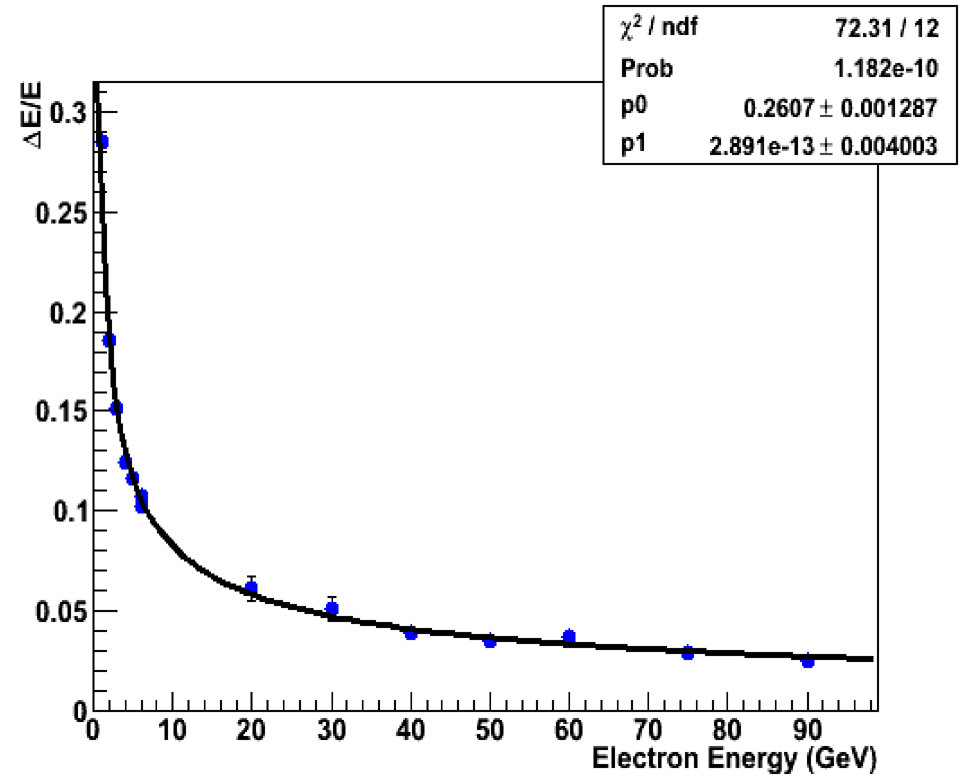




Electron beam at PS from 1-6 GeV
Quite clean beam
Positron Beam at SPS from 20-100 GeV
@ 100 GeV ADC starts to saturate, 90 is effective limit
Low energy tail in events being investigated
Brehmstrahlung? Backgrounds?

Electron Performance





Good linearity from 1 to 90 GeV. Different environment (PS & SPS) aligns nicely.
Current resolution of ~26%/√E, should be able to improve this. The constant term is zero.
Design resolution is 23%/√E
However, slight differences between design and current prototype which needs to be evaluated
Full comparison between simulation and prototype data now underway

Pad System Summary

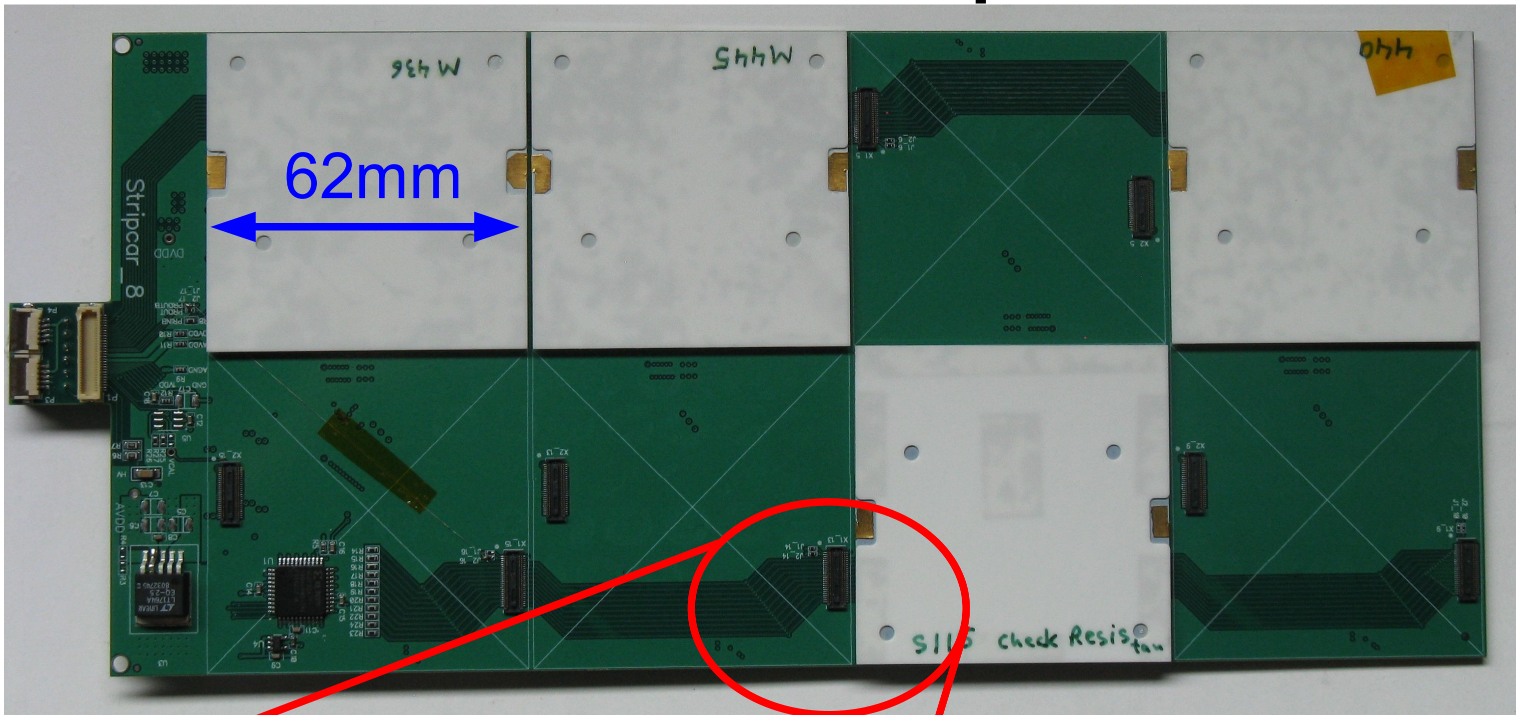
With 11 bit ADC system we are linear up to 90 GeV
We clearly see the MIP peak (for normal incident particles)
Achieved dynamic range ~ 3000, limited by the ADC saturation

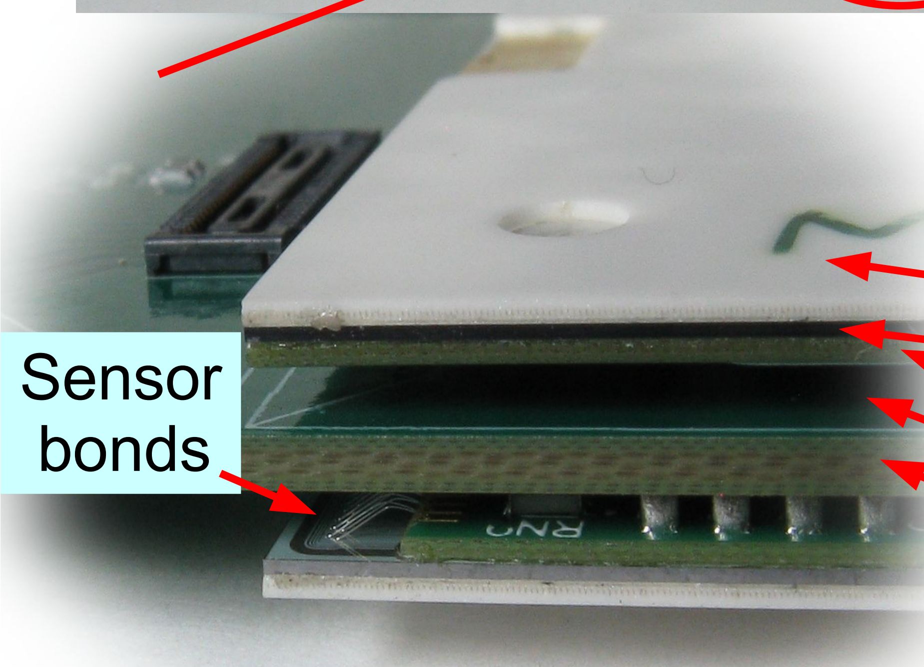
1 MIP in 0.525mm of Si = 140KeV
1 MIP in 7-layer tower = 1 MeV
50 GeV e- deposits 400 MeV in 7 layers
The noise is 1/10 of a MIP

The front-end electronics for pads meets the design requirements.

- Summing cable will be improved.
- 90 degree cable twist between brick and FEM needs modeling.
- Crosstalk is greater than expected (cables?). Fortunately it integrates to zero in 200 ns.

Strips





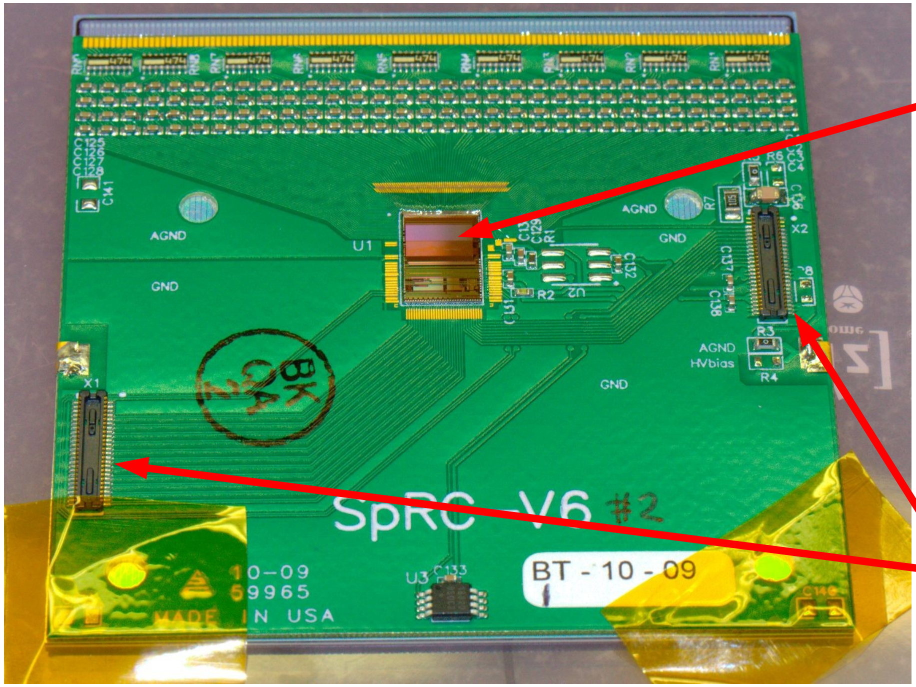
Strip Carrier with 4 X-sensors installed on top.

XY-Strip stackup
- Ceramic 0.4mm
- Silicon, X strips, 0.3mm
- Interconnect PCB 0.2mm
- Component gap, 1.0 mm
- Carrier PCB 1.0mm
- Y-strip module

Strip Readout

<u>System specifications (fully understood during this run only!!!)</u>

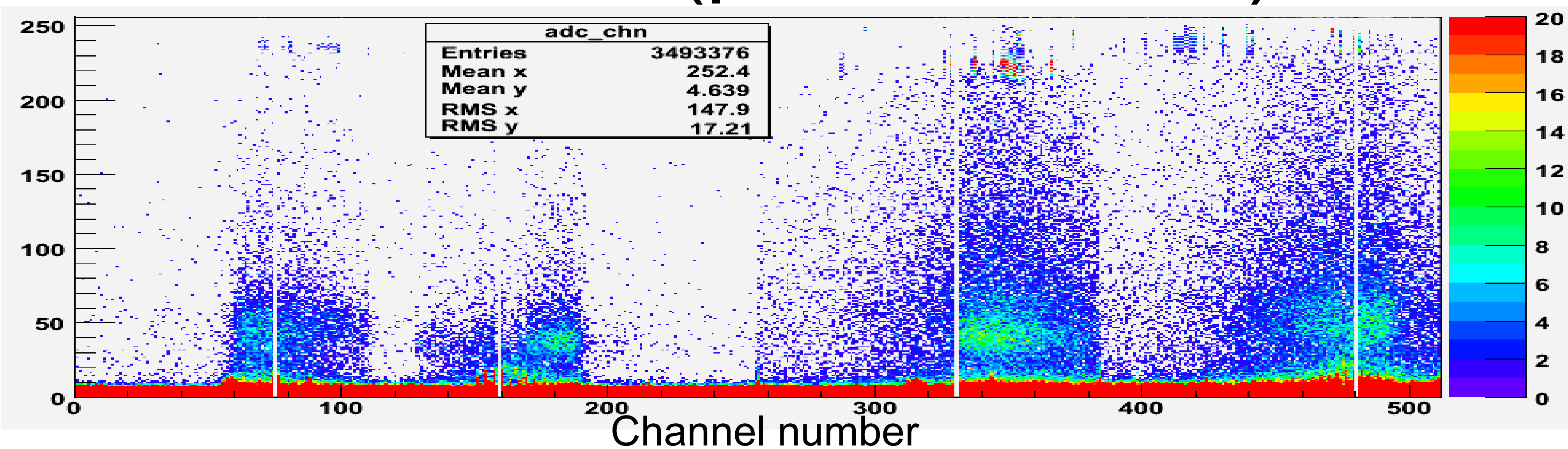
- Energy deposition range of 6-80 MeV per Si layer (50 GeV electrons),
- High occupancy, 30 strips with energies above MIP threshold (½ of MIP MPV),
- Extreme compactness.

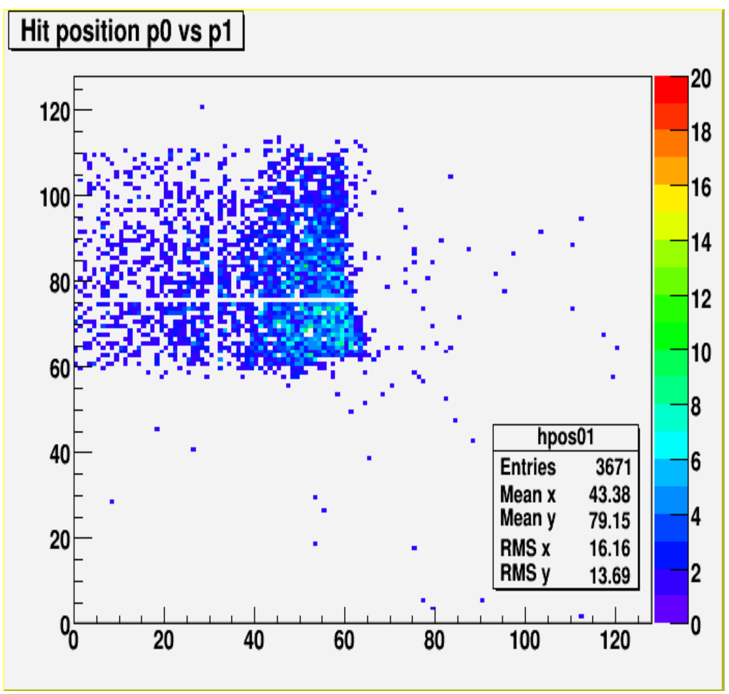


<u>Implementation</u>

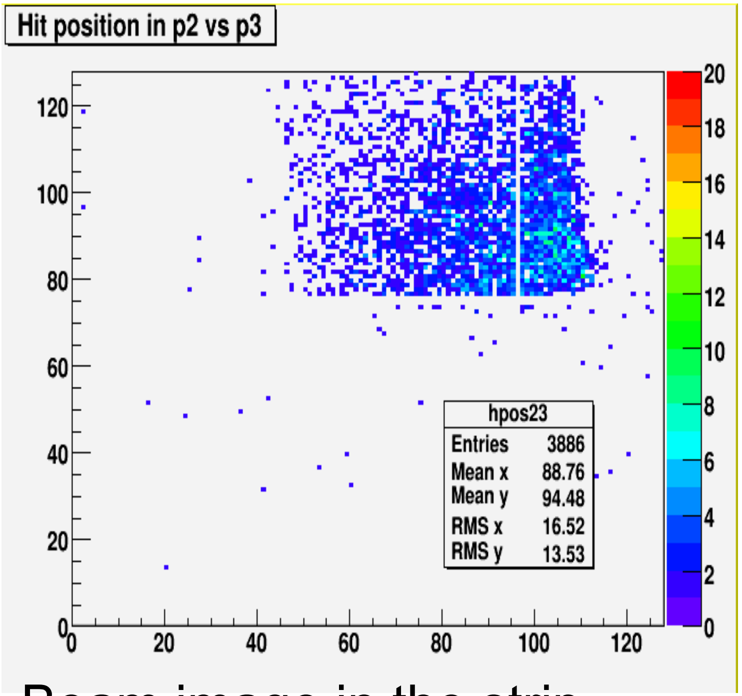
Readout chip: SVX4 ASIC, 128 channels, digital output using 8-bit on-chip ADC.
The readout card is mounted on top of the sensor.
The AC decoupling is on the readout card.
Snap-N-Place module attachment to the carrier boards.

MIP Run (pi- at 50 GeV)



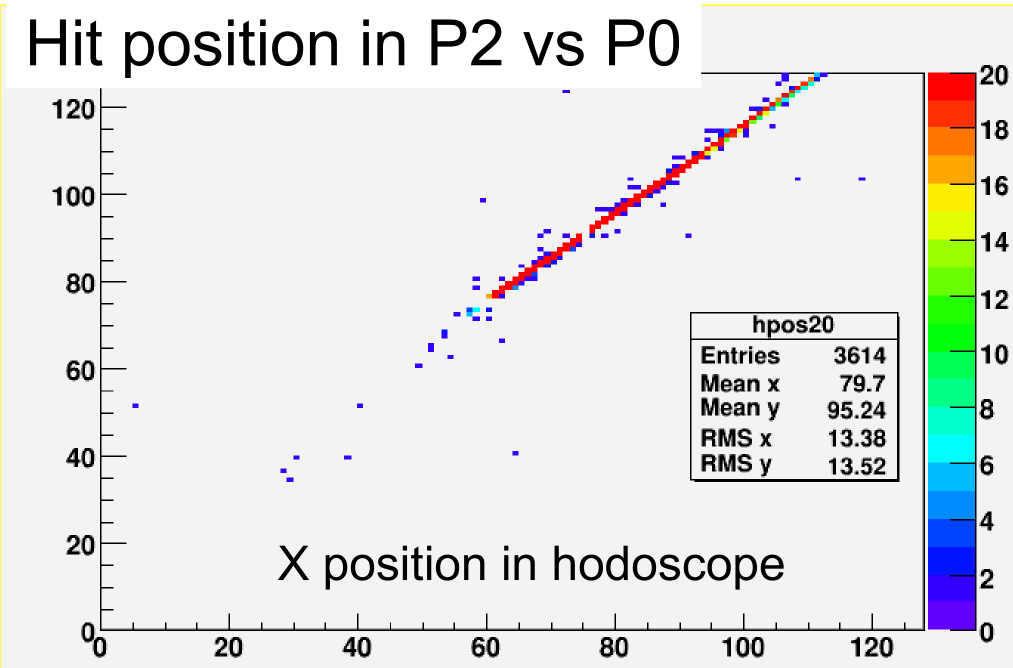


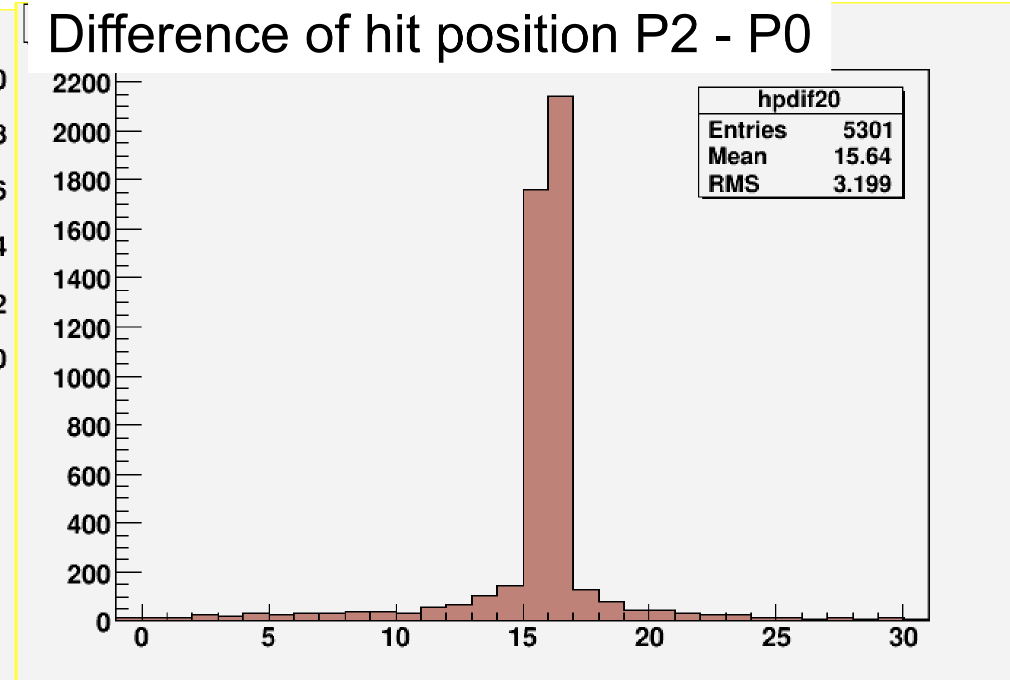
Beam image in the hodoscope strip plane.

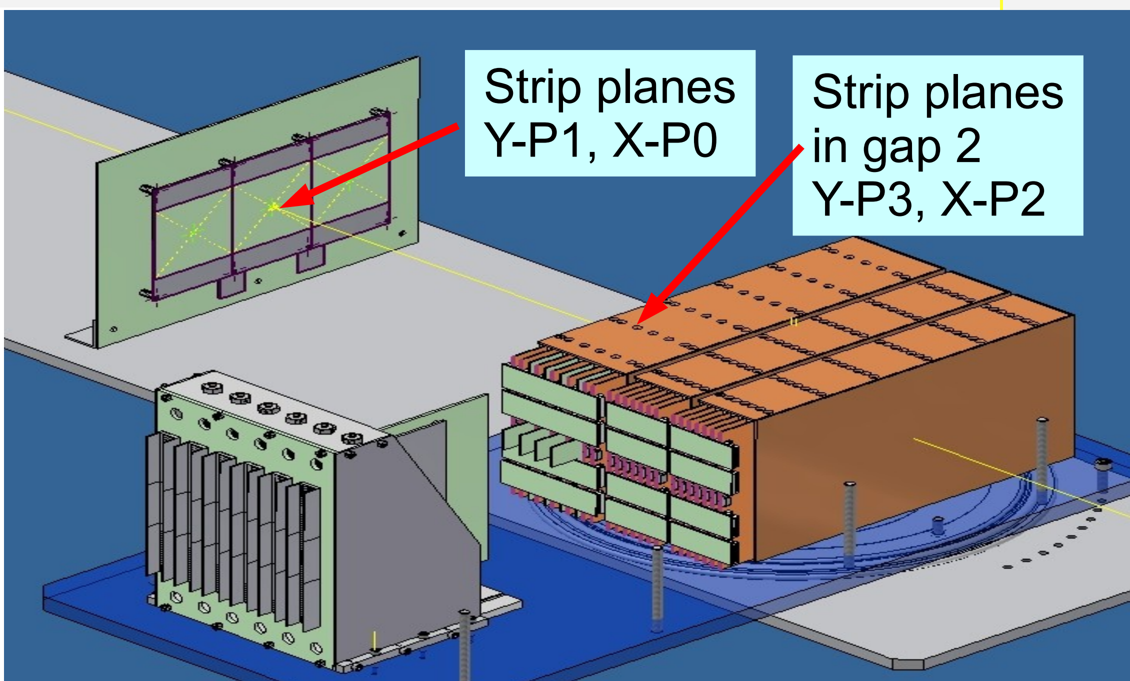


Beam image in the strip plane in gap 2, segment S0.

Strip Analysis

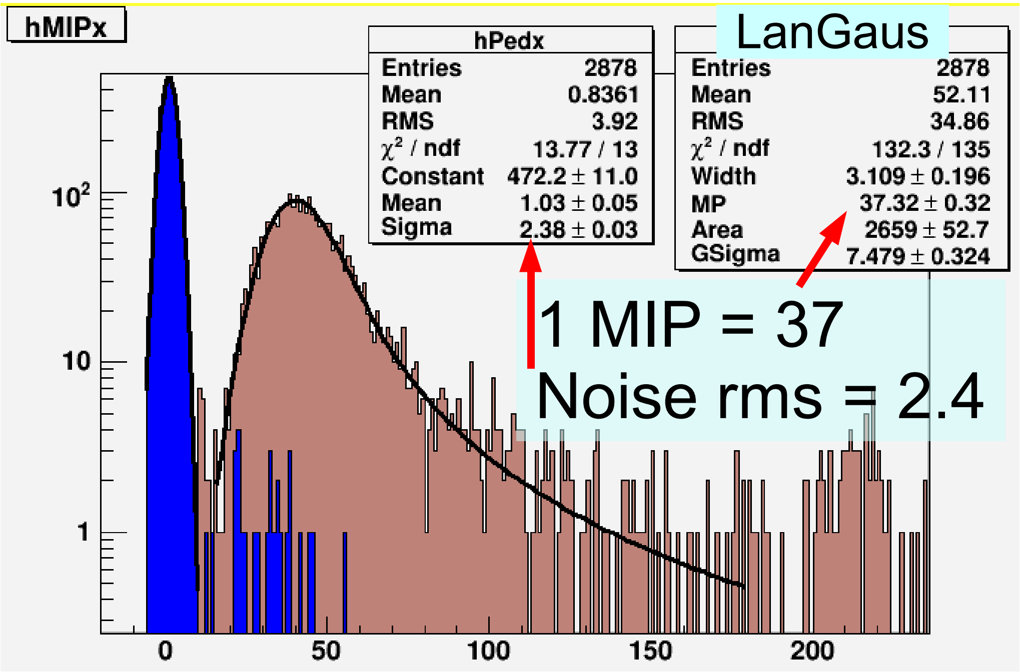


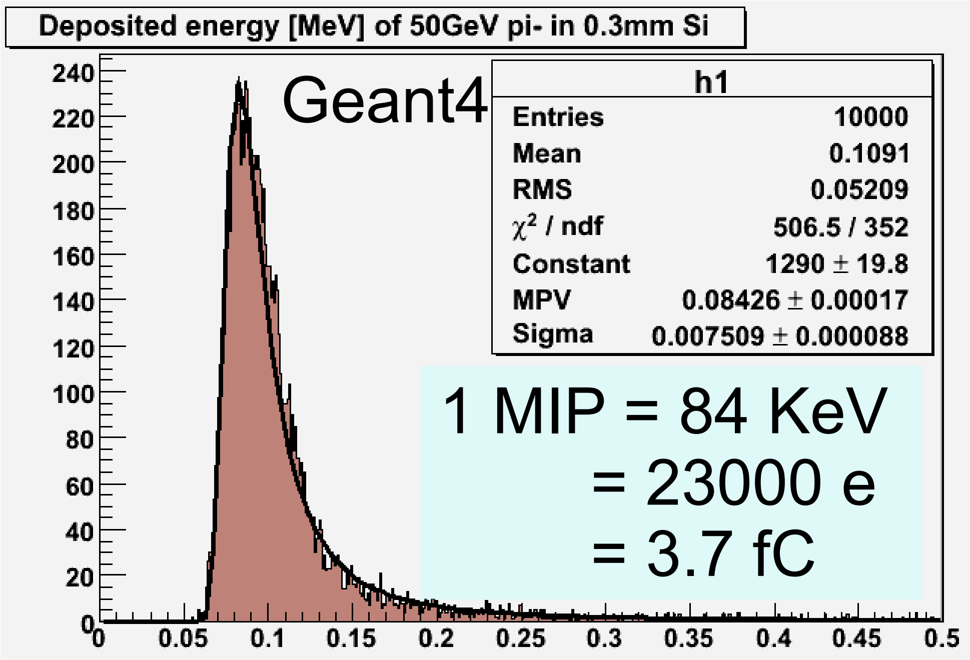




The beam was very collinear.
Very good correlation in hit position between hodoscope and calorimeter planes.
Easy MIP calibration

Strip Analysis, Signal/Noise





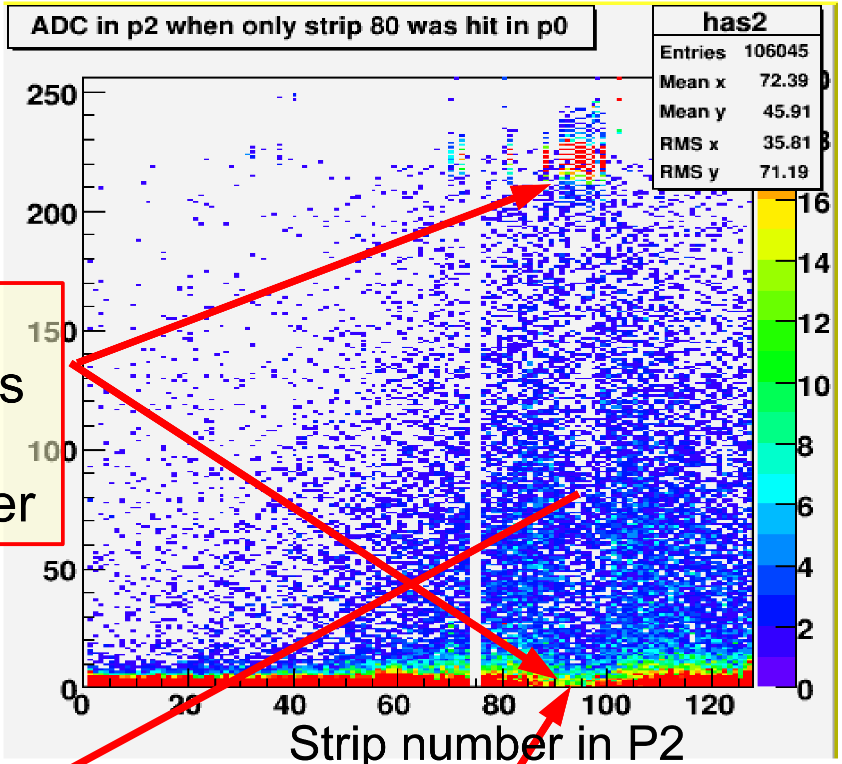
MIP is calculated by adding amplitudes of 3 strips around impact point.
The noise rms of one strip is 2.4
This corresponds to 6.6 KeV (assuming MIP deposition = 84KeV)
The equivalent noise charge **ENC = 0.24-0.29 fC (1500-1800 electrons)**.
The signal-to-noise (MIP MPV divided by RMS of the pedestal) is **12.5 - 15.5**.

Strip calorimetry. Under Study.

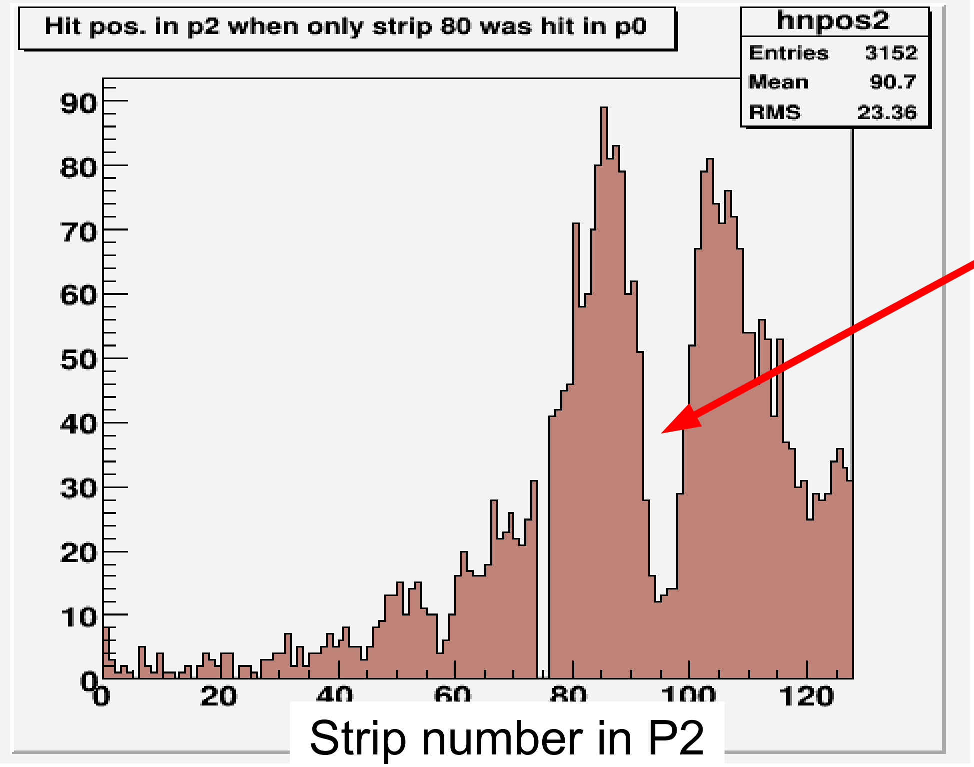
Data taken keeping the gain setting used for study the MIP signals while exposing calorimeter to 50 GeV e+.

Real-time common mode noise rejection was still active.

Overflow in several strips around the shower center

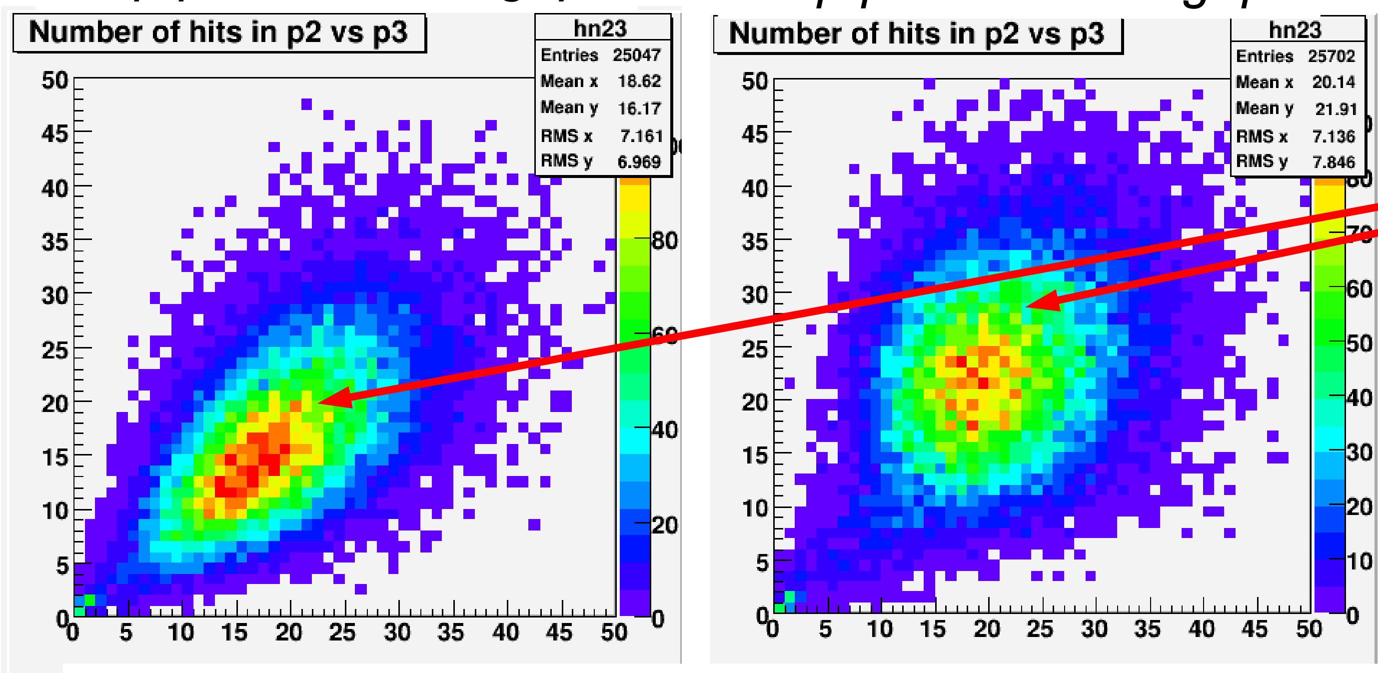


Shower position, selected using a hit in the hododscope silicon strips



50 GeV e+. Under Study.

Strip planes are in gap1 *Strip planes are in gap4*



Number of fired strips underestimated by 2 strips

Number of fired strips in X vs Y (left at 2 X0, right at 4 X0)

The gain of the system should be adjusted so that the SVX4 channels do not saturates for 50 GeV EM showers.
<u>Possible solutions are under investigation.</u> (Tune the preamp / pipeline parameters in SVX4.)

Strip Summary and Plans

The arrangement with the readout card on top of the sensor works!
Equivalent Noise Charge in the strip system is 0.24-0.29 fC (1500-1800e). The S/N = 12-15 (MIP/$Noise_{rms}$)

The strip planes when placed between the calorimeter plates do not affect the performance of pad electronics (Tested with 2 strip modules).
The grounding is adequate. It was possible to work from the single power supply providing DVDD and AVDD from separate regulators.
The Snap-N-Place mounting is safe for wire bonds.
The encapsulation of the wire bond is not necessary.
The pitch adapters on SPRC may further simplify the production and improve S/N.

- System gain should be adjusted to meet the project requirements.
- Maximize the dynamic range, push it to the limit of the 8-bit system.
- Connect FEM to PHENIX DCM.

Summary

- FOCal equals two PHENIX subsystems (pads and strips). Closest analog to pad-component (~9000 channels) is HBD (~1200 channels), closest analog to strips are two outer layers of VTX (x6 more channels then in FOCal). By the end of the run both FOCal subsystems were running in synch;
- Low energy data (PS, 1-6 GeV) agree with simulation (calorimeter performance), high energy data (SPS, 20-100 GeV) show degraded resolution (constant term) – talking to beam experts;
- Strip system (γ/π^0 discrimination) finally works but needs an extra development. Hardware organization must become more flexible, geometry and sensitivity need tuning to better match shower development, additional simulation is required to define an optimal allocation of the available dynamic range (8 bit ADC's in SVX4).

- Expect to be ready for final testing in 4 months.