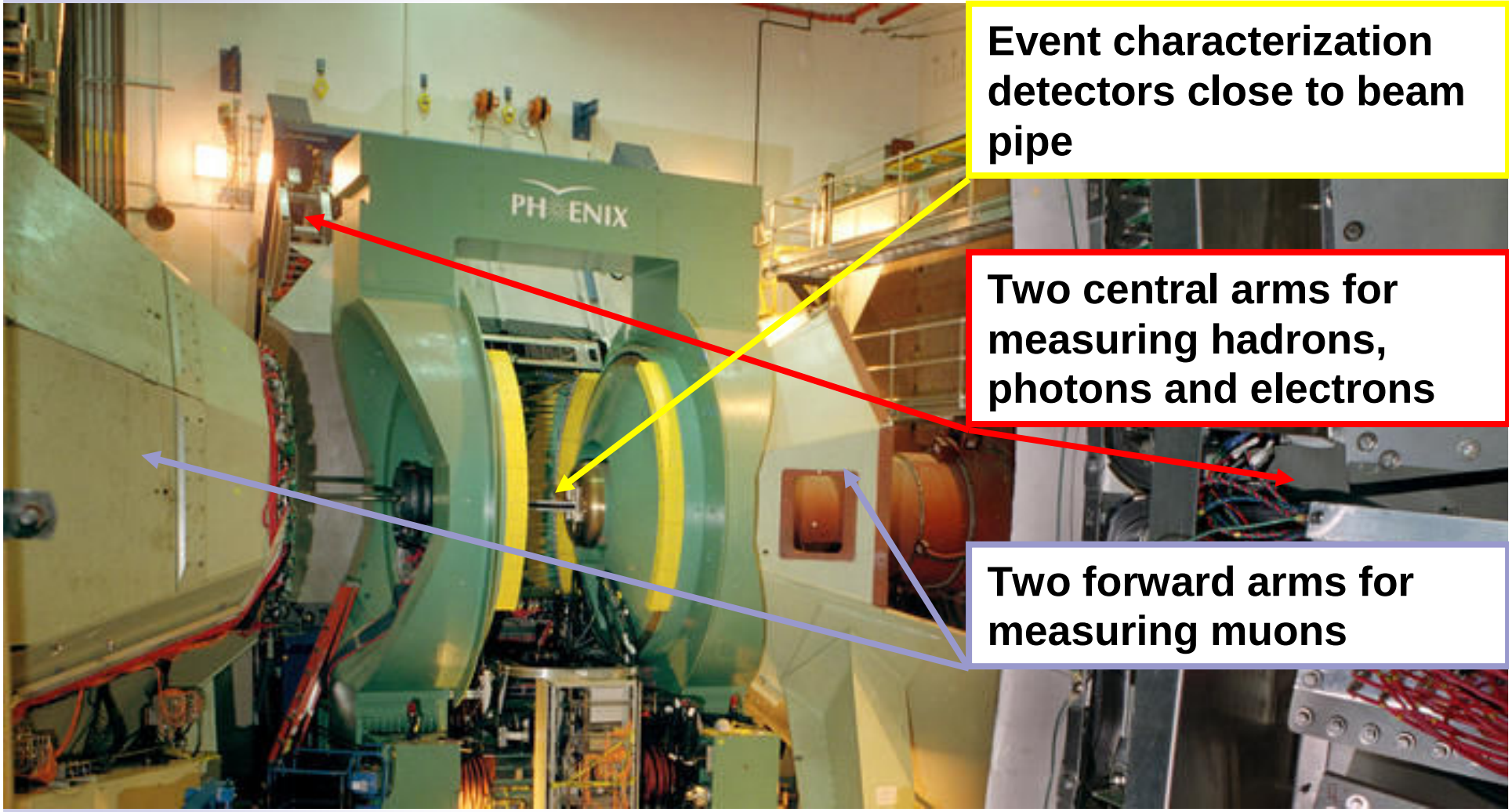
BNL, RHIC, PHENIX

# *Forward Calorimeters for the PHENIX Upgrade*

# PHENIX original



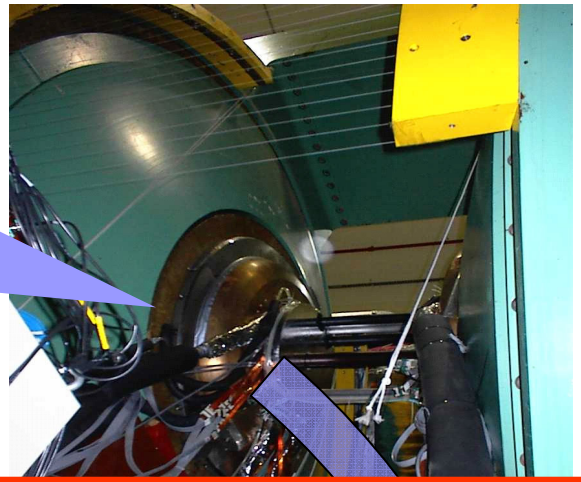
***New physics -> old observables – new phase-space region***

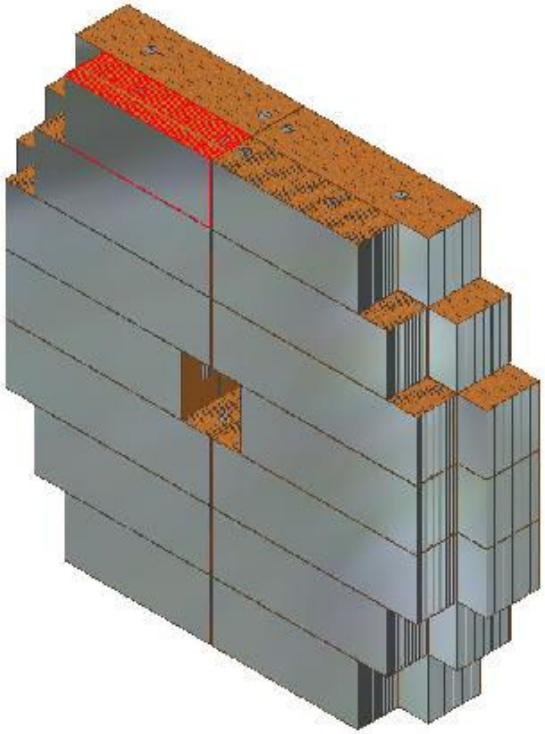
*direct photons: $p_T$>2 GeV/c*

*direct leptons: isolation*

*jets: total energy, leading $\pi^0$;*

*$\pi^0$'s*





## Detector specifications

***$\pi^0$***

***Reasonable energy resolution for em probes;***

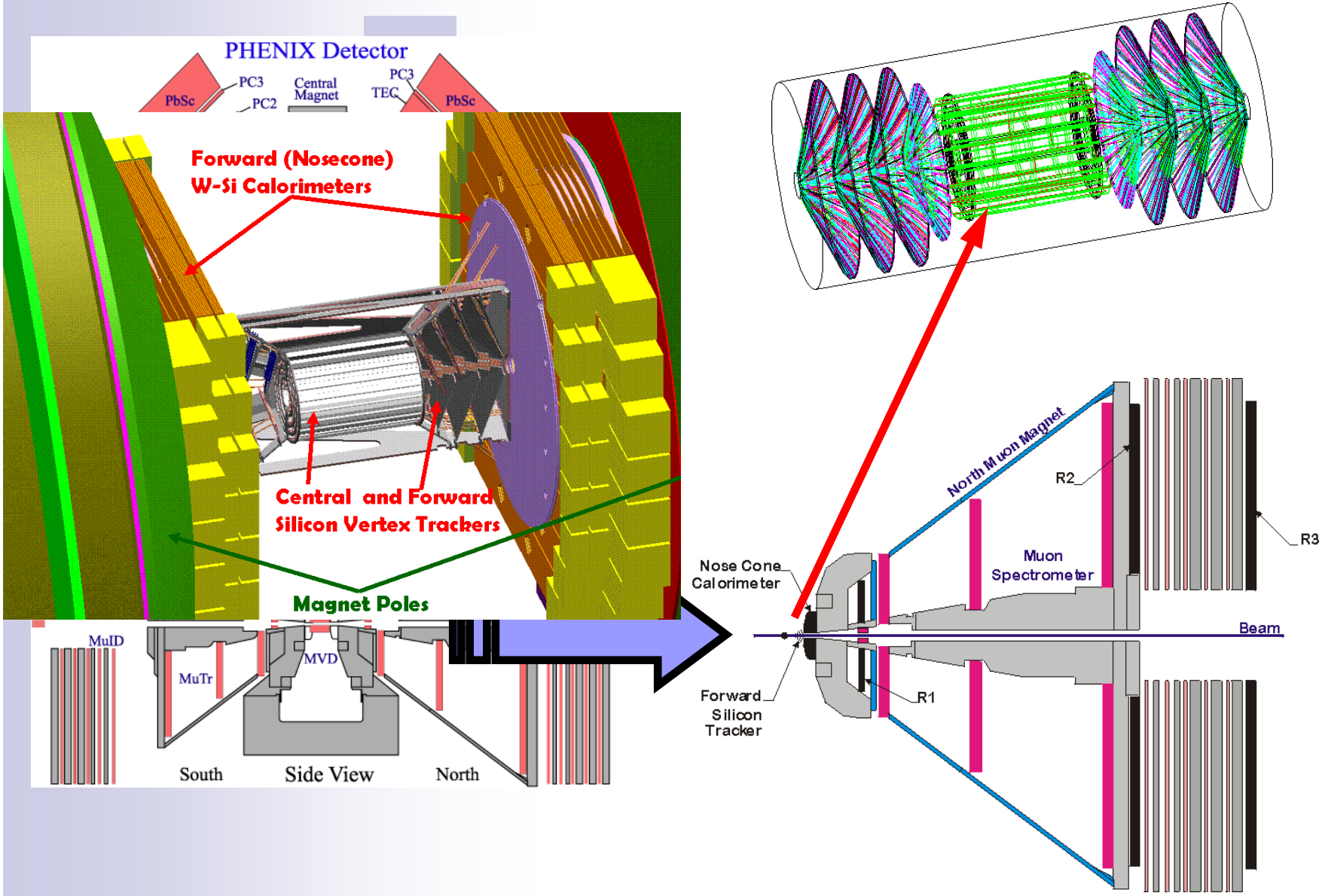
***Separation between em and hadronic signals;***

***Ability to reconstruct overlapping photons;***

***Jets***

***Cone energy measurements***

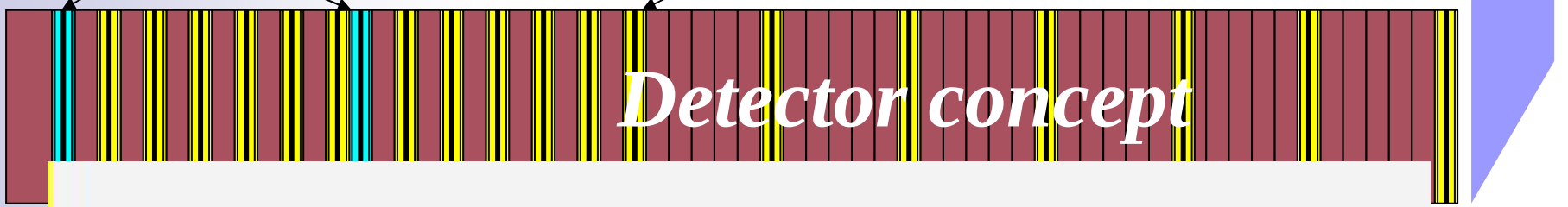
# PHENIX Upgrade

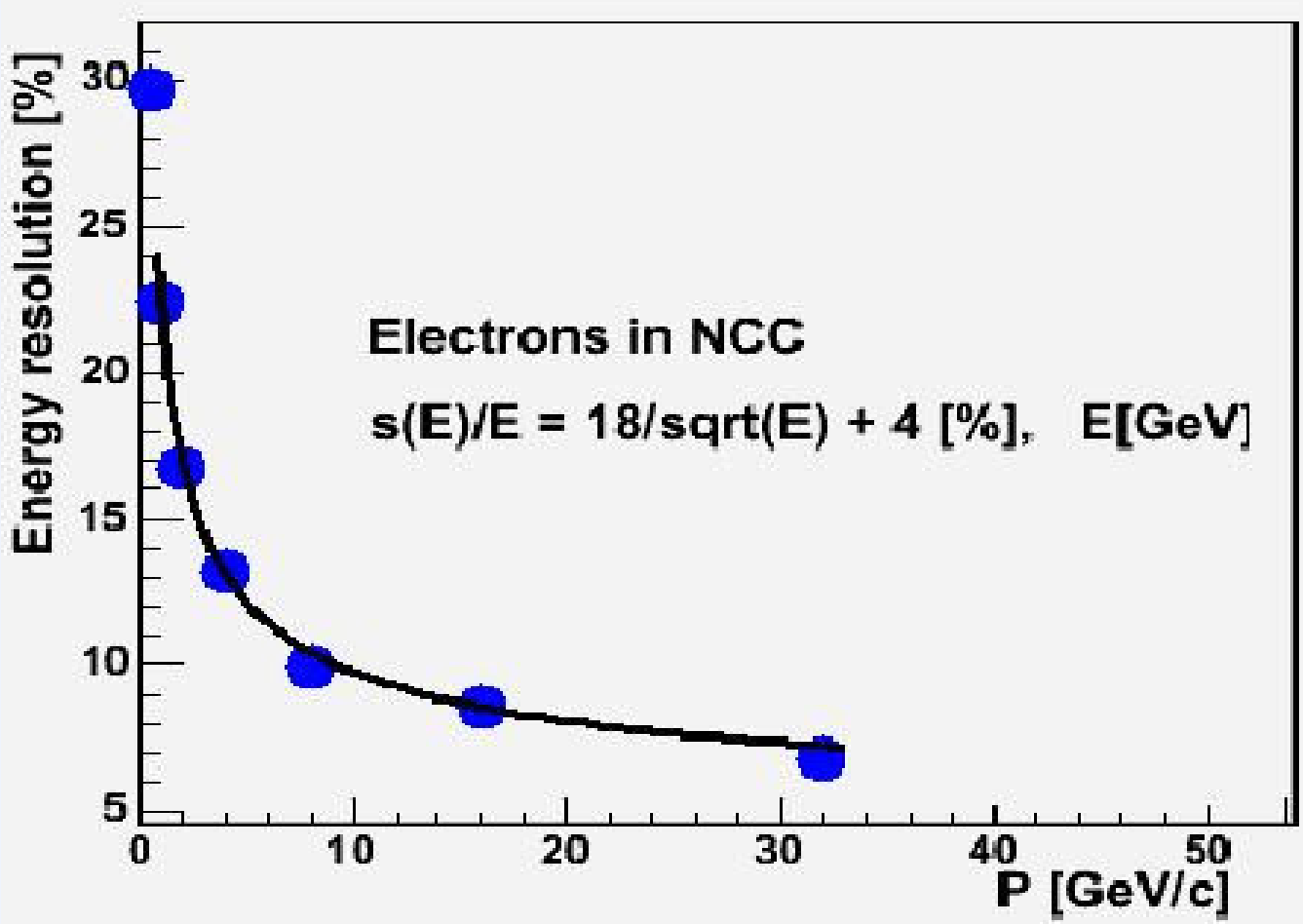


# Considerations & compromises

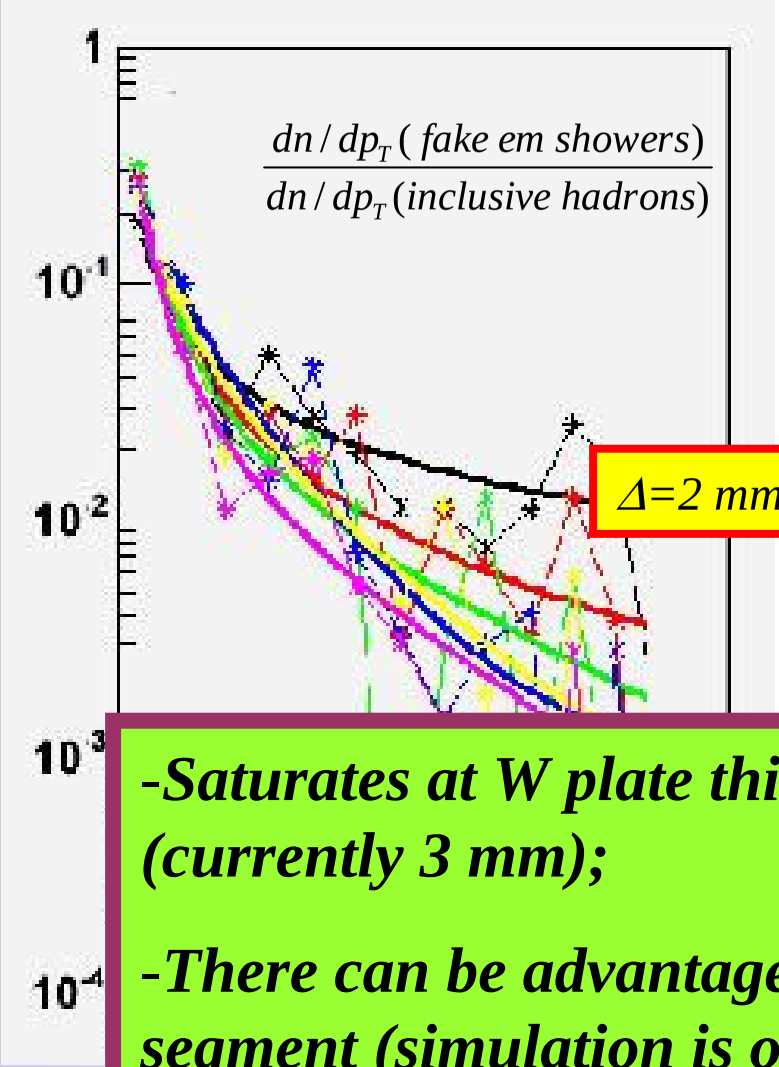
- **Designed to produce clean sample of electromagnetic showers**
  - *Segmented em-section: 7 + 5 $X_0$;*
  - *Hadronic segment: ~ 1 $\Lambda_{abs}$*
  - *Lateral segmentation: <$L_{moliere}$*
- **Optimized for $\pi^0$ reconstruction to 30 GeV/c**
  - *Converter and PreShower layers to see photons;*
  - *ShowerMax layer to measure decay asymmetry*

# Detector concept



# *Optimization: plate thicknesses vs energy resolution and hadron rejection*




© *6 sampling cells per segment (cost)*

**2 – 5 mm plates in EM1/EM2**

**11-16 % sampling term to em-resolution at 1 GeV**

**17-11 mm plates in Hadronic segment**

*thicker plates in em segments improve*

-em resolution at high energies;

-Jet energy measurements

***-Saturates at W plate thickness in EM segments > 3mm (currently 3 mm);***

***-There can be advantage in switching to Pb in hadronic segment (simulation is ongoing).***

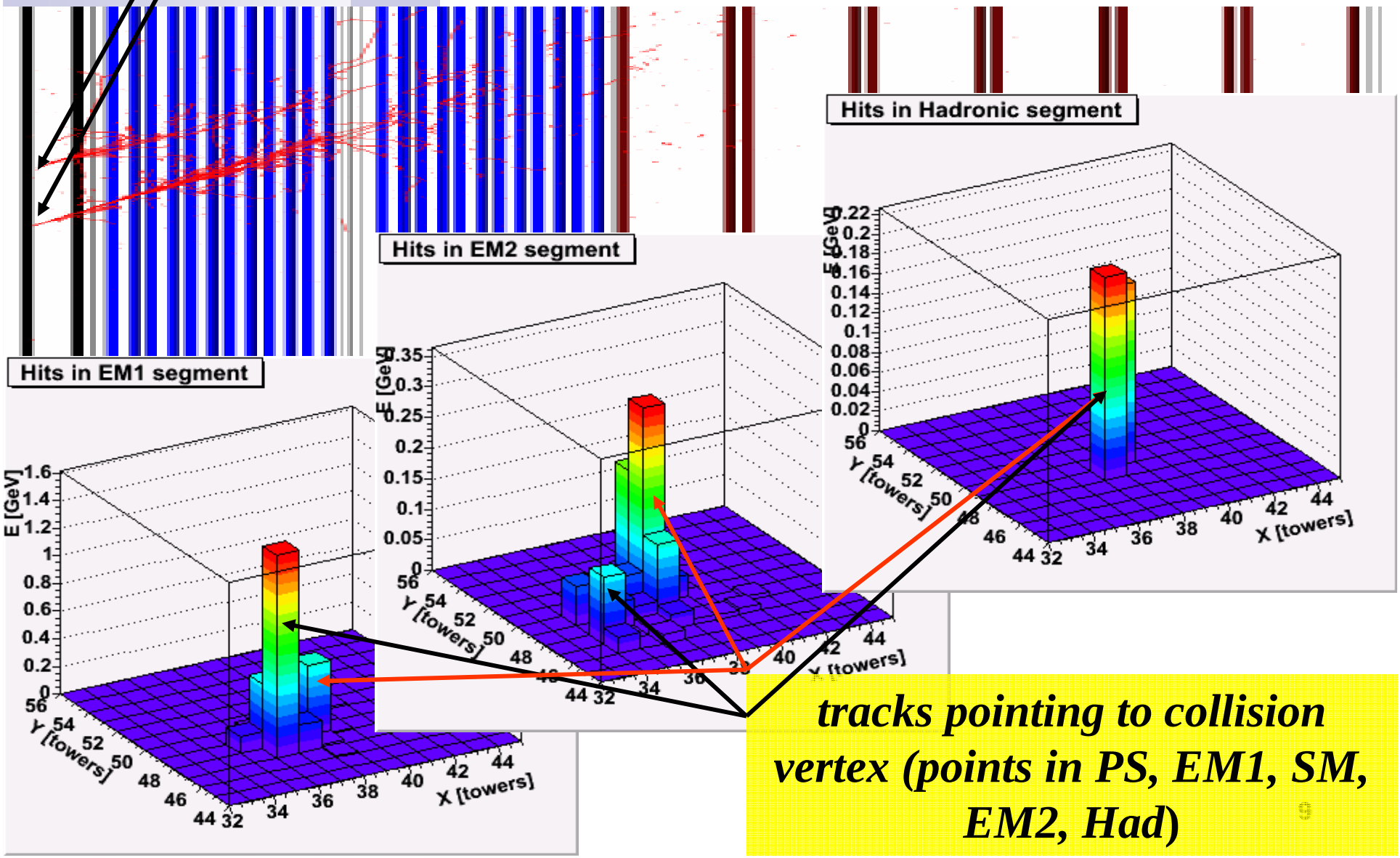
# NCC –tracking calorimeter

| Parameter | | Value | Comment |
|---|---|---|---|
| Distance from collision vertex | | 40 cm | |
| Radial coverage | | 50 cm | |
| Geometrical depth | | ~19 cm | |
| Absorber | | W | 42 Lrad or 1.6 Labs |
| Readout | | Si pads (15x15 mm2) and pixeleted strips (.0.5x0.5 mm pixels grouped into 60 mm long strips) | |
| Calorimeter | | EMC(12 sampling cells: 3mm W + 2.5 mm readout) longitudinally structured into two identical nonprojective sections.<br>Leakage(6 sampling cells: 15 mm W + 2.5 mm readout) | |
| Preshower detector (PS) | | 2 Lrad W converter followed by a stripixel layer (0.5 mm strips) with 2-d readout | |
| Shower max detector (SMD) | | In between two EM sections at ~ 7 Lrad depth. Stripixel layer (0.5 mm strips) with 2-d readout | |
| Multiple scattering in NCC combined with Fe magnet pole | | 133 MeV | To compare with 106 MeV in the existing configuration with Cu NoseCone |
| Expected EM energy resolution % | | ~18/sqrt(E) | |
| Expected jet energy resolution % | | ~100/sqrt(E) | |
| Two showers resolved at | in calorimeter | 3 cm | |
| | in preshower | 2 mm | In simulation effective for shower separation down to 4 mm |
| | in shower max. | 4 mm | |

# $\pi^0$ tracking: 5 GeV/c example

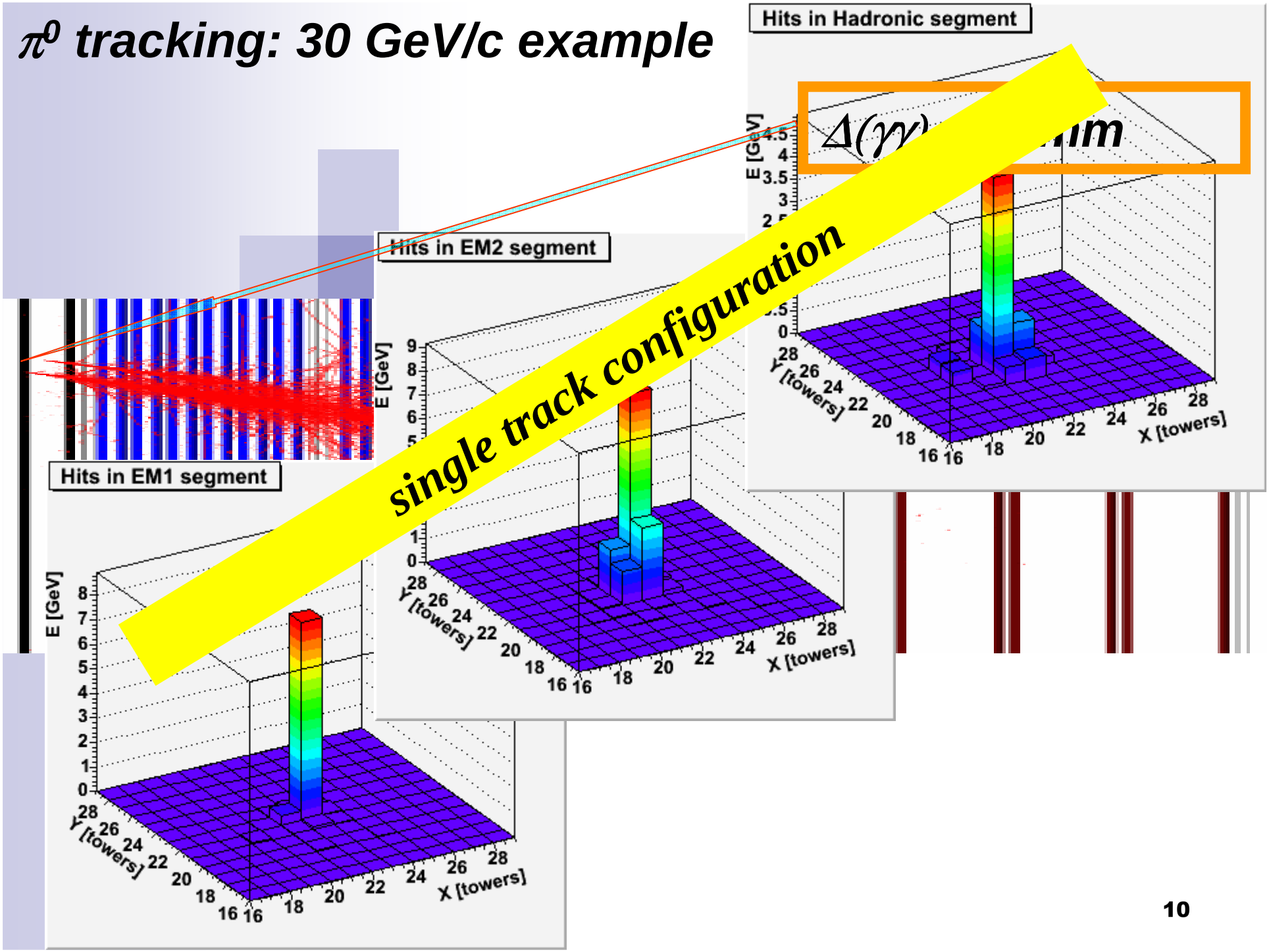
$\pi^0 \rightarrow \gamma\gamma$, d = 25 mm

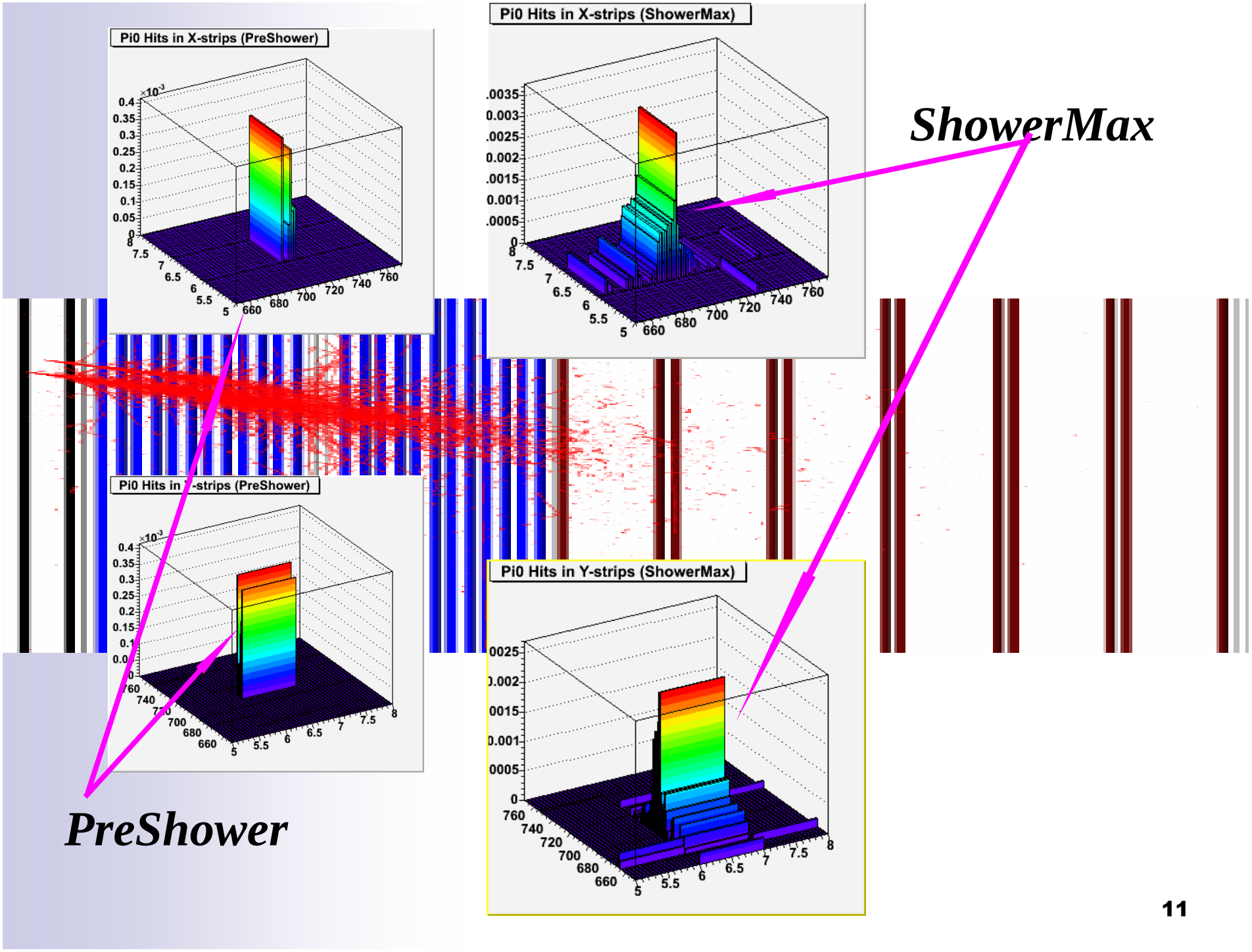
**Multitrack configuration**



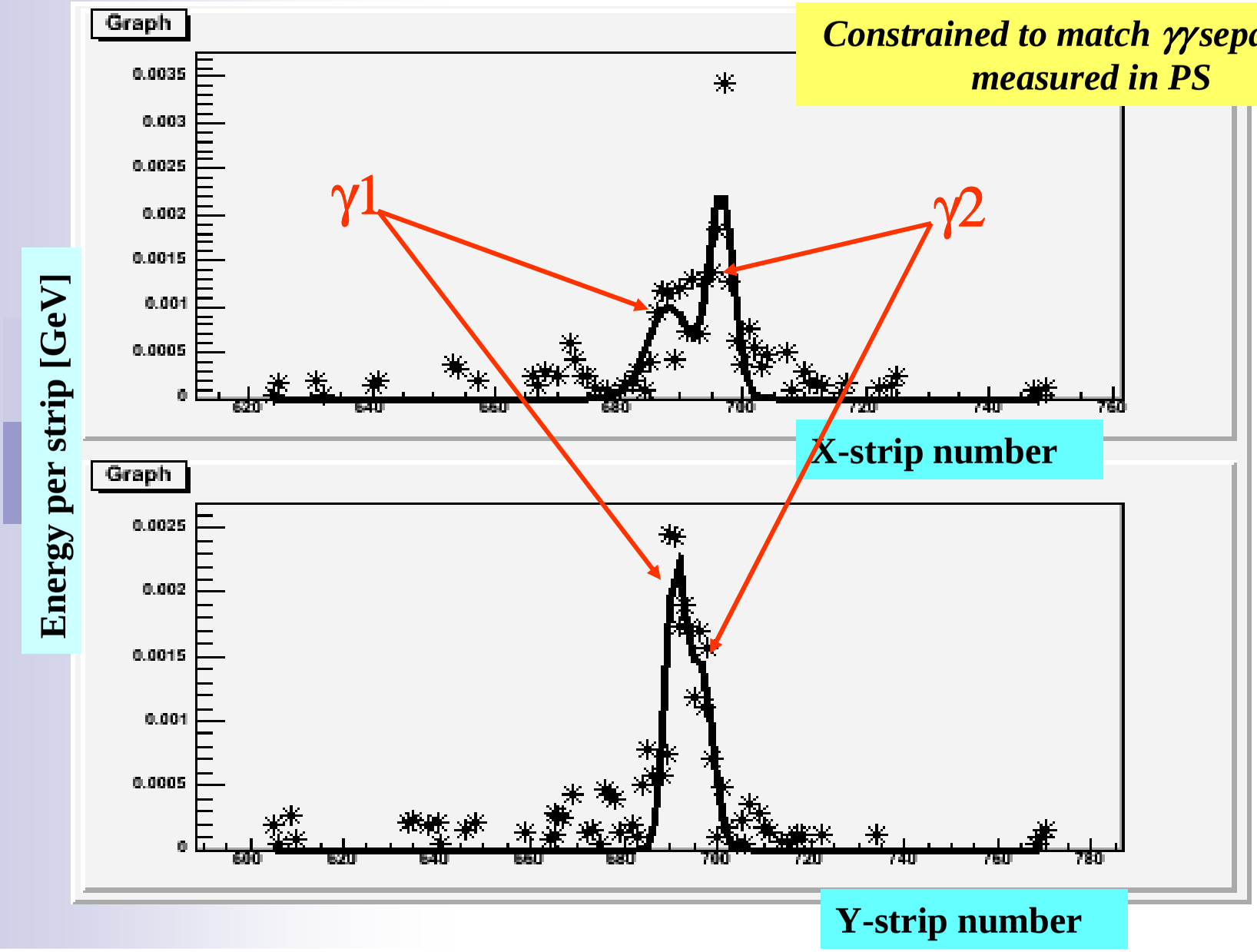

*tracks pointing to collision vertex (points in PS, EM1, SM, EM2, Had)*

# $\pi^0$ tracking: 30 GeV/c example




Pi0 Hits in X-strips (PreShower)
Pi0 Hits in X-strips (ShowerMax)
ShowerMax
Pi0 Hits in Y-strips (PreShower)
Pi0 Hits in Y-strips (ShowerMax)
PreShower

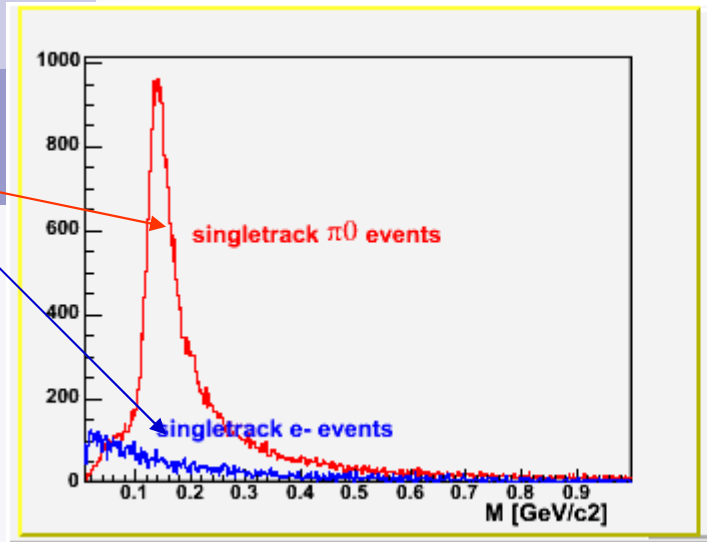
# *Fit to extract decay asymmetry*

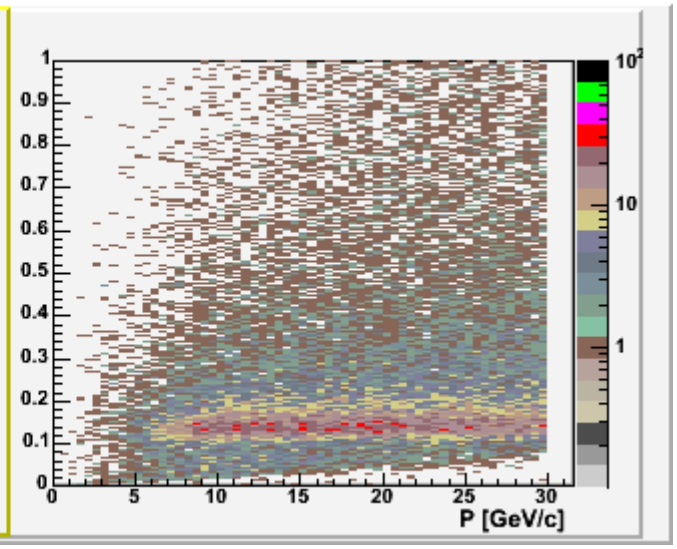


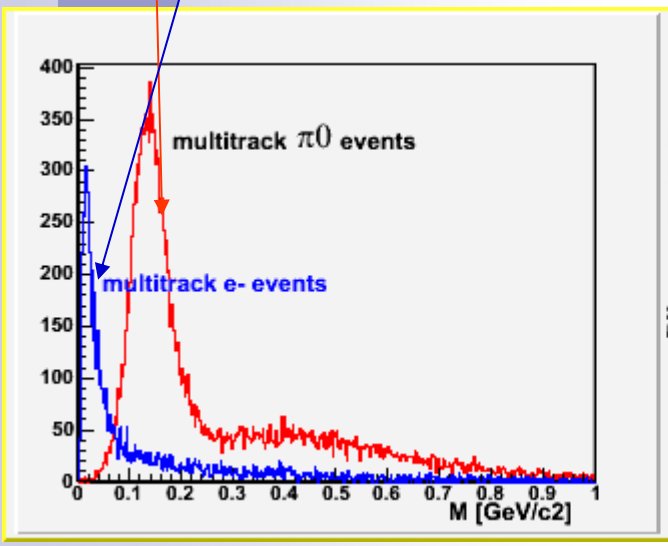

***Constrained to match γγ separation measured in PS***

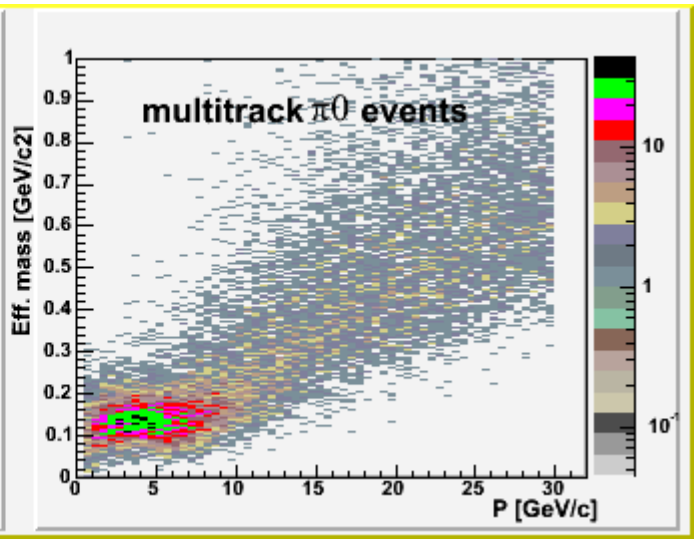
# *Concept works on simulated data, needs further tuning with simulated and test beam data*

Single-particle
($\pi^0$ and e)
simulation in NCC

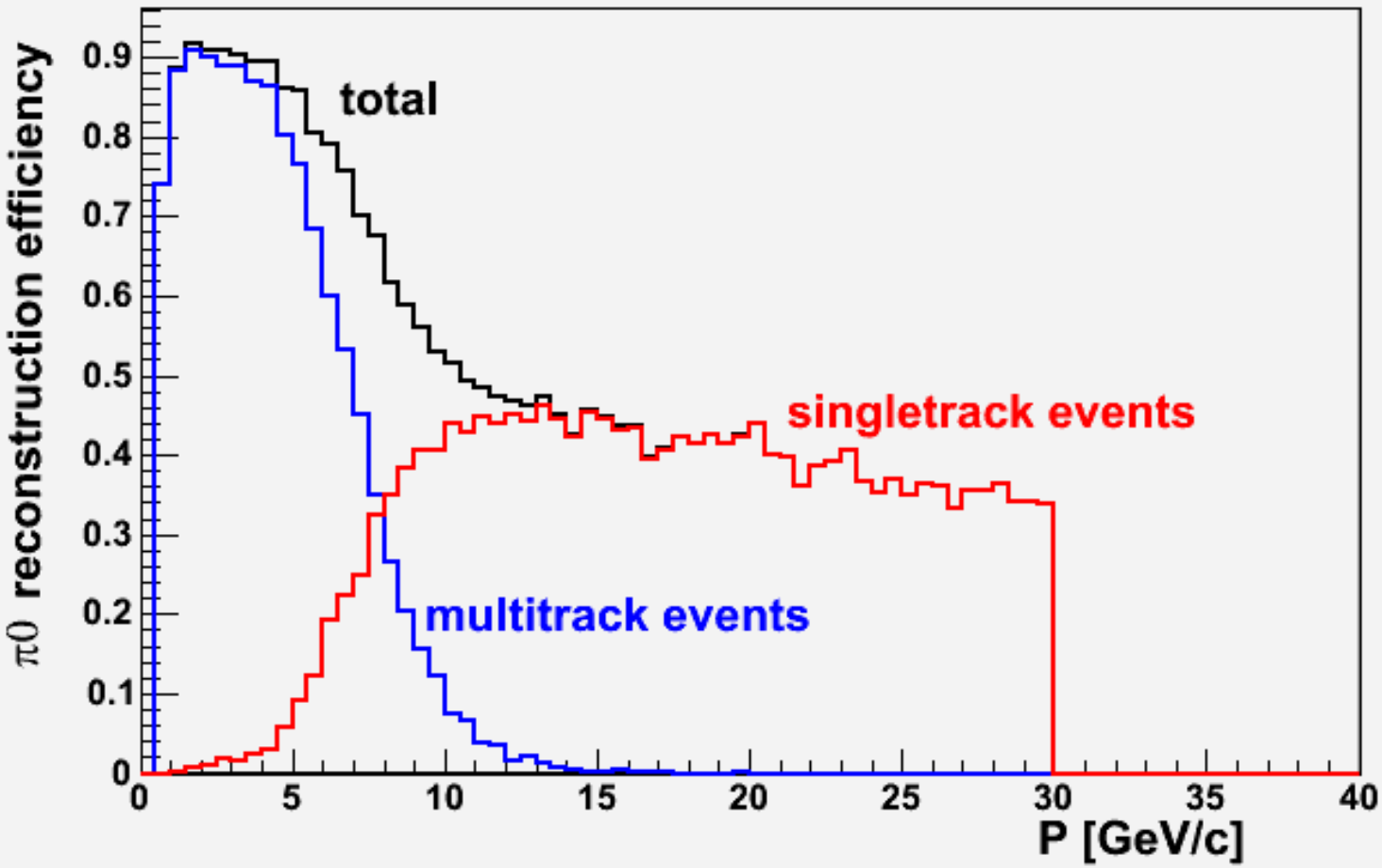


# $\pi 0$ efficiency: *zero approximation*



# *Road to construction:* 2004-2007

- Optimize detector, develop construction design;
- Develop, prototype and test Si sensors;
- Develop, prototype and test Si ladders (StriPixels and Pads);
- Develop, prototype and test readout.

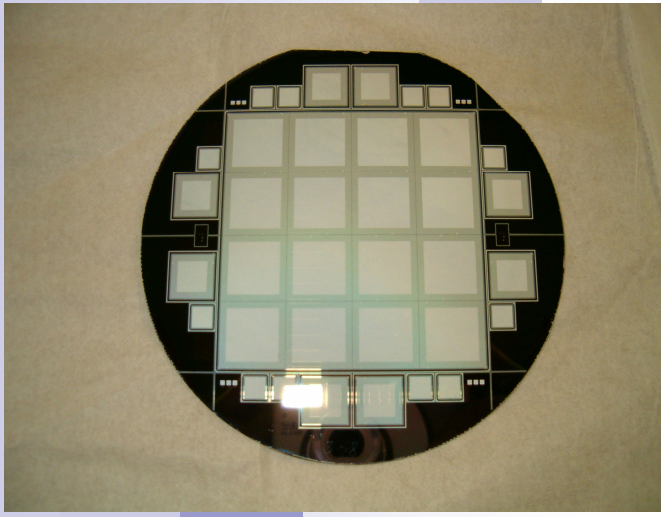
**Major milestones:**

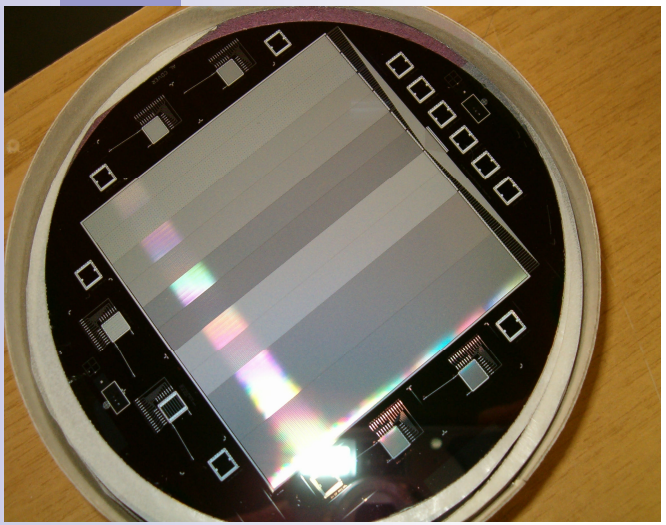
**Proof-of-principle prototype: built and tested in the beam in 2005;**

**System prototype to be constructed and tested in the beam in 2007.**

# R&D 2004-2005: BNL-MSU-UCR-RIKEN

## *Sensors*



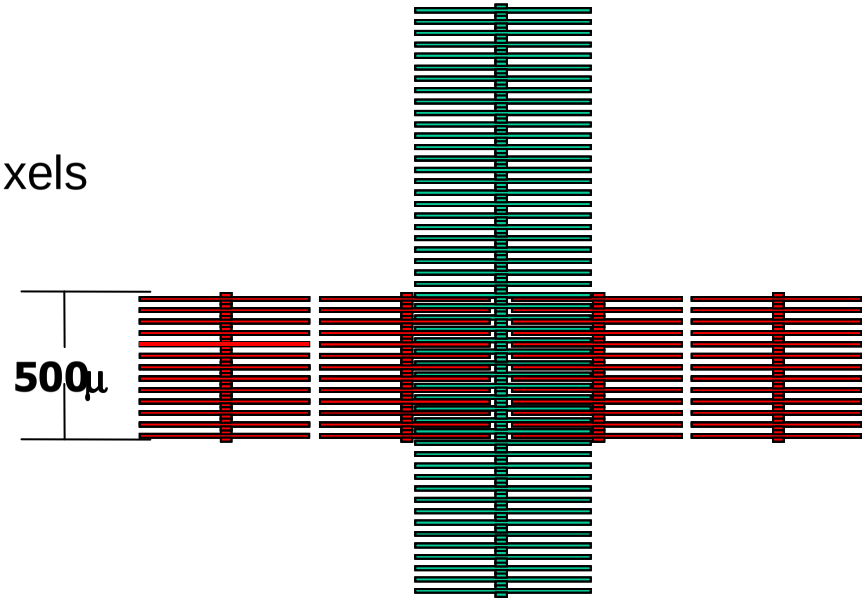


DC coupled, pad structured - ***completed***

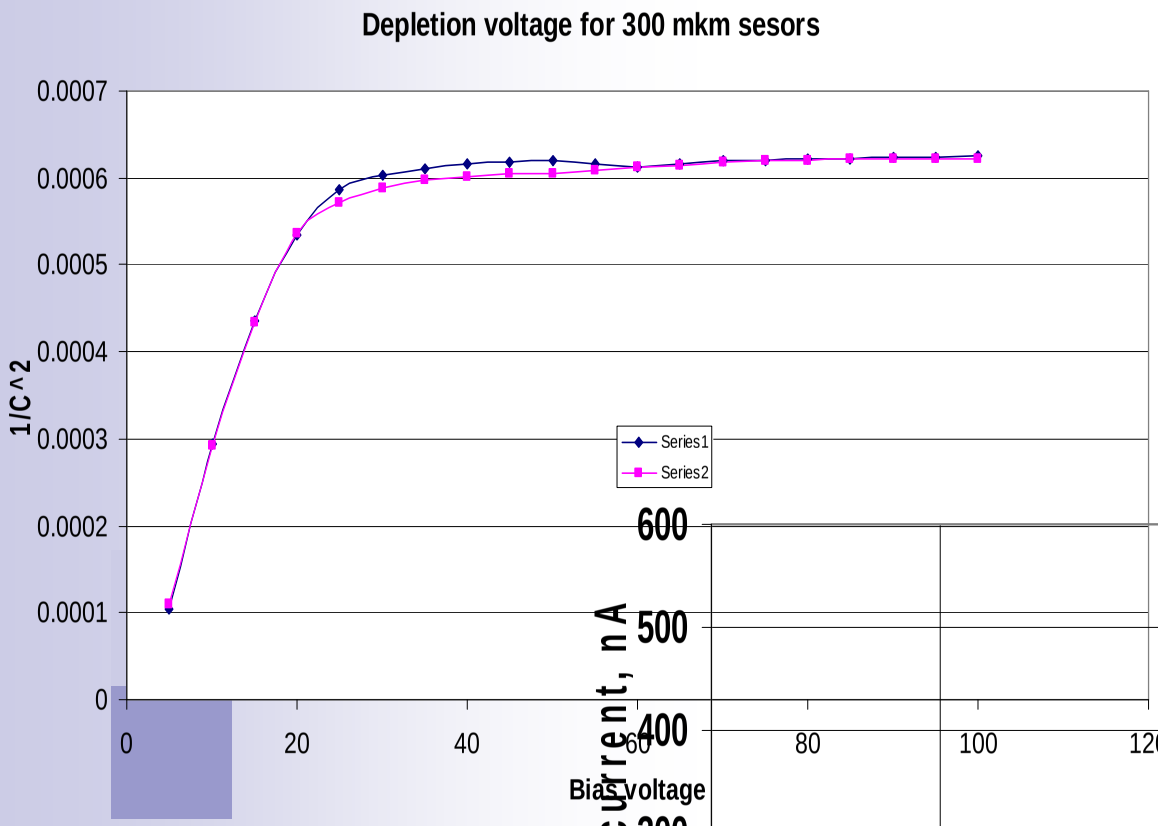
AC coupled, pad structued - ***completed***

DC coupled, r-biased, pad structured – ***at ELMA and ON Semi***

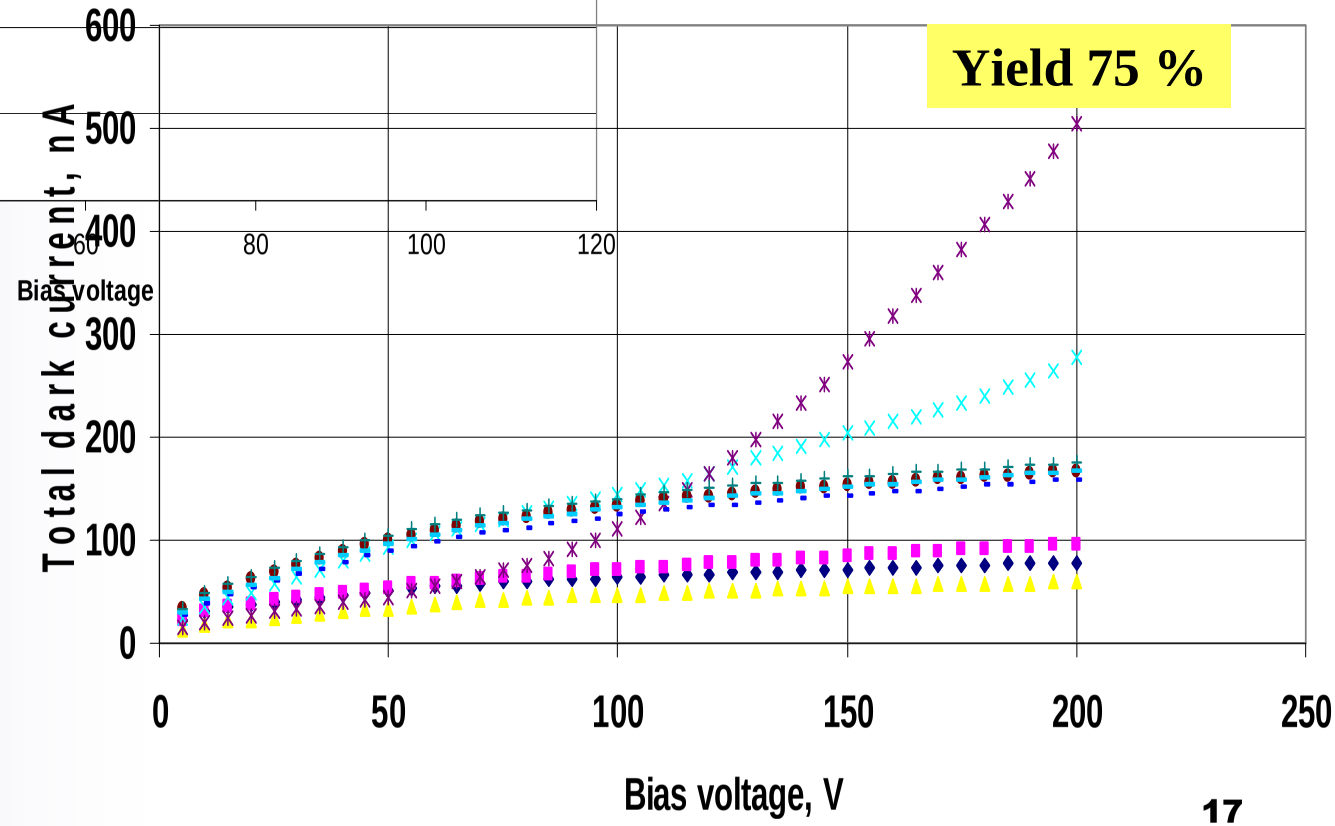
StriPixels



# *ELMA: DC-coupled pad-structured sensors (300 μm Si, $160 base cost)*

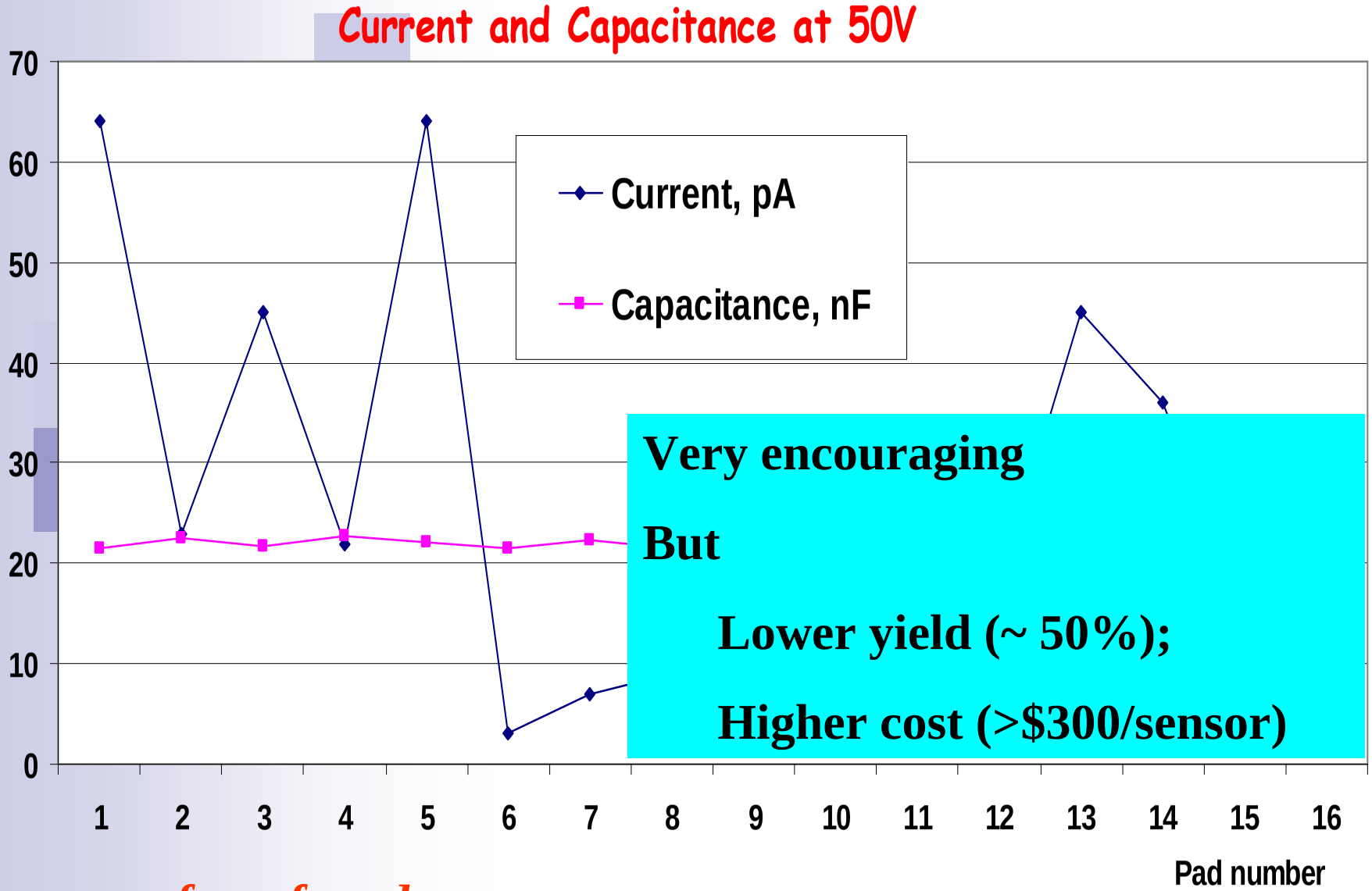



I vs V




*Used to construct proof-of-principle prototype*

# *ELMA: AC-coupled pad-structured sensors*




**Very encouraging**

**But**

**Lower yield (~ 50%);**

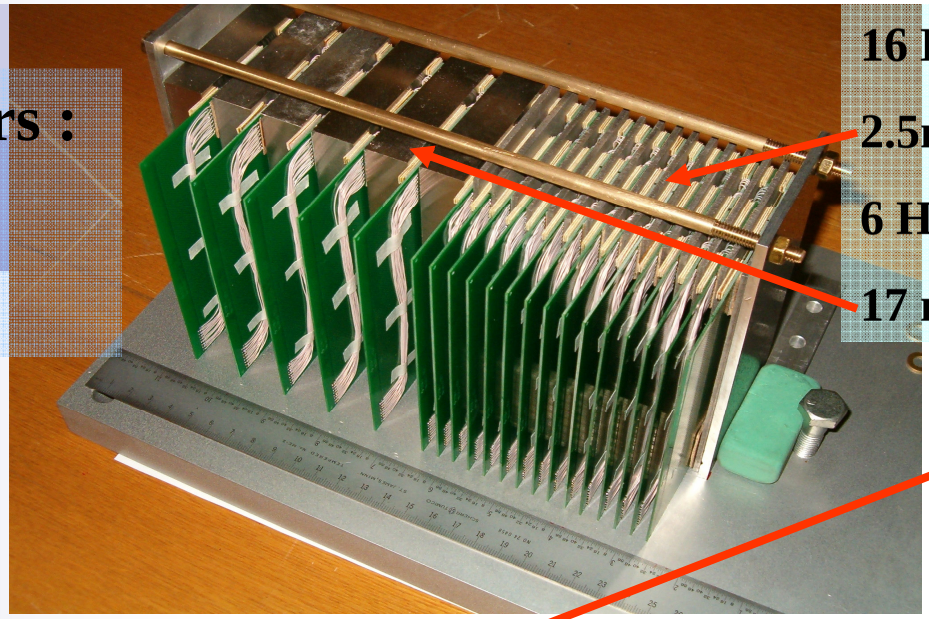
**Higher cost (>$300/sensor)**

*Just came from foundry*

# *First confirmation that technology is robust*

**22 sampling layers :**

**4 EM + 2 HAD segments**

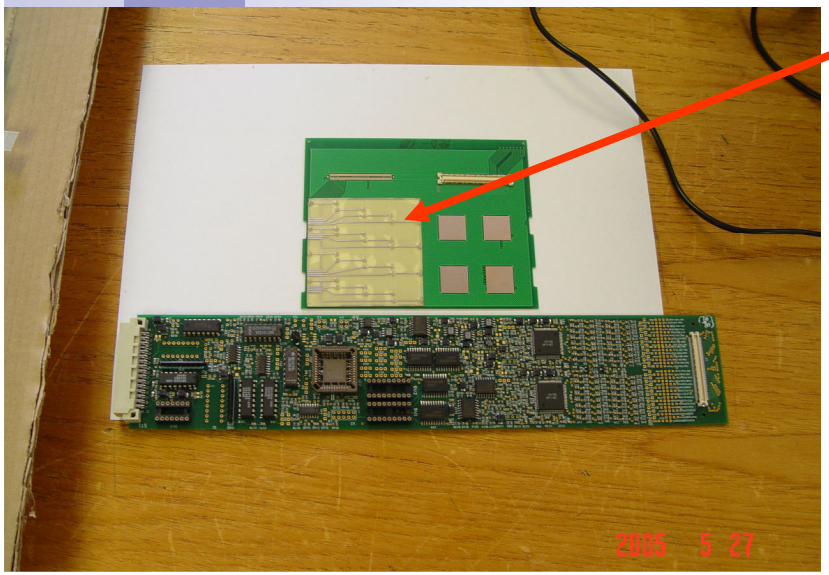


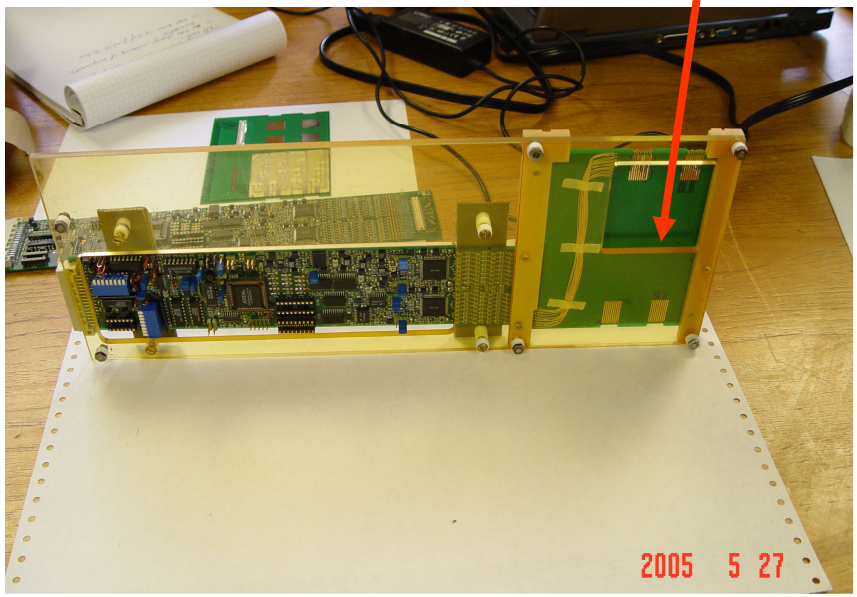
**16 EM sampling cells:**

**2.5mm W + 2.5 mm ROU**

**6 HAD sampling cells:**

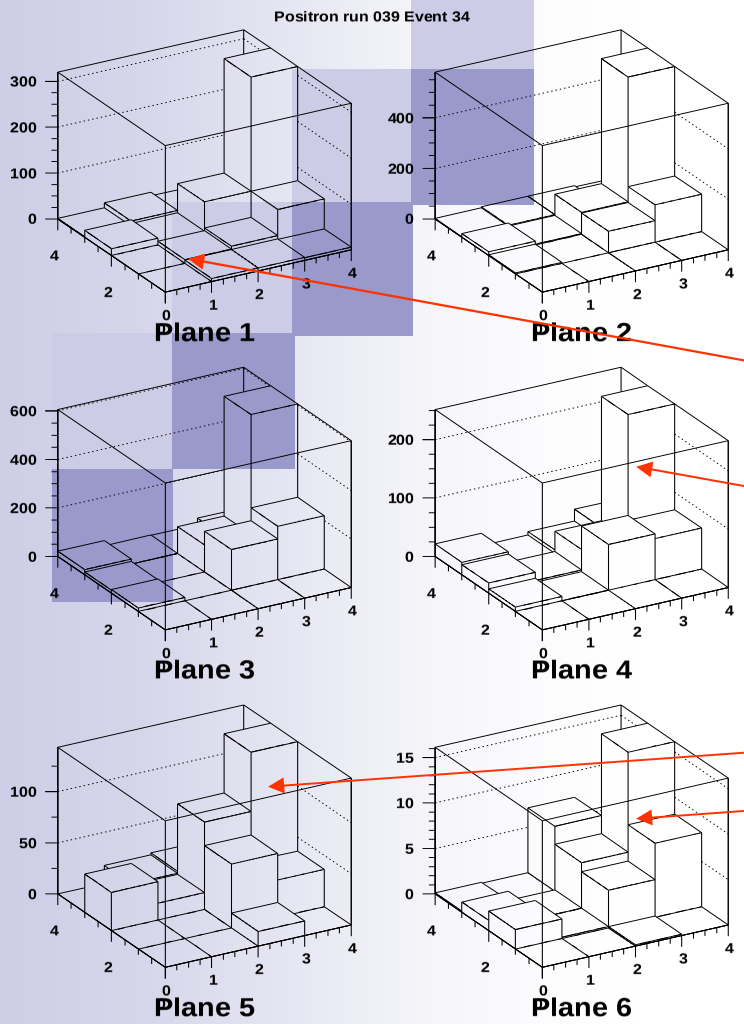
**17 mm W + 2.5 mm ROU**

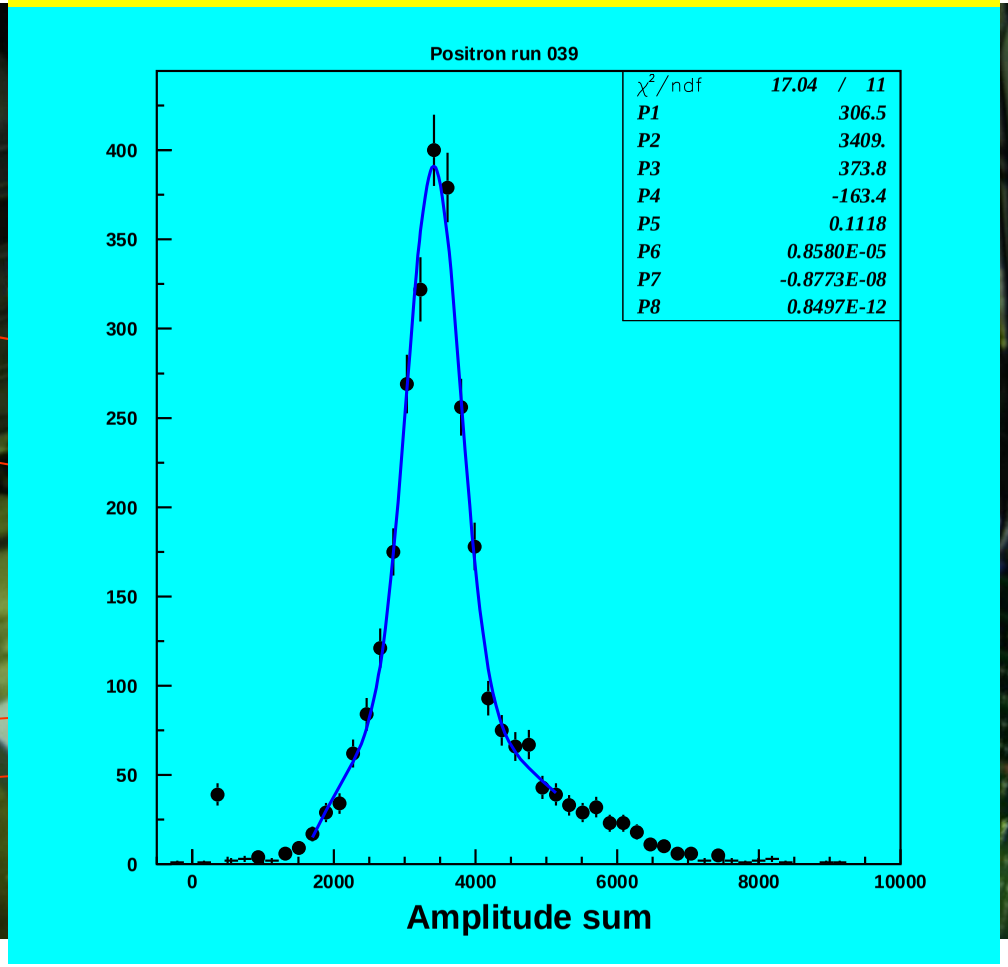


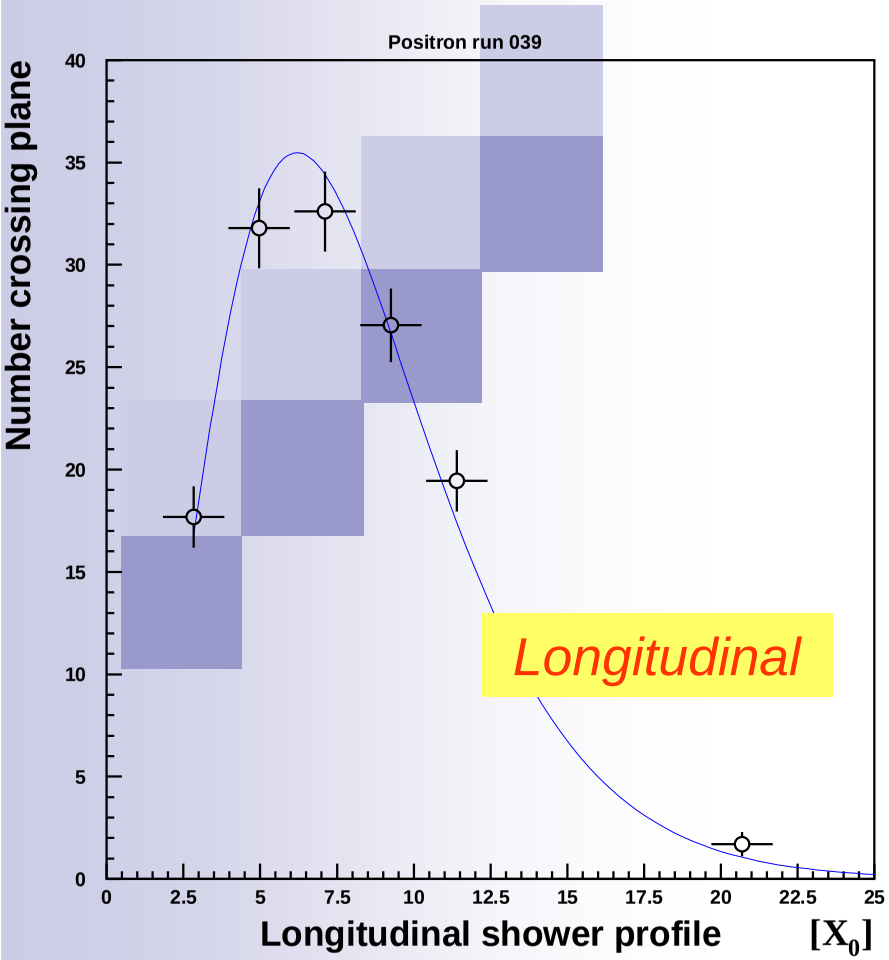
# Energy measurements

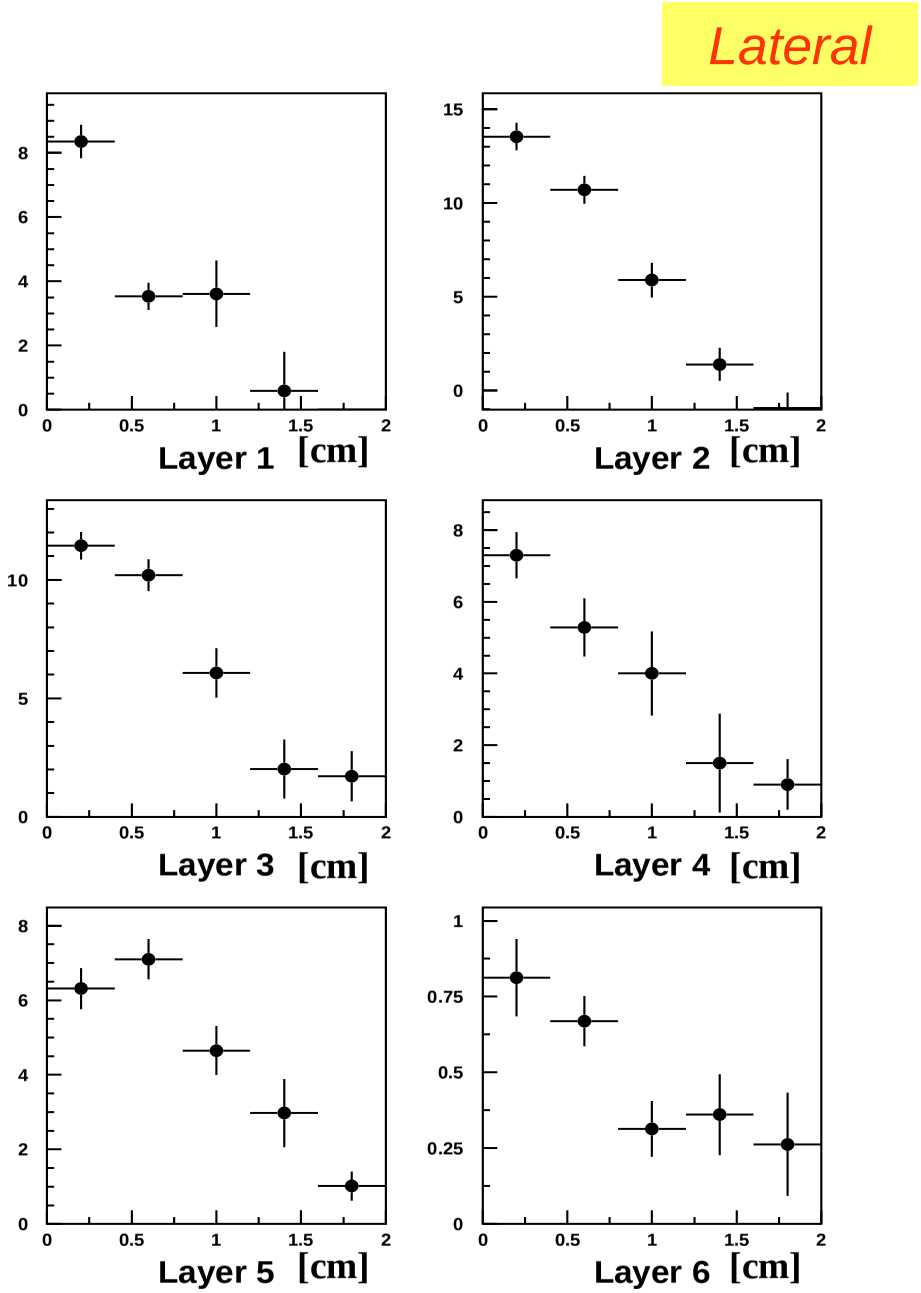
**Measured resolution ~ 11% driven by very thick plates in Hadronic segments**



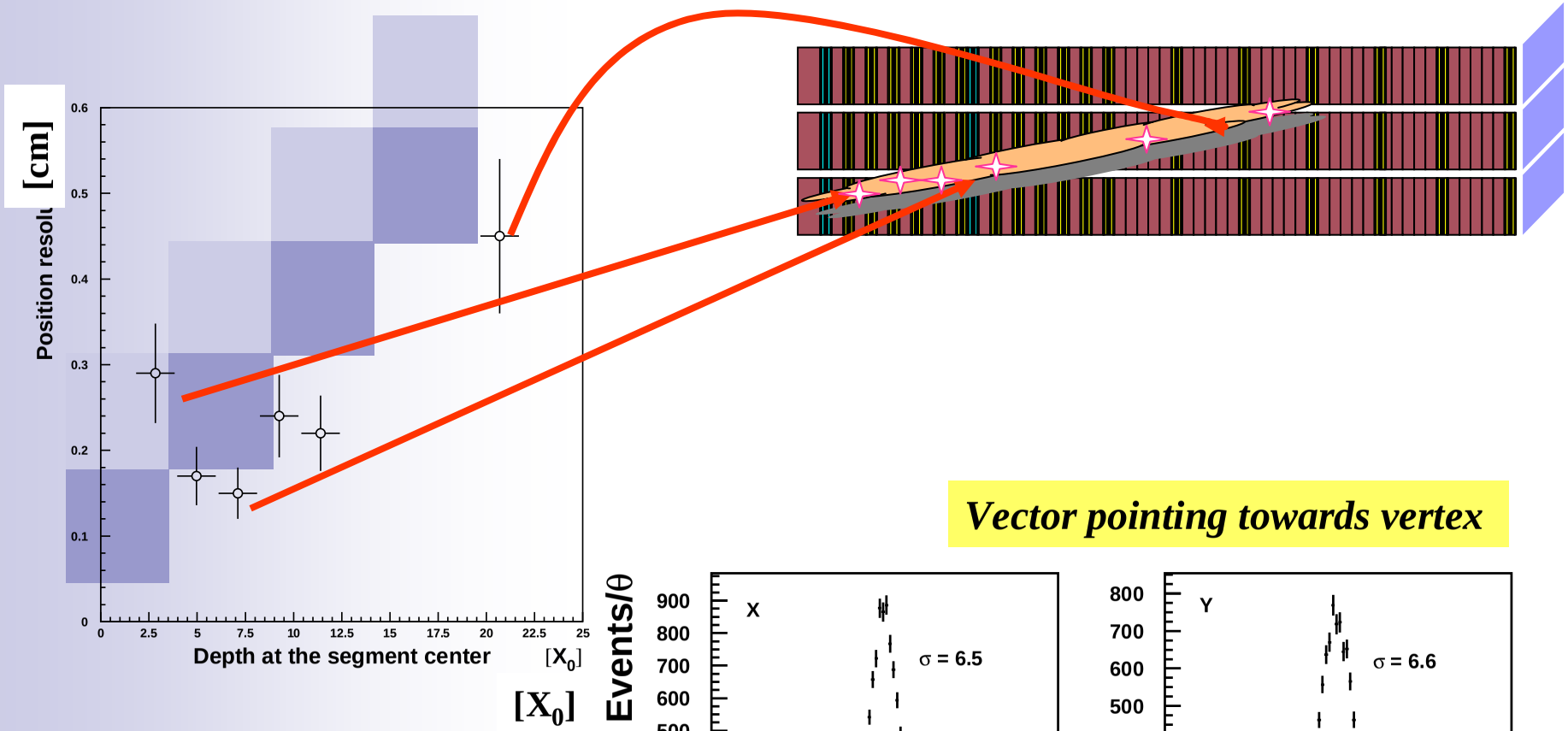



# Shower development

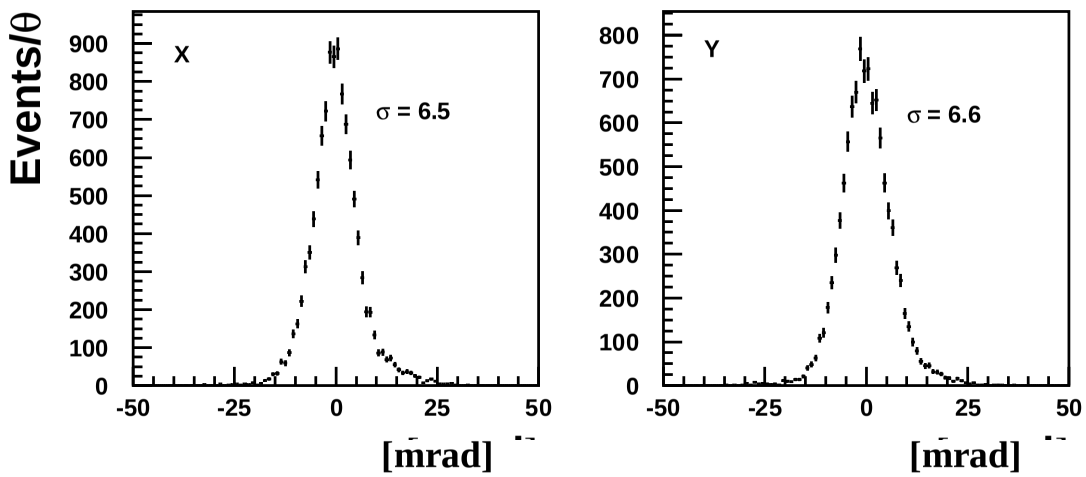


# Position and directional measurements

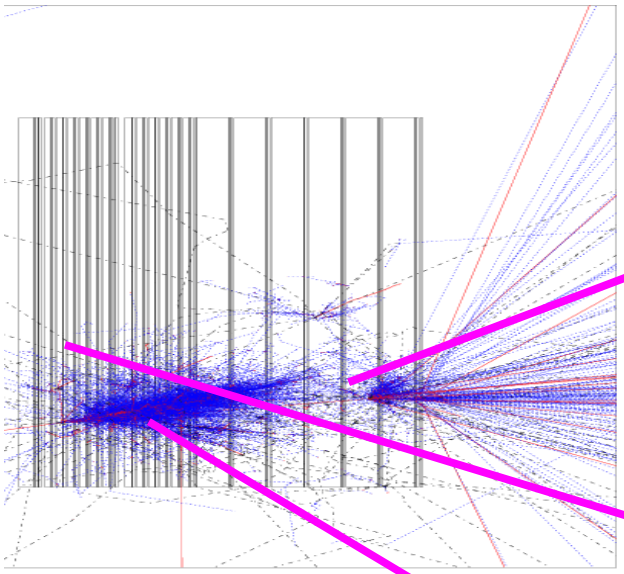


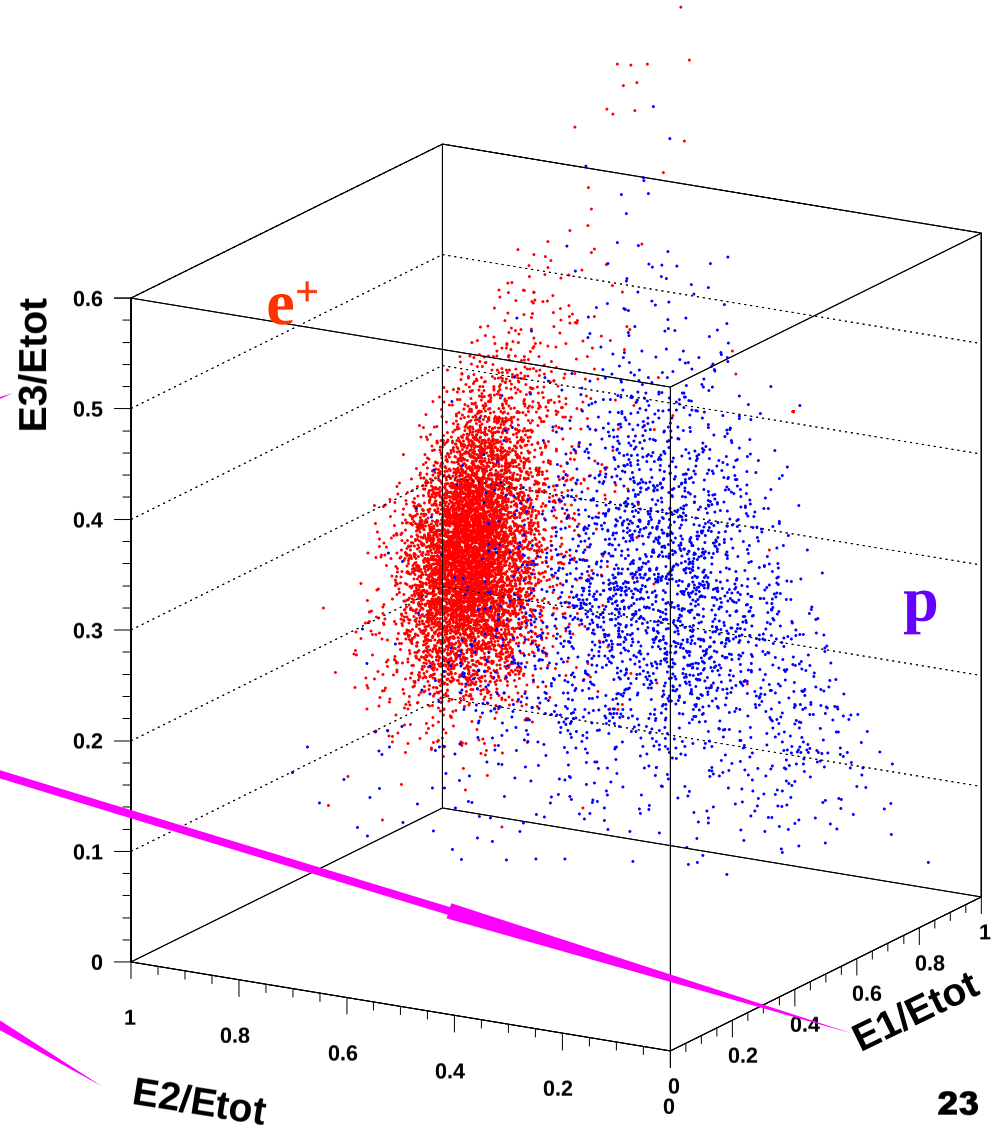

*Vector pointing towards vertex*



***e/h separation: works but … more data needed.***

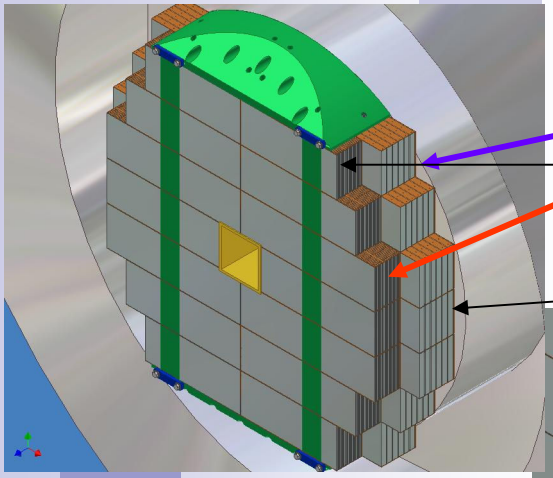
***Next test-beam experiment in 2007***





# *Calorimeter design*

**Assembly unit: *Brick***

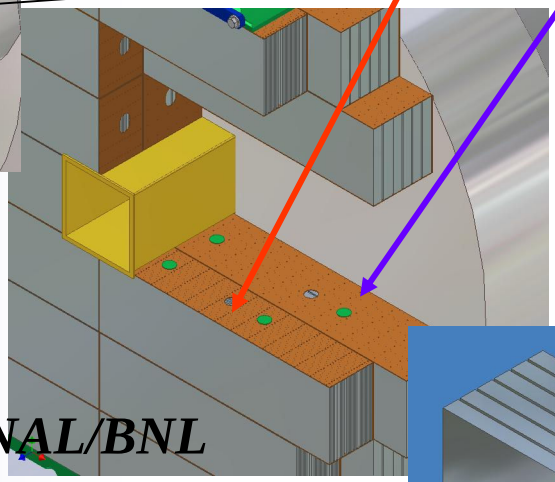


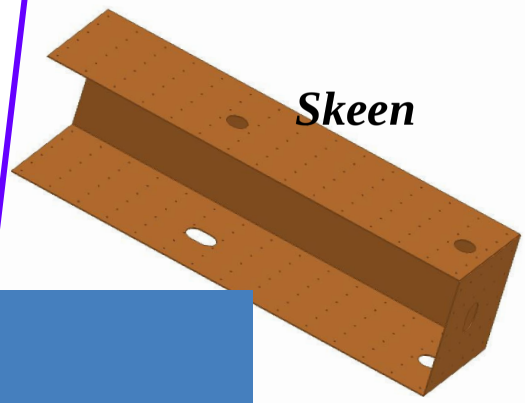
***Electomagnetic (14)***

***Hadronic (14)***

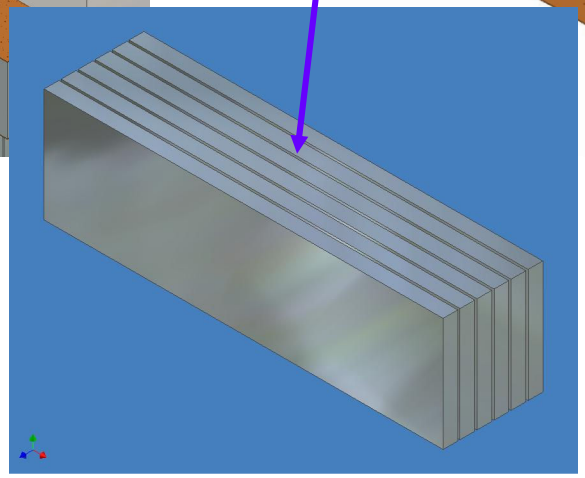
**2 x 5 sensors minimum**

**2 x 7 sensors maximum**





***Skeen***



***Design: JINR(Dubna)/FNAL/BNL***

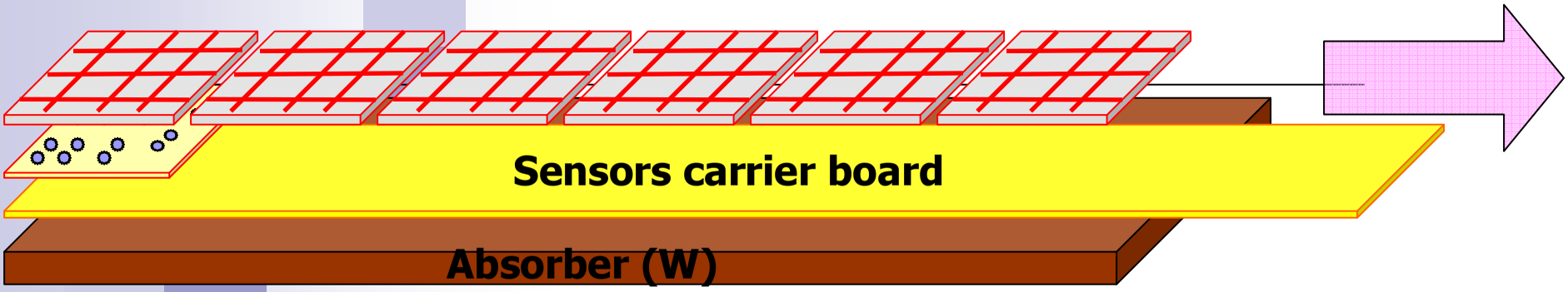
***W plates: US***

***Mechanics: JINR(Dubna)***

***Assembly: BNL***

**ROU's not shown**

# Pad-structured ROU (ladder) design




Detector ladder  attached to the W plate

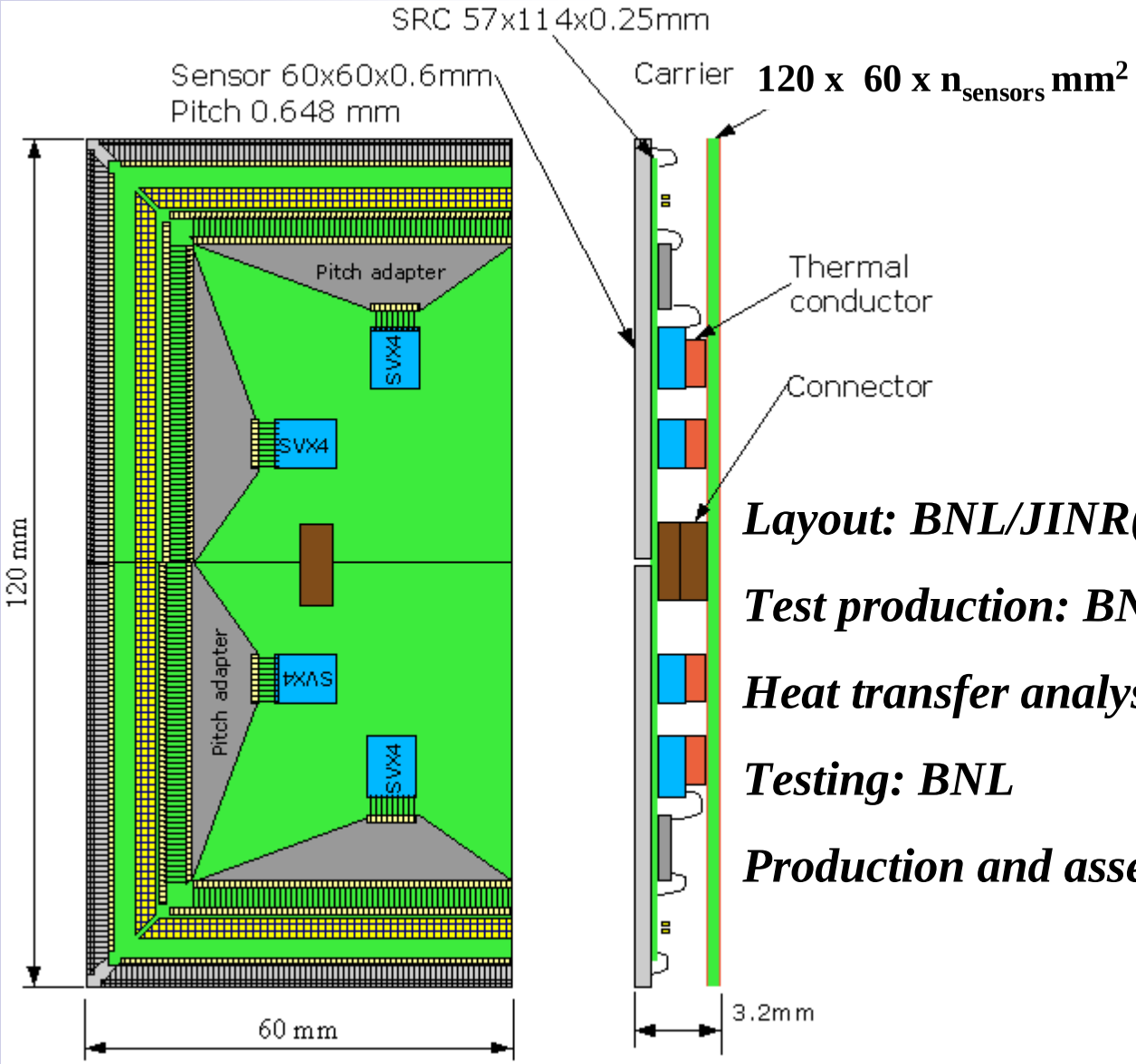
Decoupling capacitors and bias resistors are part of hybrid amplifiers

Interconnect board to allow replacement of the sensor (last resort …). Have bonding pads to wire-bond sensors and soldering pads (or wires)  to solder to the carrier board.

***Layout: BNL/MSU***

***Implementation: BNL/Komposit (Ekaterinbourg, Russia)***

# StriPixel ROU (ladder) design




***Layout: BNL/JINR(Dubna)***

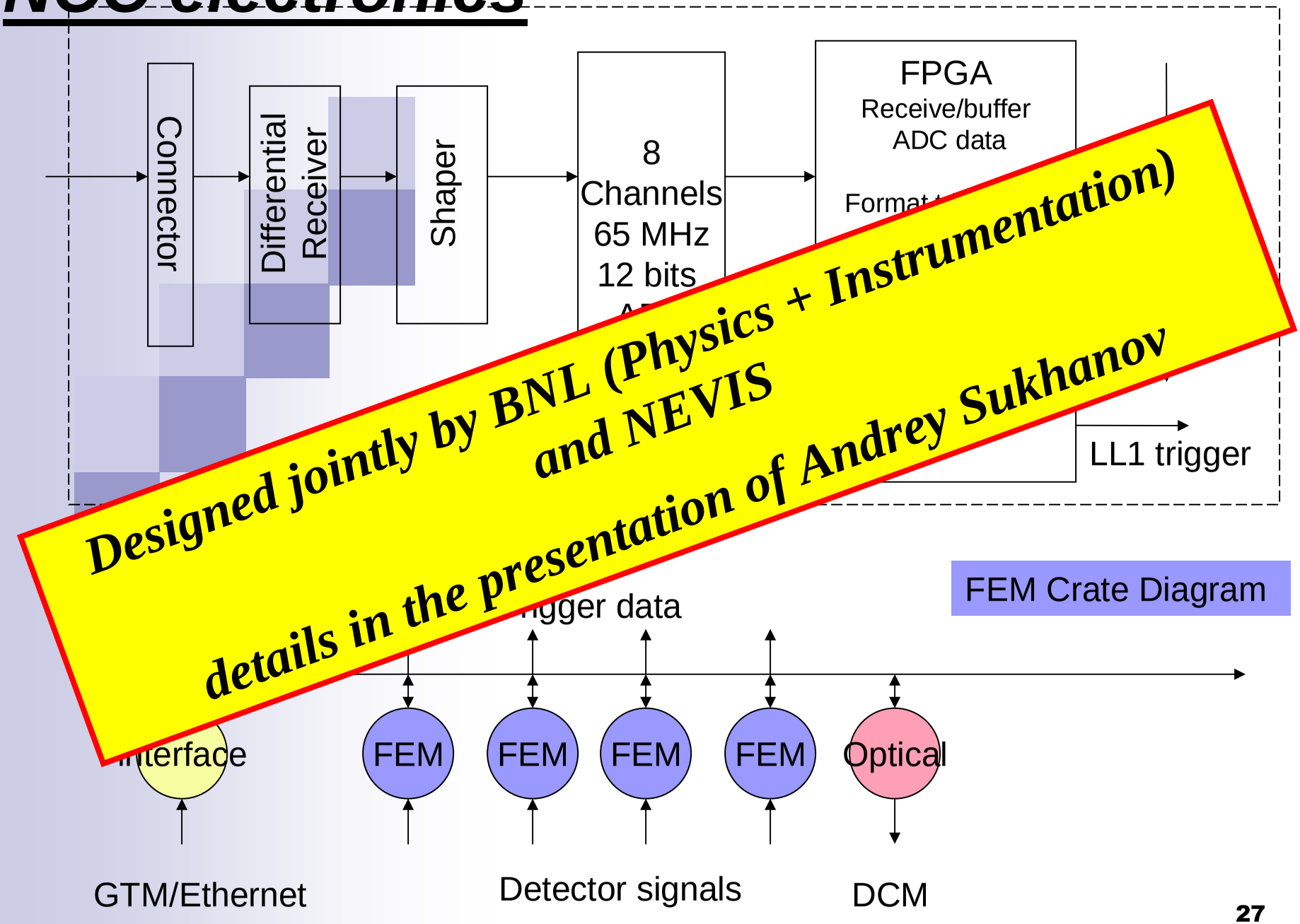
***Test production: BNL/FNAL***

***Heat transfer analysis: FNAL***

***Testing: BNL***

***Production and assembly: BNL/JINR(Dubna)***

# NCC electronics




**Designed jointly by BNL (Physics + Instrumentation) and NEVIS**

**details in the presentation of Andrey Sukhanov**

# Summary

- ***There is a lot of momentum ……***
- ***Next two years are***
  - ***To optimize design and performance;***
  - ***To test production chain;***
  - ***To accumulate test beam data and build analysis chain;***
- ***Three years for high-tech construction project are tough but feasible.***

**We propose to start construction in <u>FY 2008</u> and finish in <u>FY 2010</u>**