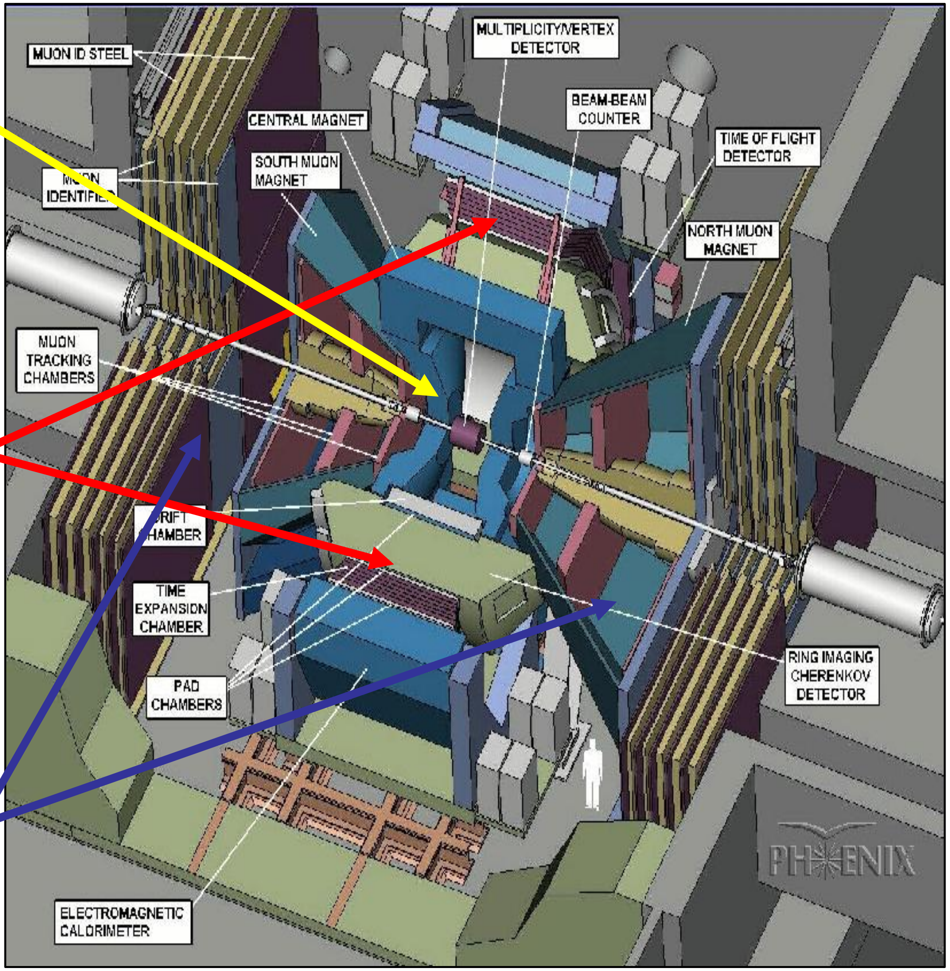
Silicon – W Calorimeters for the PHENIX Forward Upgrade

PHENIX today

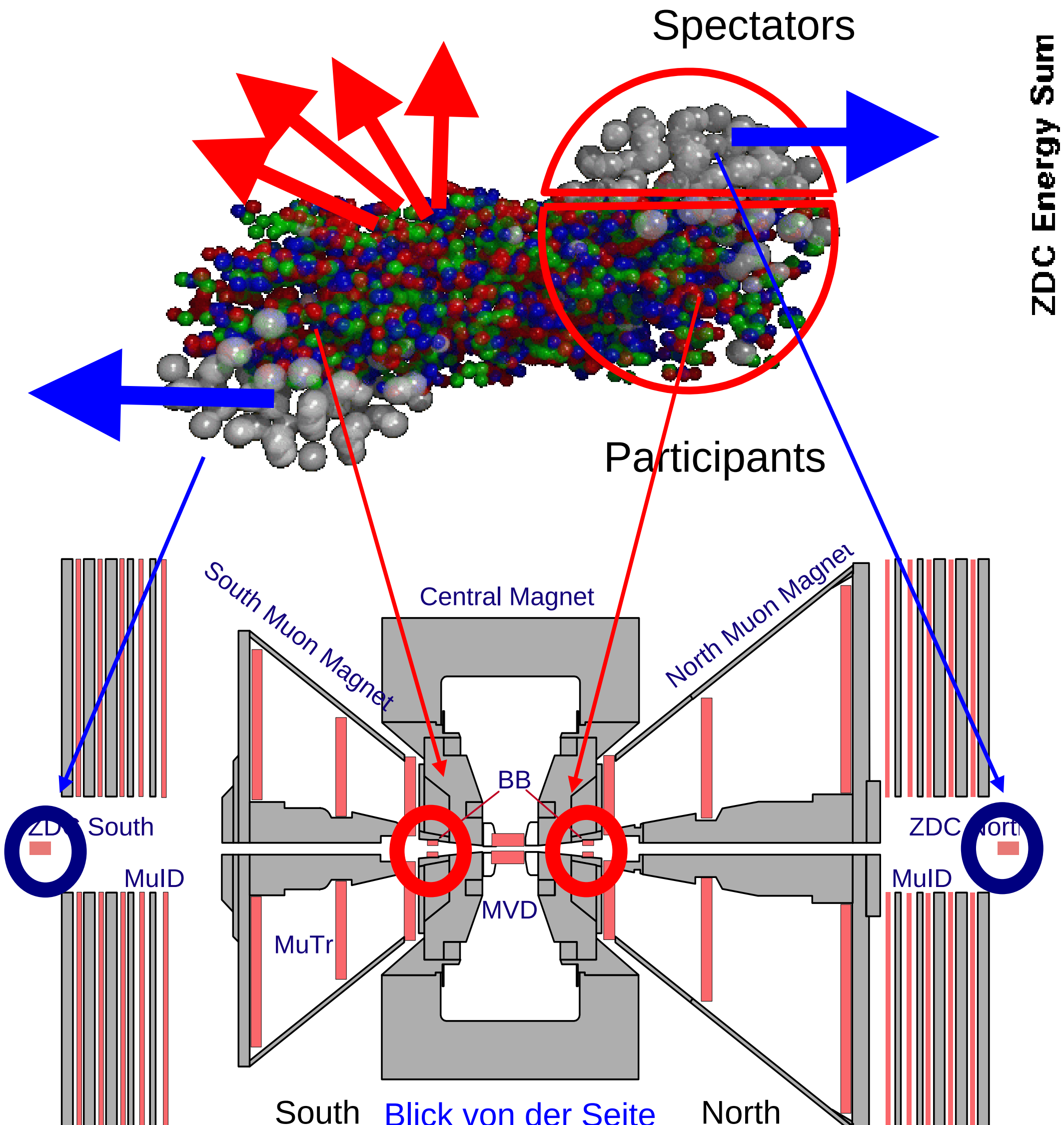
Event characterization detectors in middle

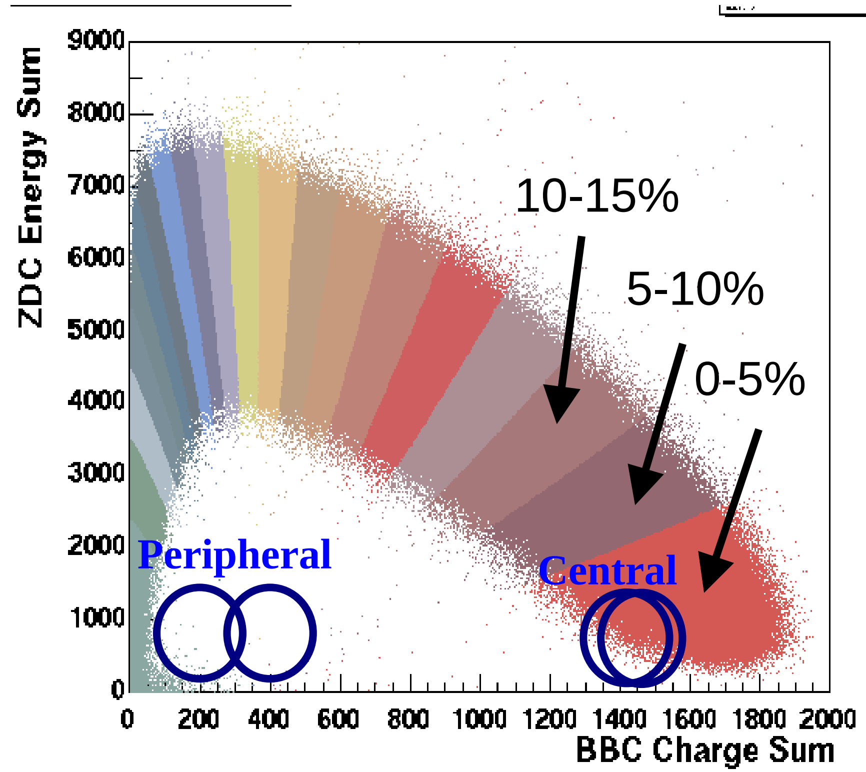
Two central arms for measuring hadrons, photons and electrons

Two forward arms for measuring muons



How PHENIX works





- **Centrality selection : Sum of Beam-Beam Counter (BBC, |η|=3~4) and energy of Zero-degree calorimeter (ZDC)**
- **Extracted N_{coll} and N_{part} based on Glauber model.**

History lessons and future directions

The devil in the details:

PHENIX needs luminosity, acceptance and sensitivity to right probes

-PHENIX contribution to sQGP discovery heavily relied on p0 and direct g measurements in central electromagnetic calorimeters: build on success – extend acceptance for electromagnetic probes;

-All experiments at RHIC measure jets only indirectly – via leading particles. Include direct jet measurements whenever possible;

-Use unique feature of PHENIX: muon spectrometer

Optimal strategy for upgrade:

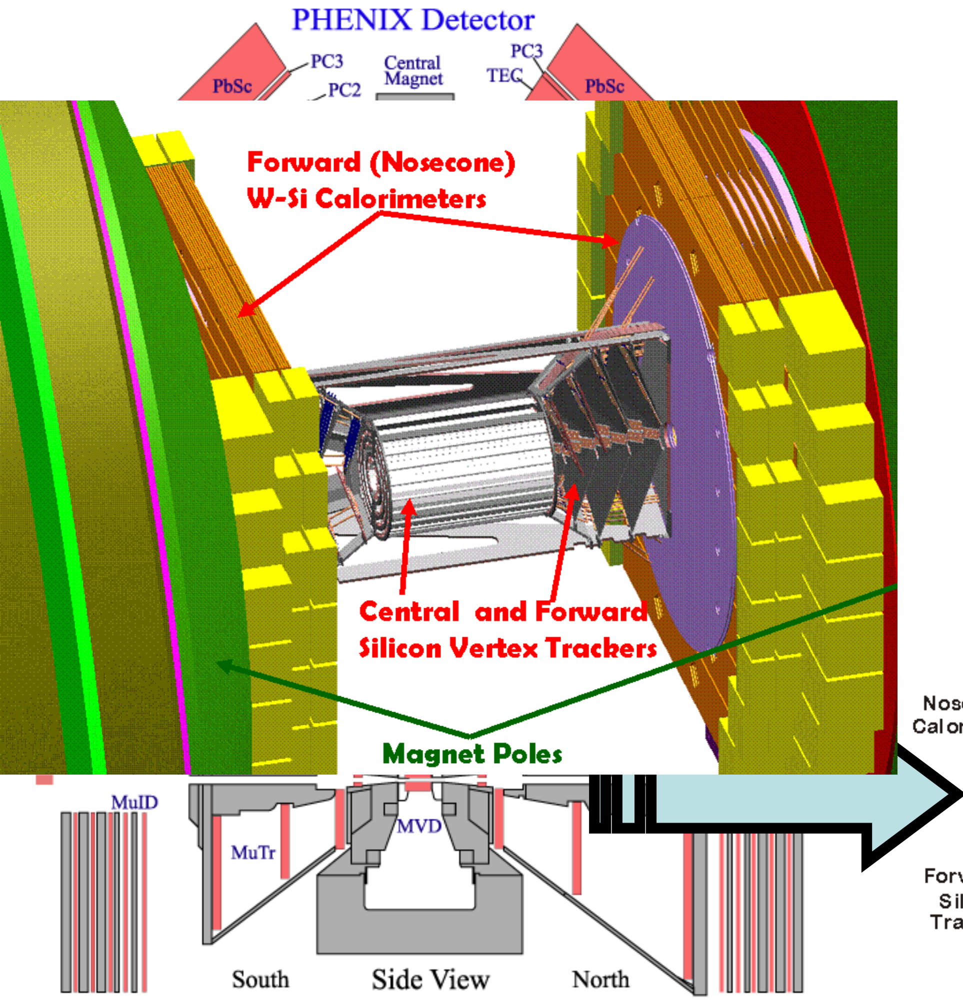
Convert

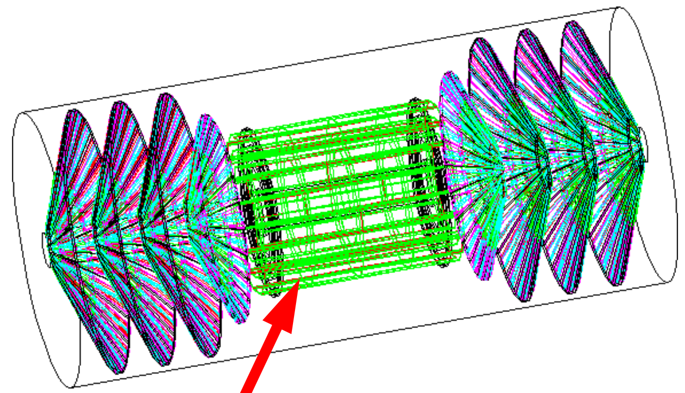
PHENIX Forward Muon System

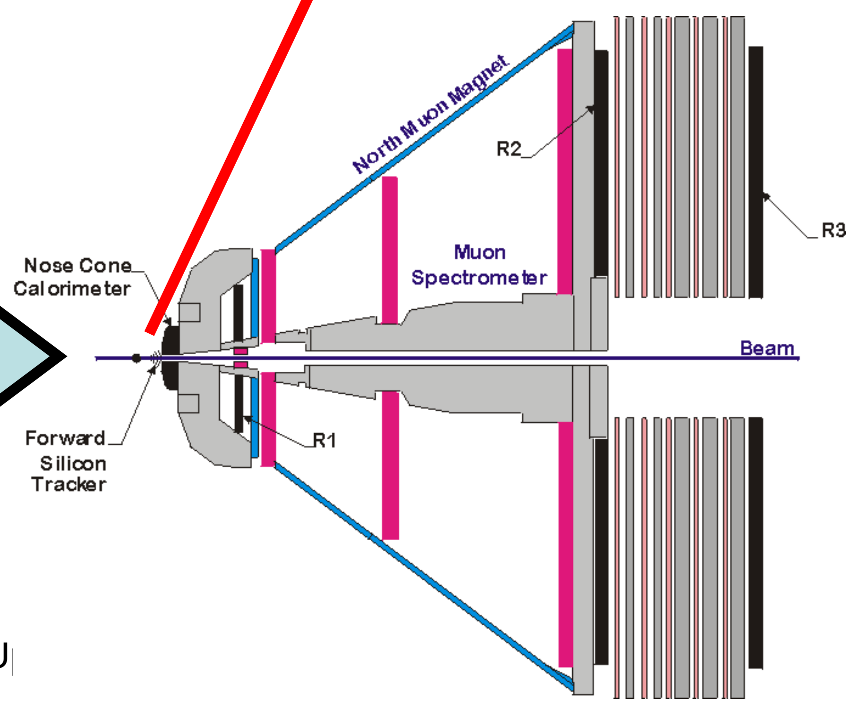
into

PHENIX Forward Spectrometer

PHENIX Upgrade







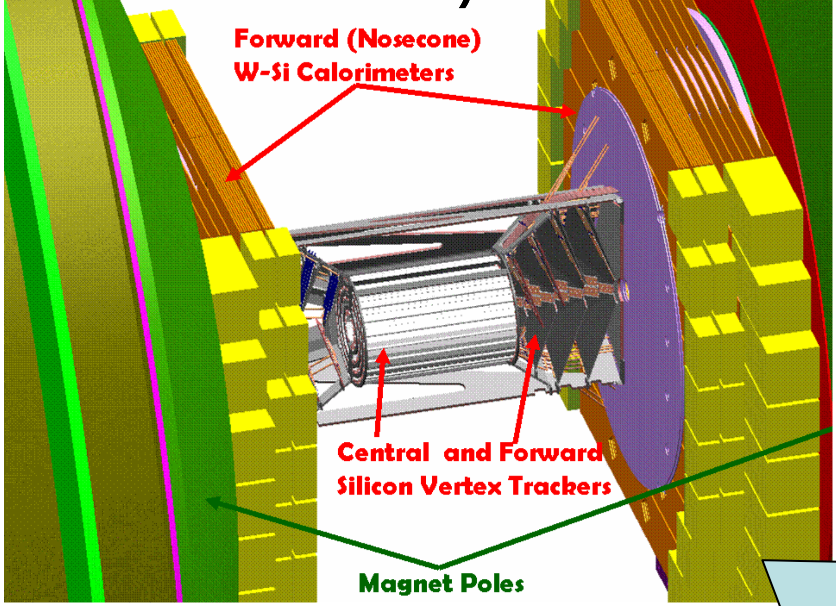
Constrains

-*space*

40 cm from collision vertex

20 cm total depth

***-no tracking upstream* (momentum and charge unknown)**



Goals

-Reasonable energy resolution for em probes;

-Best possible separation between em and hadronic signals

-Ability to reconstruct p0's to ~30 GeV/c

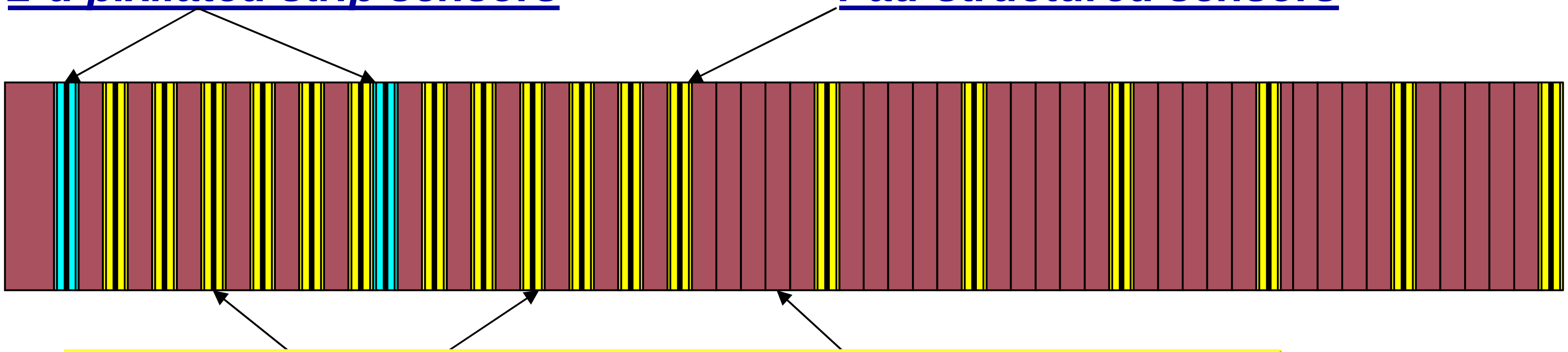
-Jet identification and cone energy measurements for lepton tagging and isolation testing

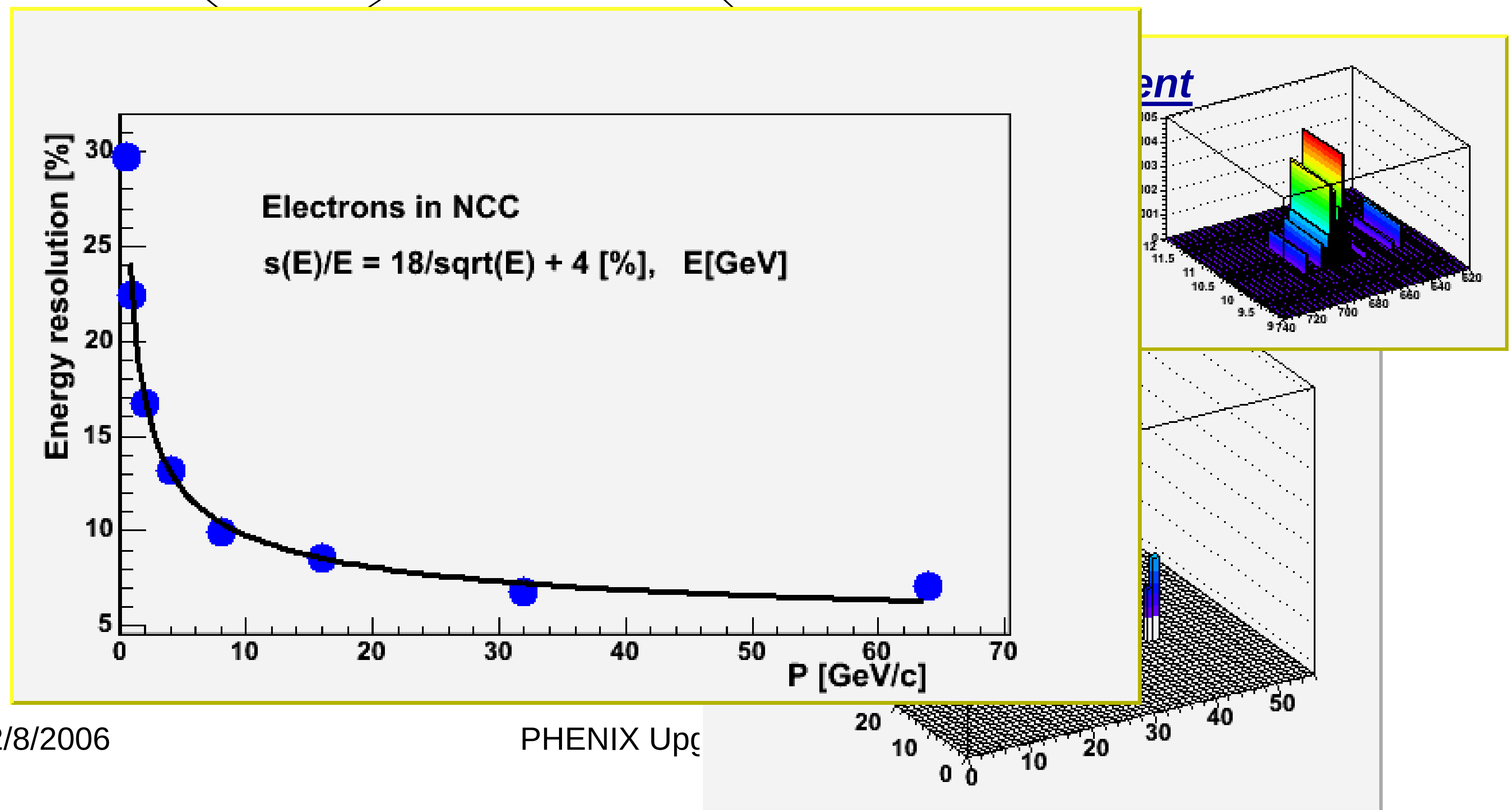
NCC –tracking calorimeter

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. 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 %	~20/sqrt(E)	
Expected jet energy resolution %	~100/sqrt(E)	
Two showers resolved at: in calorimeter	3 cm	
Two showers resolved at: in preshower	2 mm	In simulation effective for shower separation down to 4 mm
Two showers resolved at: in shower max.	4 mm	

2-d pixilated strip sensors

Pad-structured sensors





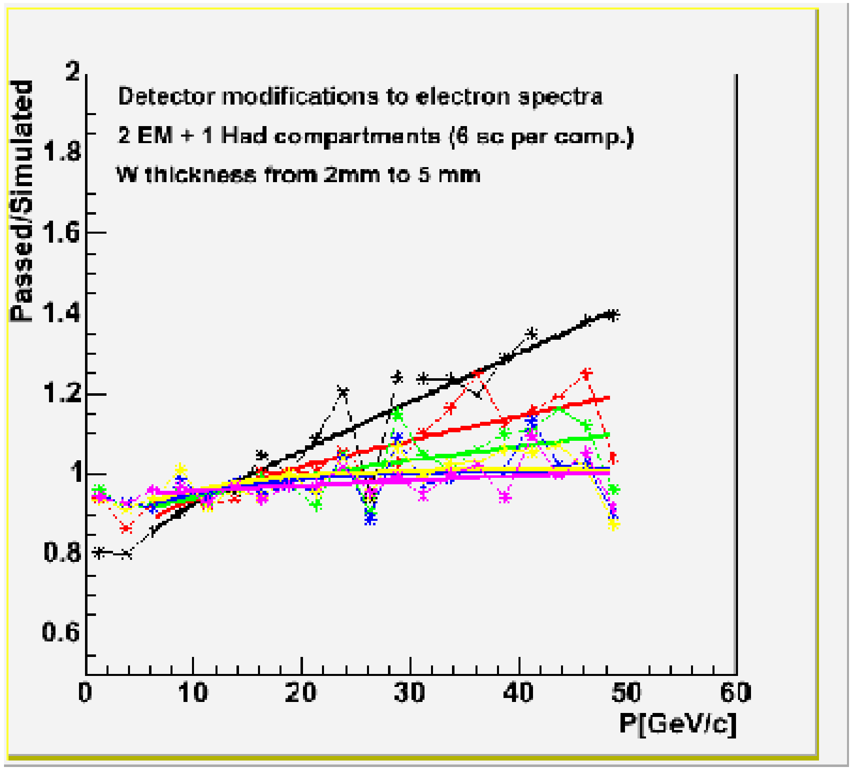
Design optimization

-Total depth fixed to 19 cm

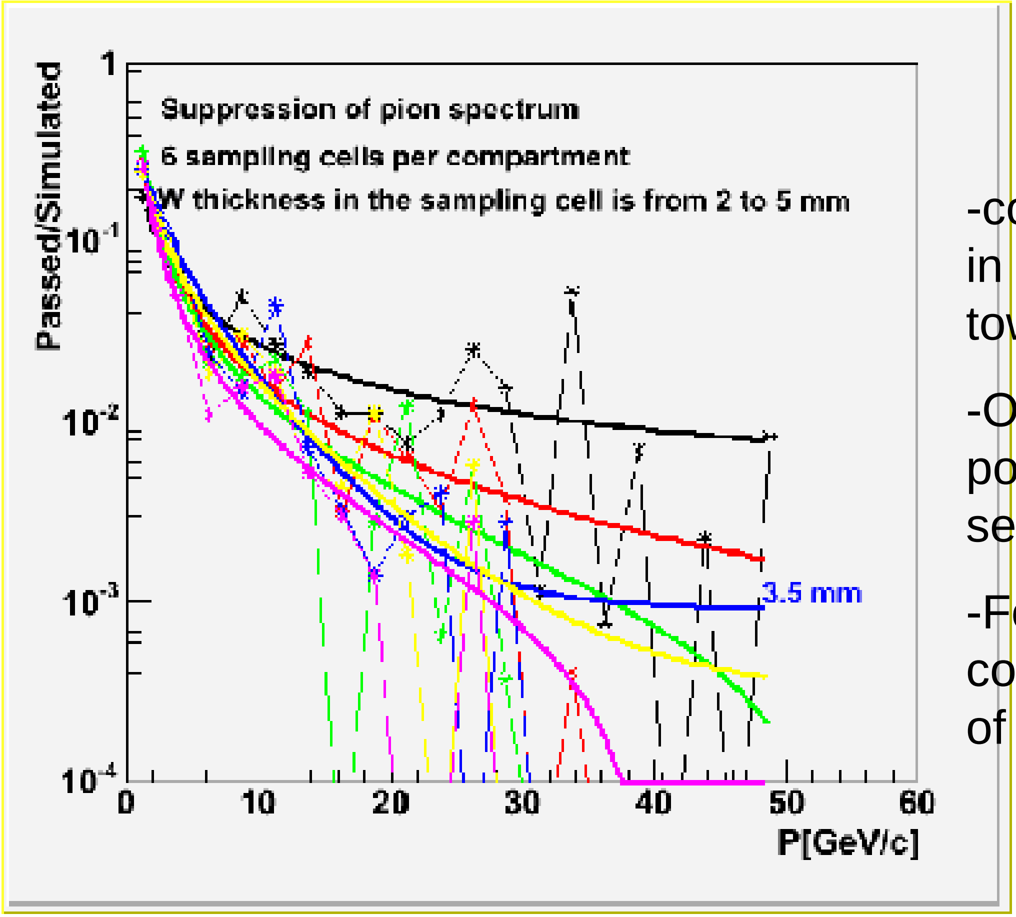
-Three segments (EM1/EM2/Hadronic)

-Plate thickness in EM segments varied from 2 mm up in steps of 0.5 mm

-Plate thickness in Had segment is "whatever fits" the total depth limit



Design optimization: electromagnetic vs hadronic



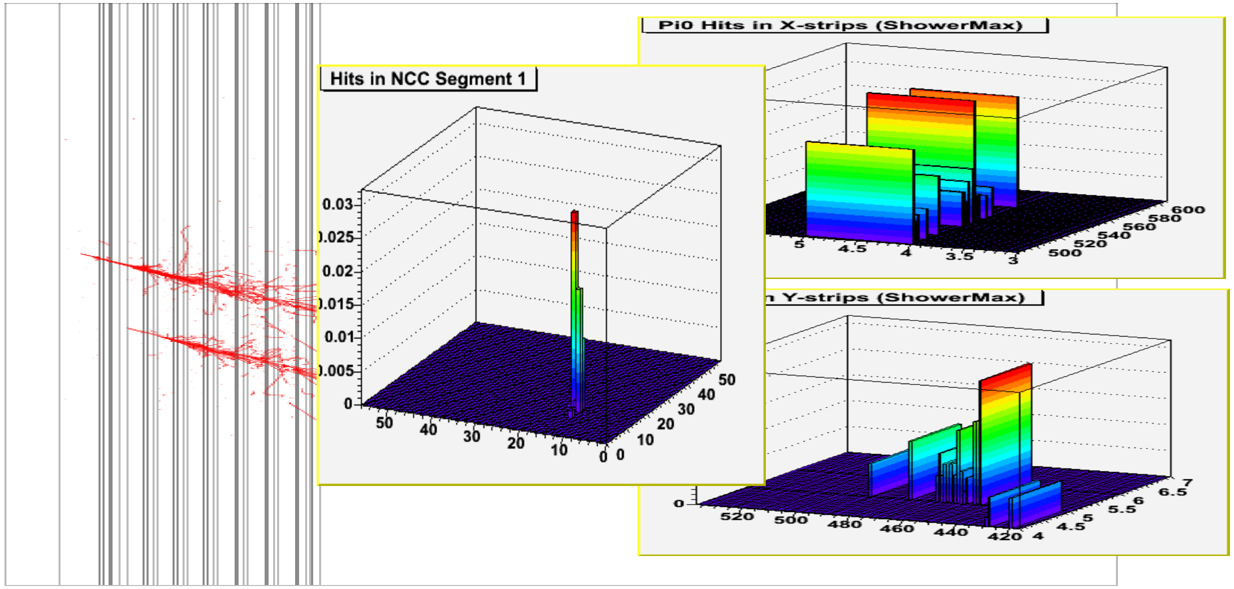
-correlations between plate thicknesses in em and hadronic segments push towards thicker plates in em segments;

-Optimal em resolution and discrimination power is reached for W plates in em segments 3 mm or thicker;

-For a fixed total calorimeter depth there could be advantages to using Pb instead of W in hadronic segment.

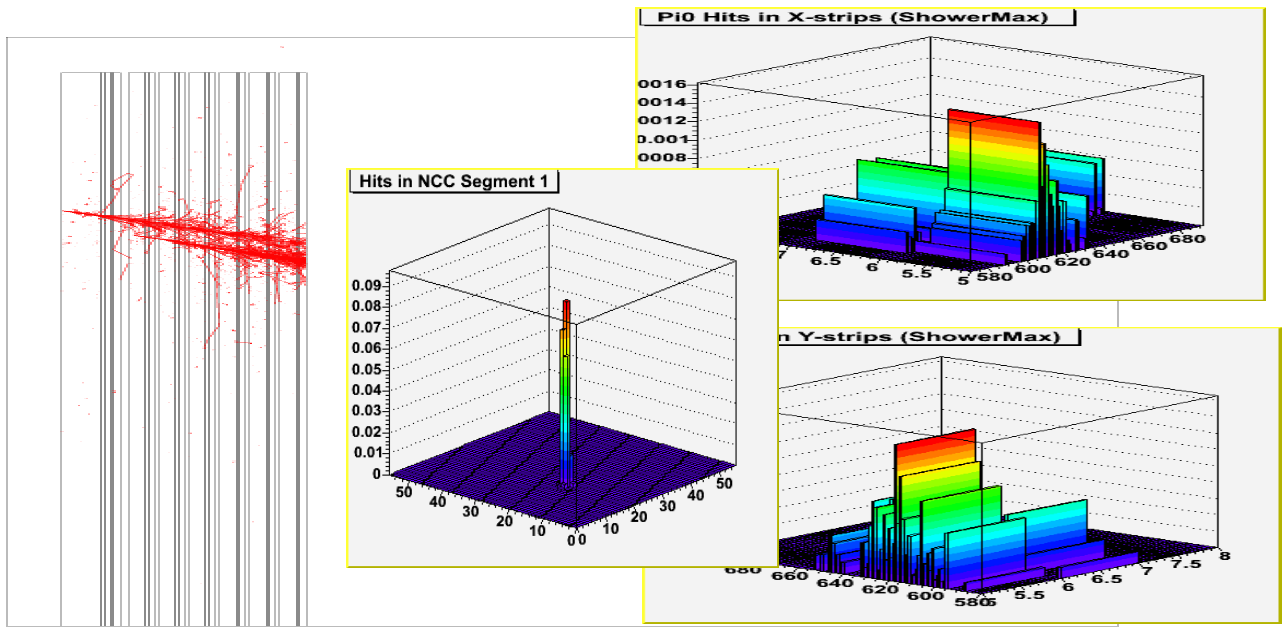
$\pi^0 \rightarrow \gamma\gamma$

5.3 GeV/c



$\pi^0 \rightarrow \gamma\gamma$

29.5 GeV/c

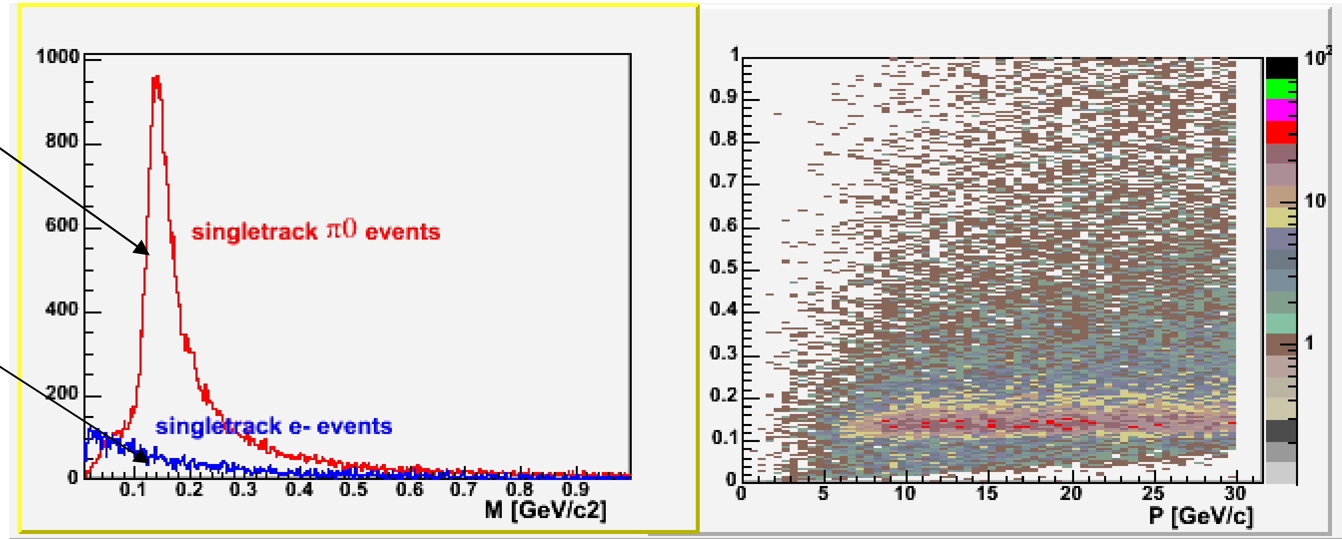


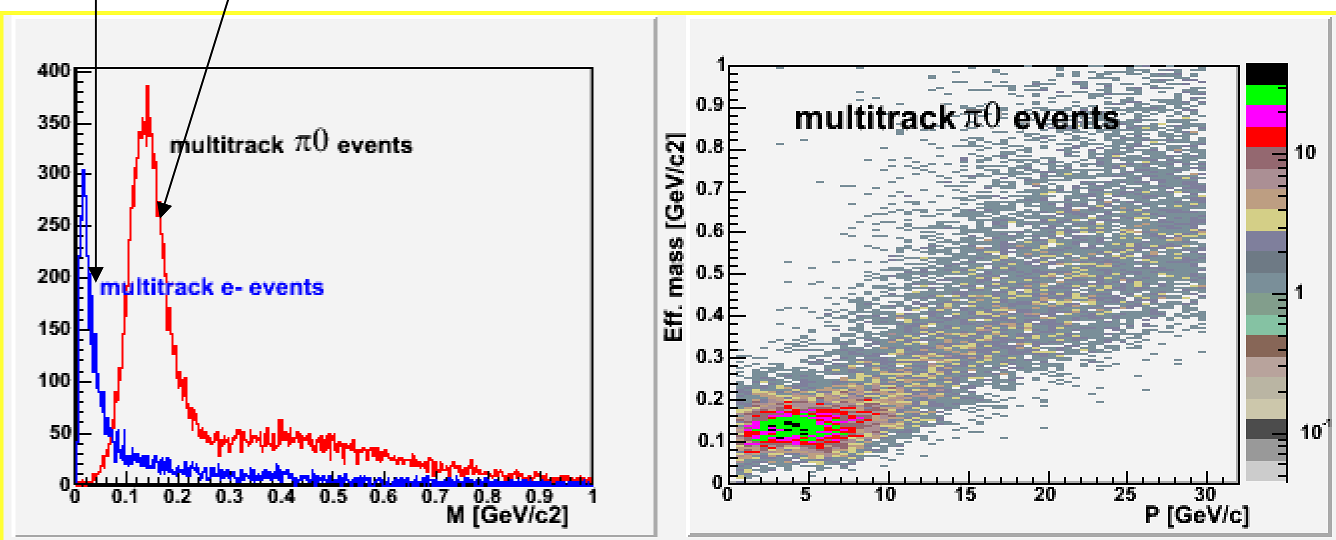
P0 – recognition/reconstruction

- Select clusters of amplitudes in all segments;
- Combine energy ordered clusters from different segments into “tracks”
- Define “regions of interest” in PS and SM foe every cluster (cluster energy dependent);
- Discount clusters with only one hit in PS, for multiple hits in PS – compute separation between two hottest hits;
- Select two clusters in SM (constrained by hit separation in PS) and fit energy ratio;
- Use total track energy, hit separation from PS and energy ratio from SM to compute effective mass;
- Retain those within p0 window as “p0” candidates, build effective mass combinatorics among everything else.

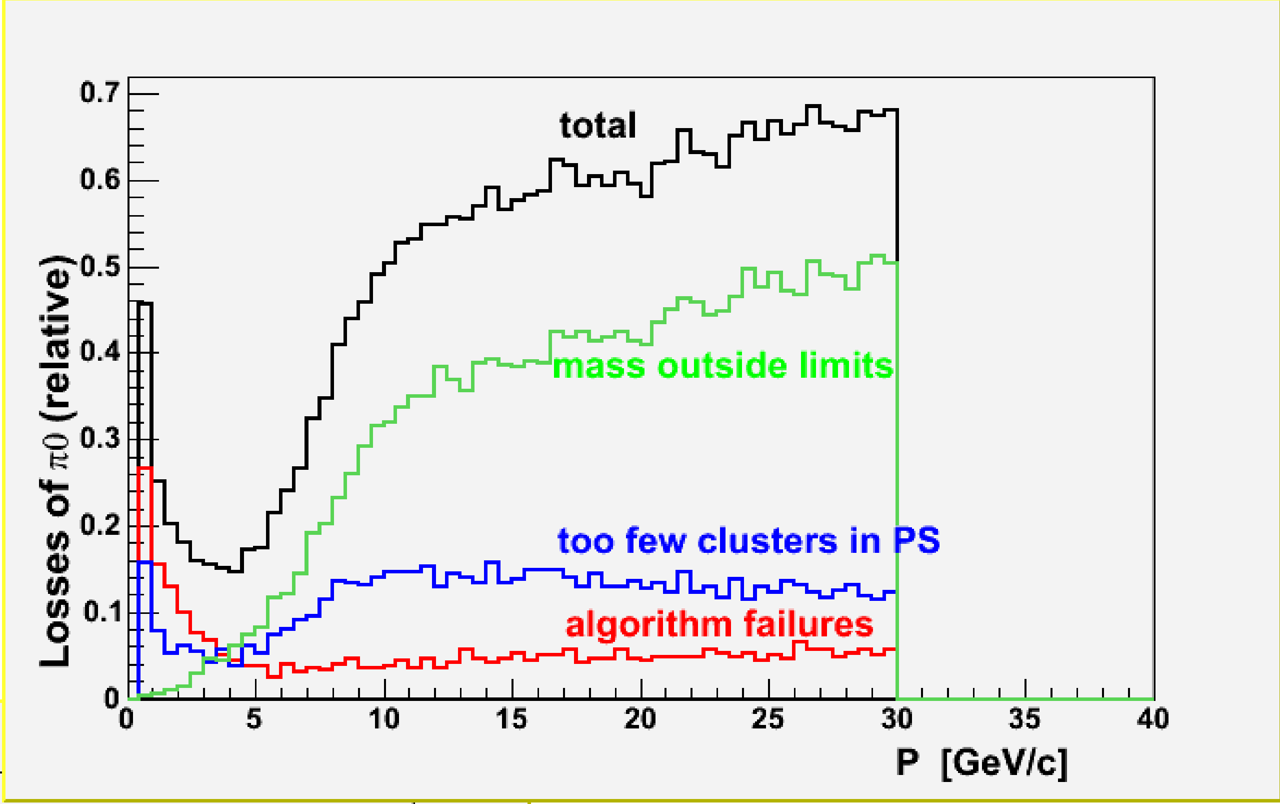
Claims to substantiate

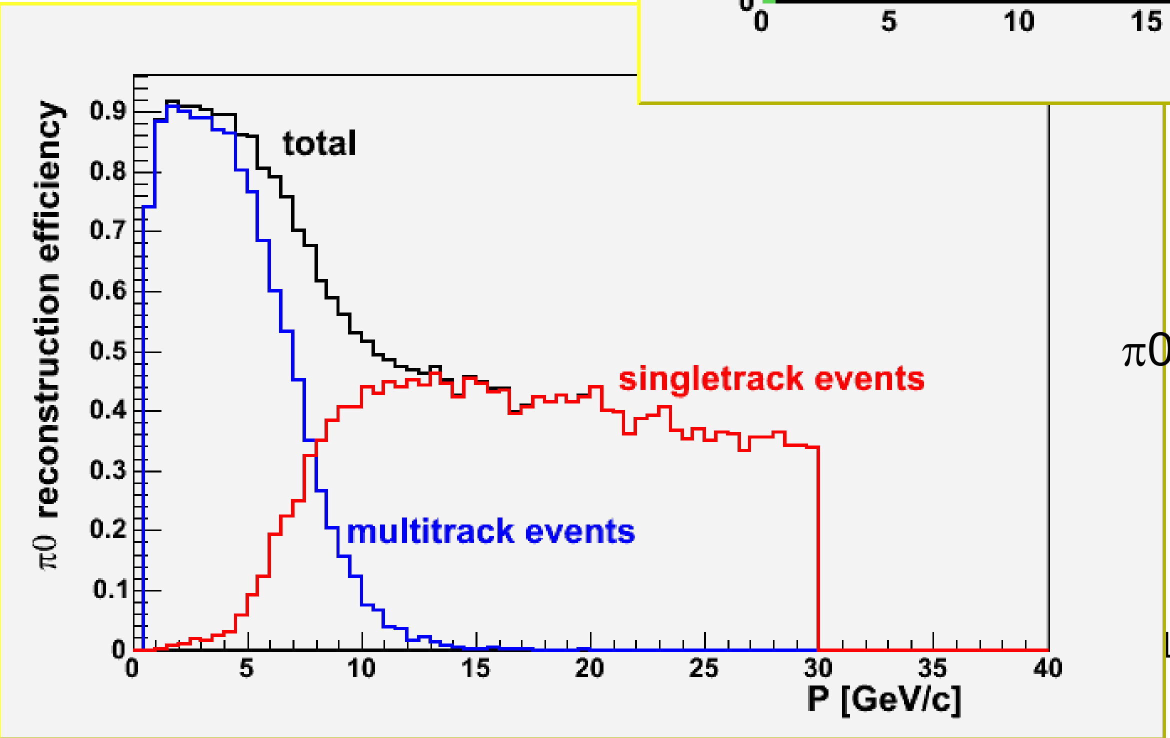
Single-particle (π0 and e) simulation in NCC





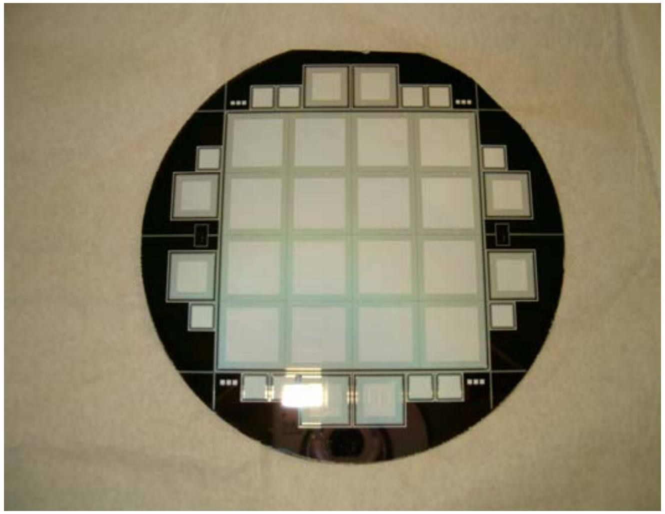
π0 losses today





π0 efficiency today

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

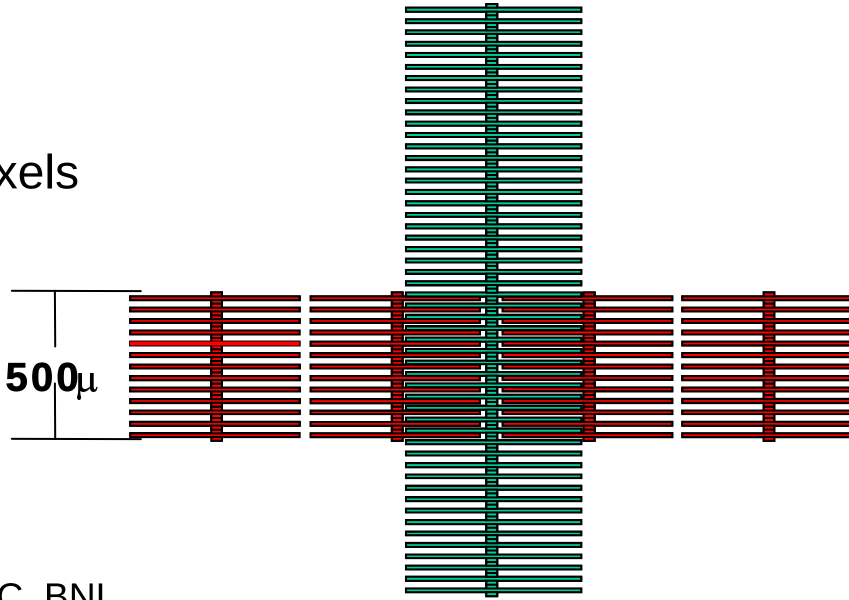


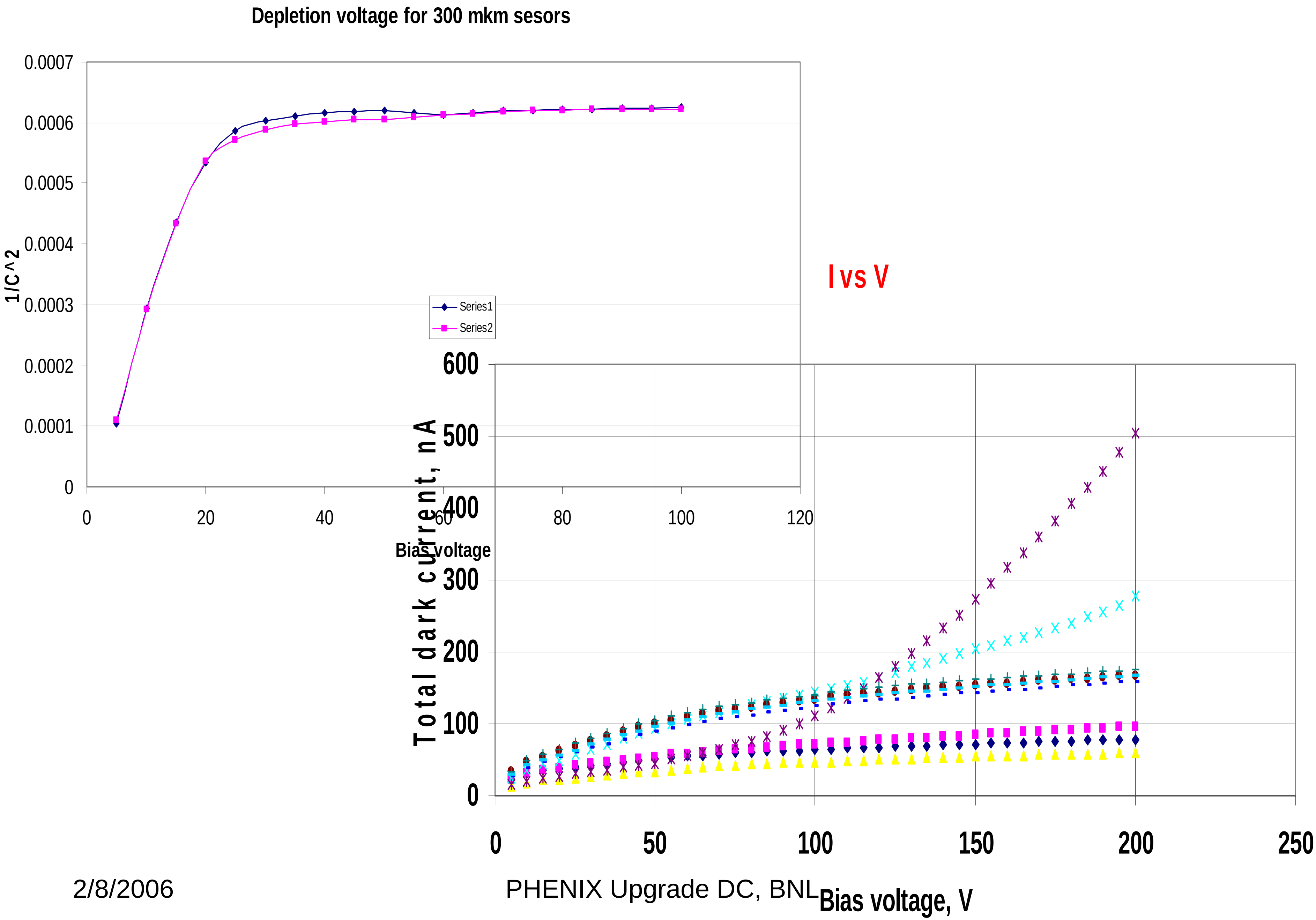
DC coupled, pad structured - ***completed***

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

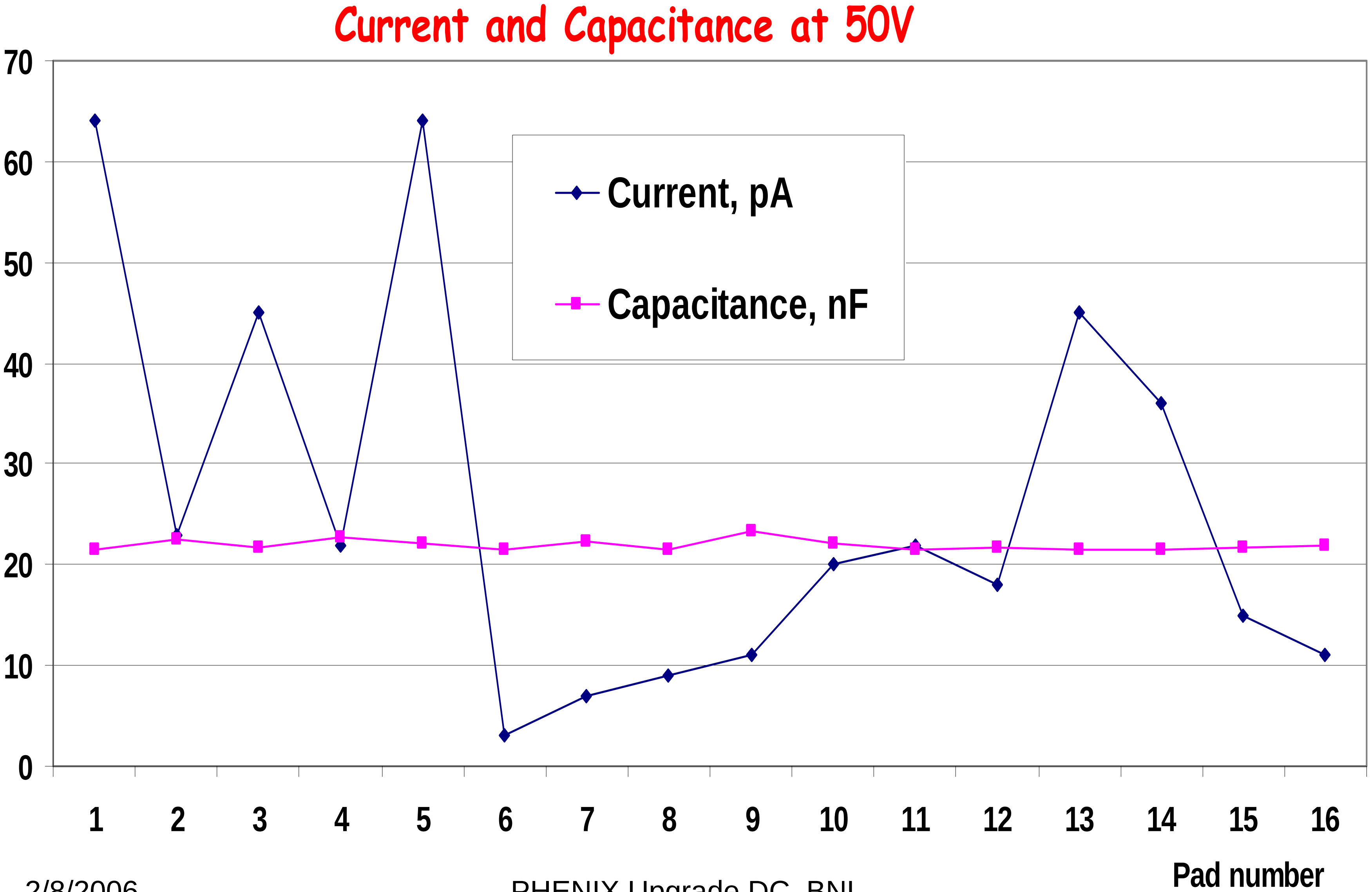
DC coupled, r-biased, pad structured – ***at ELMA and ON Semi***

StriPixels

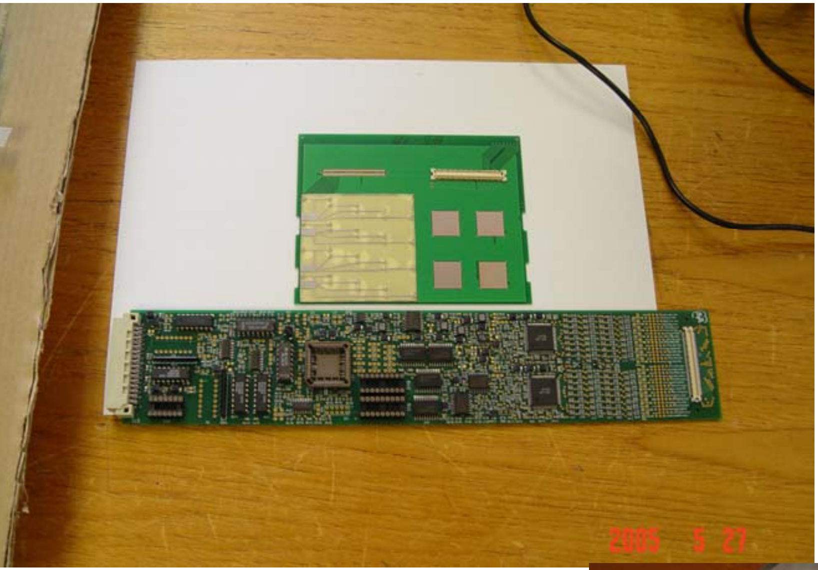


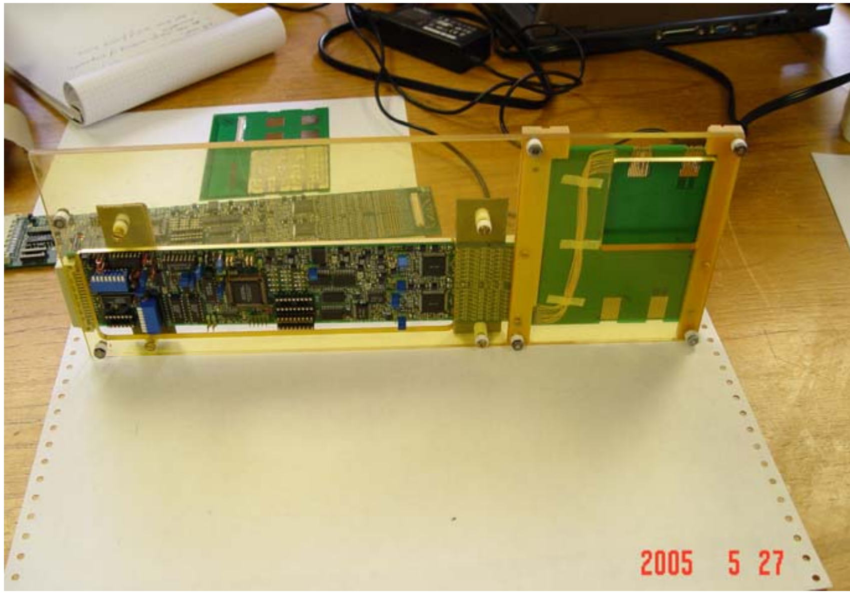


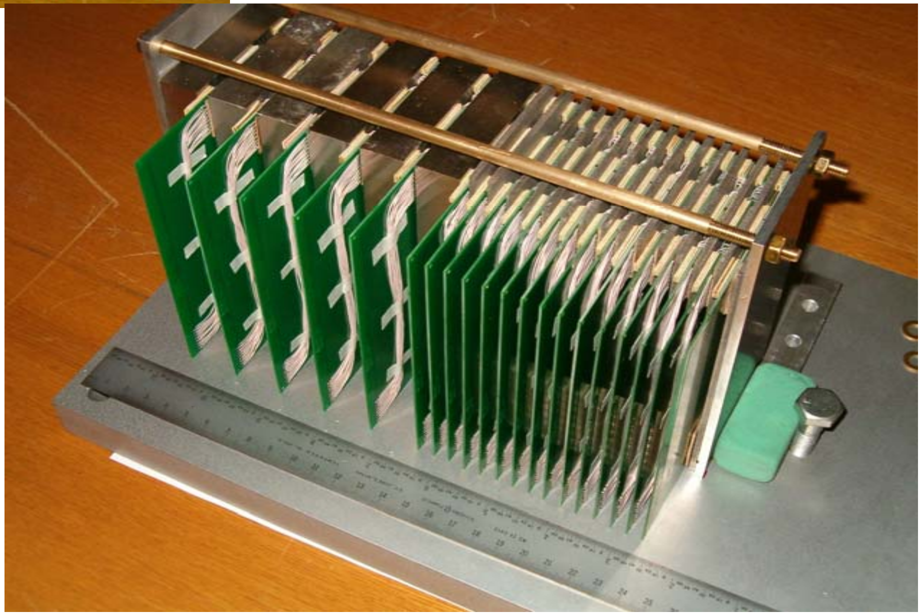
Depletion voltage for 300 mkm sesors
1/C^2
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
0
20
40
60
80
100
120
Bias voltage
Series1
Series2
I vs V
Total dark current, nA
600
500
400
300
200
100
0
0
50
100
150
200
250
Bias voltage, V


Current and Capacitance at 50V
70
60
50
40
30
20
10
0
Current, pA
Capacitance, nF
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Pad number

We can really do it

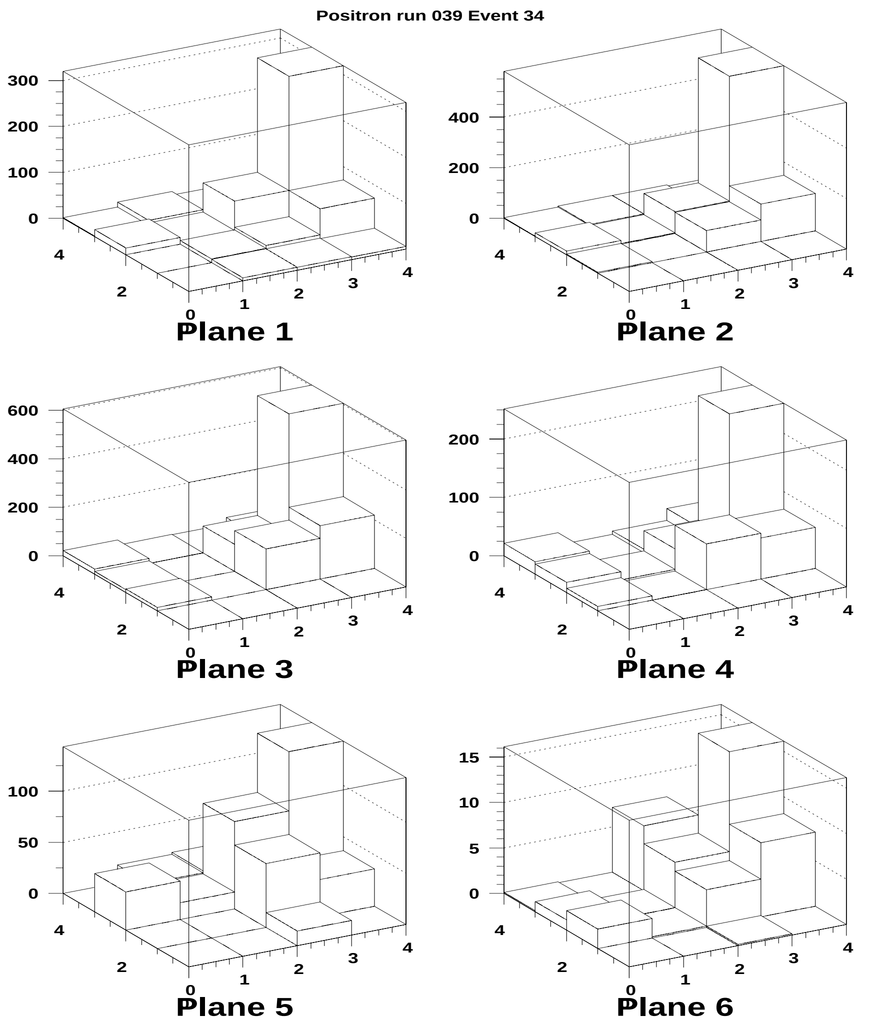


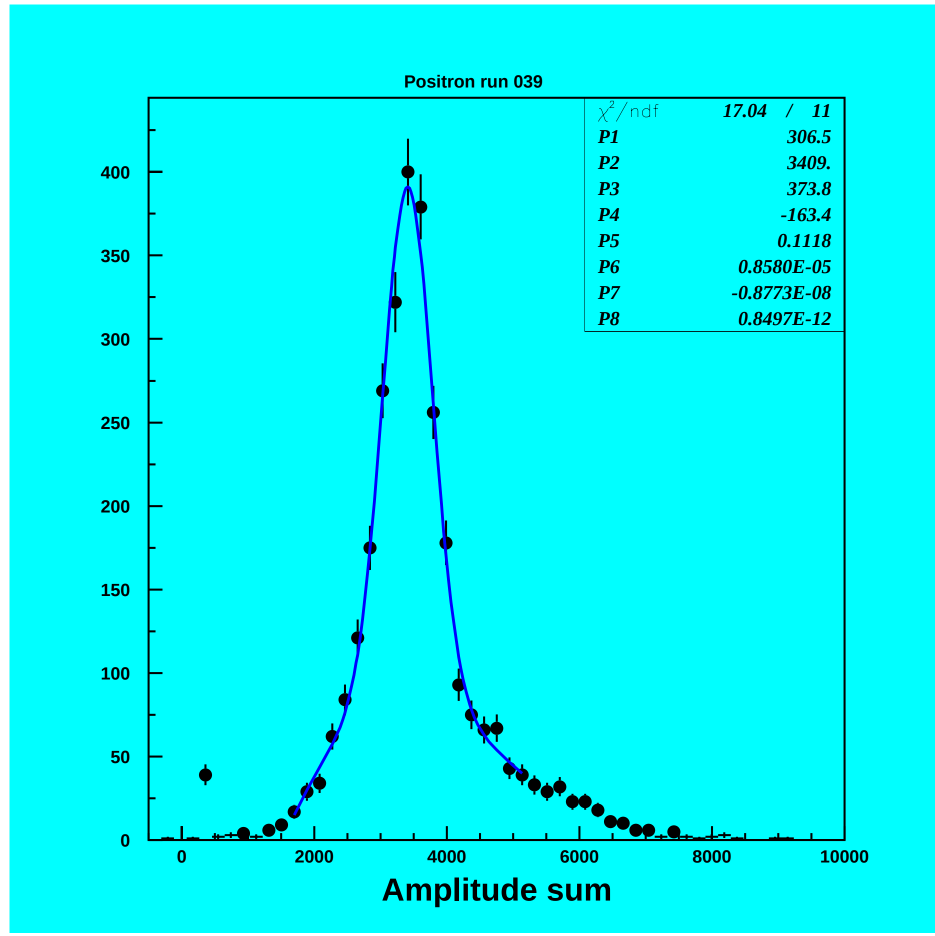




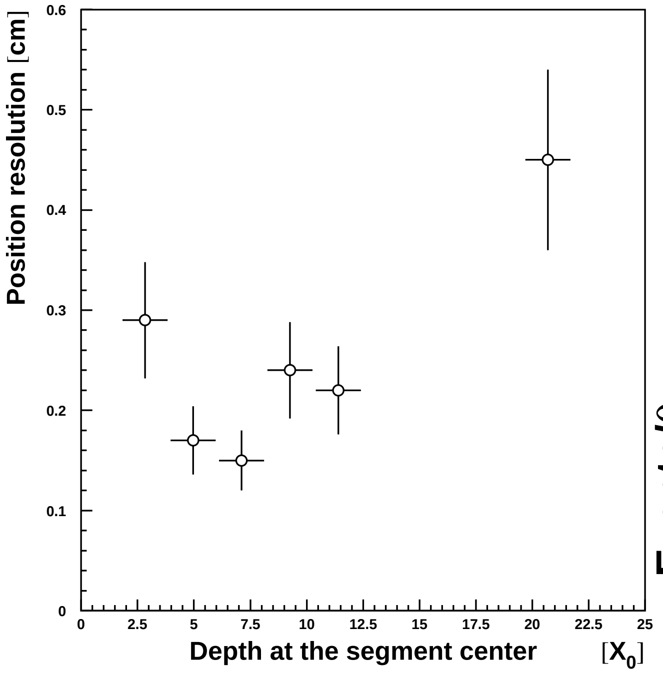
2/8/2006

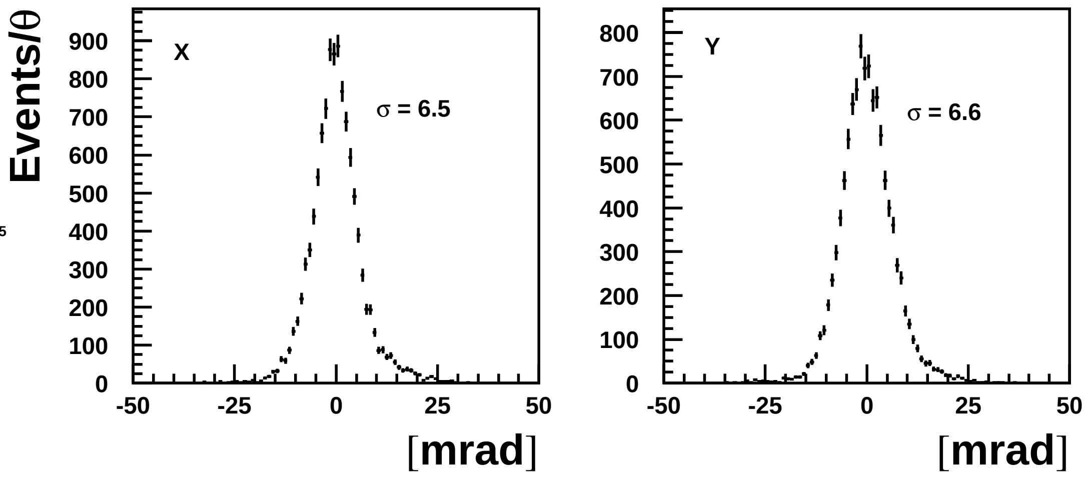
Eneregy resolution





Pointing resolution





R&D to complete 2006-2007

R&D 2006-2007: Development	2006(k$)	2007(k$)	Total(k$)	Funding source
Pxilated strip sensors (StriPixels)	26,300		26,300	RIKEN R&D
Pad-structured readout units	18,565		18,565	DOE Generic R&D
Strip-structured readout units	5,000	15,000	20,000	RIKEN R&D
Pad readout analog elecronics		15,200	15,200	RIKEN R&D
Pad readout digital electronics	3,000	5,813	8,813	DOE Generic R&D
StriPixel readout electronics	4,000	8,250	12,250	RIKEN R&D
R&D 2006-2007: Design and Prototyping				
Mechanical Design	60,000		60,000	UCR R&D
Pad-structured sensors	70,000	22,531	92,531	RIKEN R&D
Pad-structured ROU's	5,000	19,323	24,323	DOE Generic R&D
Electronics for pad-structured layers	10,000	27,500	37,500	DOE Generic R&D
Pixilated strip sensors (StriPixels)		10,540	10,540	DOE Generic R&D
StriPixel ROU's and electronics		18,185	18,185	DOE Generic R&D
Mechanical Structure	5,000	8,850	13,850	DOE Generic R&D
Testing (bench and Test beam)		17,038	17,038	DOE Generic R&D
2006-2007 request to DOE	41,565	107,247	148,812	
2006-2007 request to RIKEN	105,300	60,981	166,281	
Others (UCR)	60,000	0	60,000	

Project at a glance

Funding Source	Base cost	Contingency [%]	Overhead [%]	Cost to Project
DOE Generic R&D Funds	$104,500	31	17.5	$160,323
RIKEN R&D Funds	$138,500	10		$152,500
UCR R&D Funds	$50,000	20		$60,000
MSU R&D Funds	$0	0		$0
JINR (Dubna, Russia) R&D Funds	$0	0		$0
Czech group R&D Funds	$0	0		$0
Korean group R&D funds	$0	0		$0
DOE Construction Funds	*$2,431,630*	*34*	*17.5*	*$3,823,540*
Collaboration construction funds	$2,386,630	44		$3,426,804
NCC Project	$5,189,759	37		$8,301,003

Summary

- ***There is a lot of momentum ……***

- ***Next two years are***
  - ***To substantiate the performance claims;***
  - ***To accumulate data to build analysis chain;***
  - ***To finish design and test production chain;***

- ***Three years for construction project are tough but feasible. We can get to the physics of saturation in 2010.***