Design of the Time of Flight System

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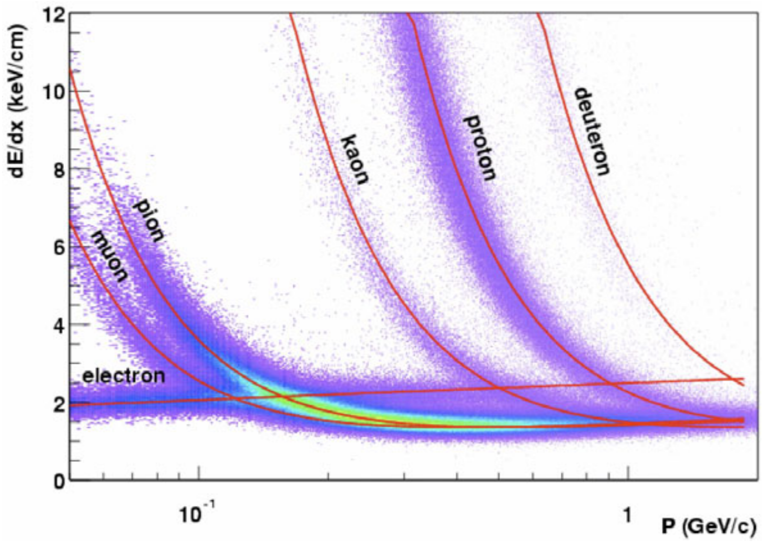
☆ *Analysis Meeting, BNL, 3/14/2011*

Outline:
What information is of interest?
How do we collect this information?
What detectors were implemented and how do they work?
Resolution & Performance
Geometrical Acceptance

What information would be helpful?



Particle Identification via TPC dE/dx

- π & K to ~0.6 GeV/c
- p to ~1.0 GeV

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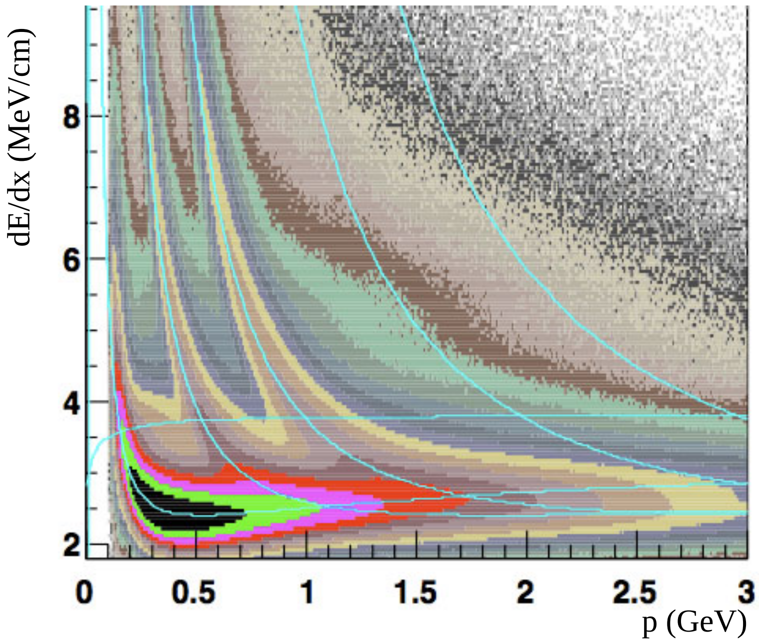

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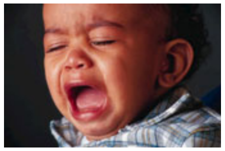
Limits not that high compared to the spectra
~half of the spectrum is above these limits…

Electrons cut through π/K/p bands….



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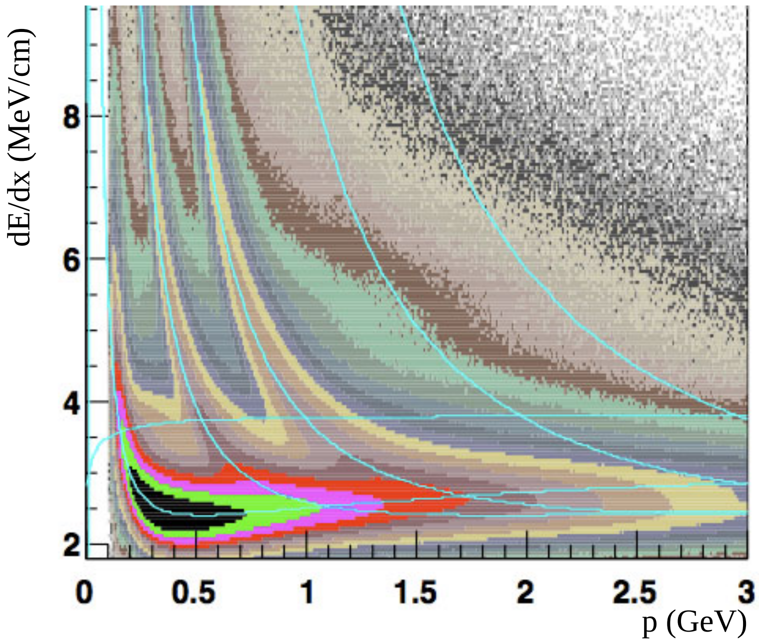

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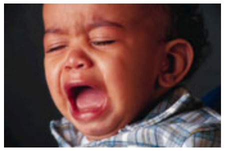
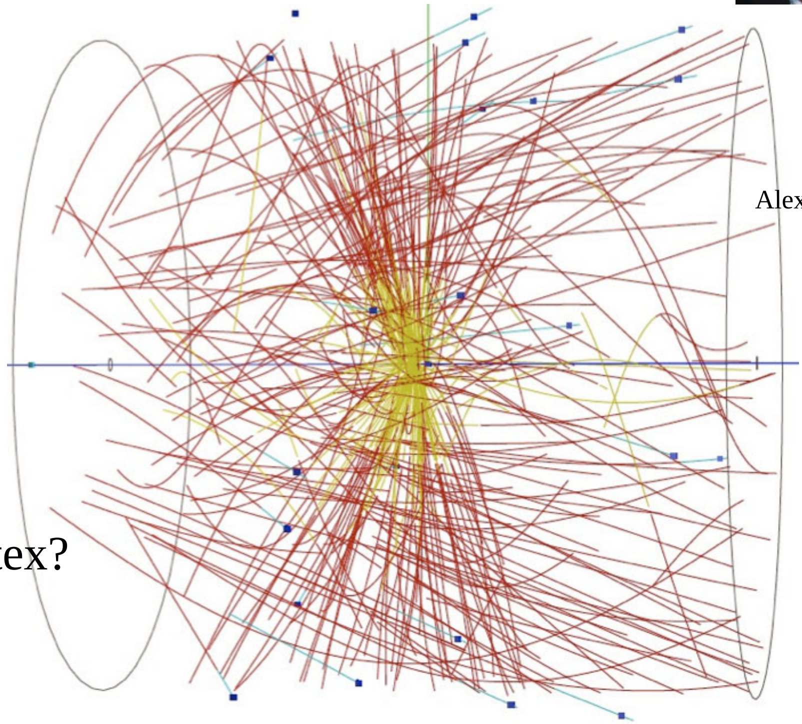




Alexander Schmah

Au+Au collision from the BES:
Nice vertex, but completely out of time!

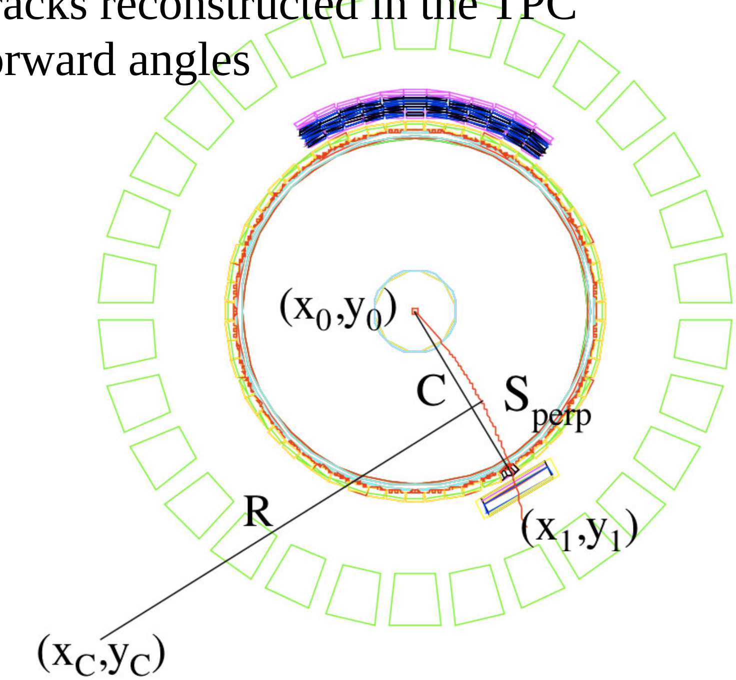
…and can we think of another way to
measure the location of the collision vertex?

How do we collect information that would help here?

Precision Timing to the rescue!

at midrapidity, measure the flight time for the tracks reconstructed in the TPC

make similarly precise measurements at very forward angles



….at mid-rapidity:

Flight time: "stop time" minus "start time"

$\Delta t = T_{stop} - T_{start}$

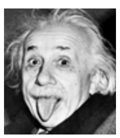
TPC measures

momentum, p (GeV/c)

path length, s (cm)

$s = \beta c \Delta t$

$p = \gamma\beta m$



…a "precise" Δt gives track Mass

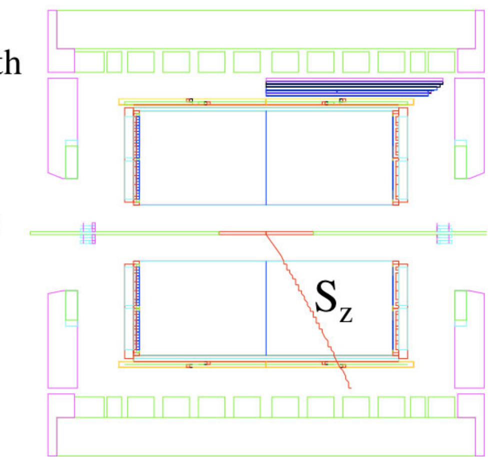
$s = \sqrt{(s_{perp}^2 + s_z^2)}$ with

$s_{perp} = 2R \sin^{-1}(C/2R)$

$s_z = z_1 - z_0$

R is the helix radius

$C = \sqrt{((x_1 - x_0)^2 + (y_1 - y_0)^2)}$



….and at very forward time angles:

$\Delta t = T_{east} - T_{west}$

$Z_{vtx} = c \Delta t / 2$

…a "precise" Δt gives the collision vertex position

How precise must this be?

…at mid-rapidity:

$s = \beta c \Delta t$

$p = \gamma\beta m$

$\delta x = \Delta x / x$

$\delta M = \delta p \oplus \gamma^2[\delta s \oplus \delta t]$

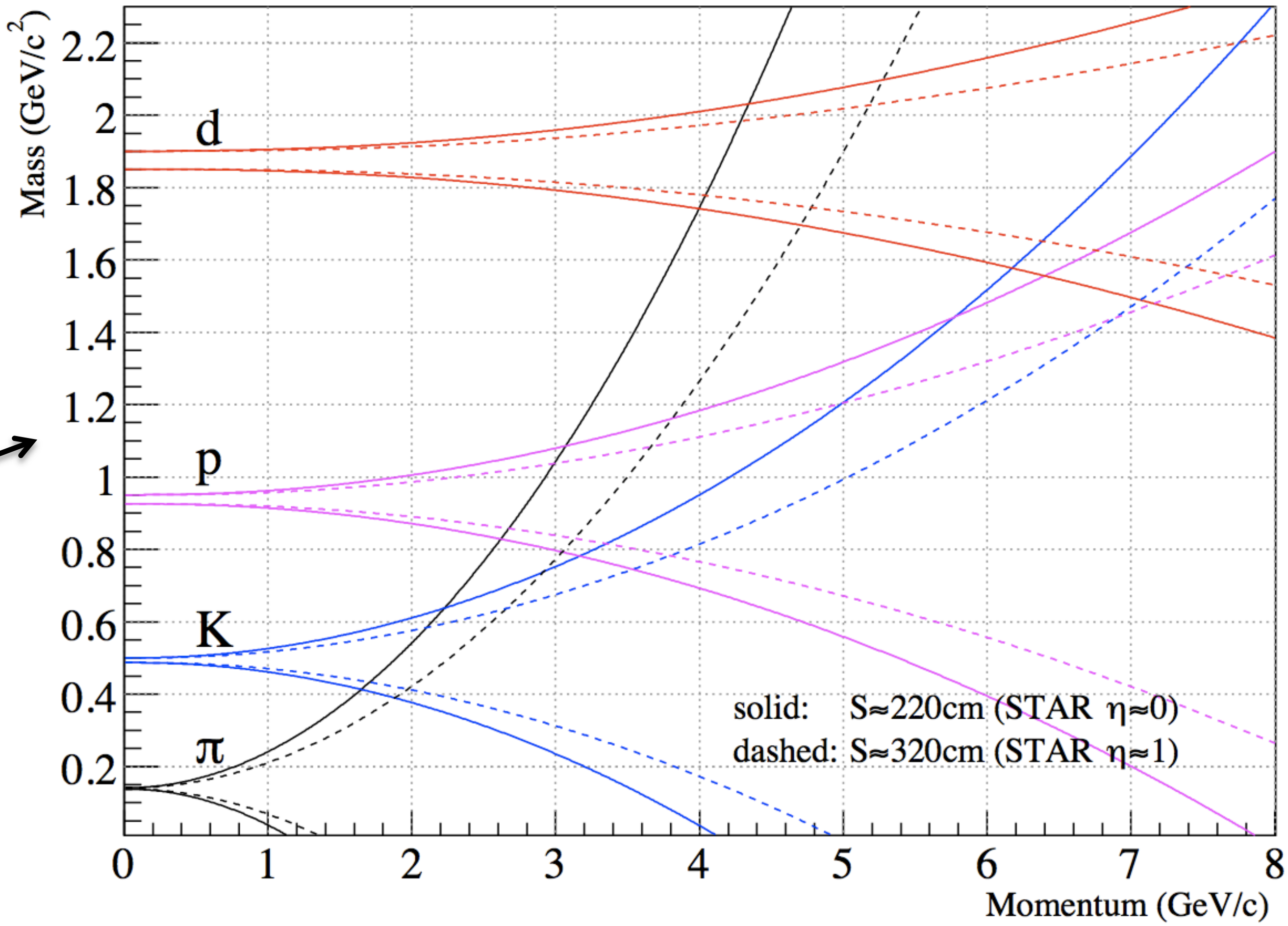
ballpark values:

$\Delta p/p \sim 1.3\%$

$\Delta s/s \sim 0.2\%$

$\Delta t \sim 100ps$

Nucl. Inst. and Methods, Section A, **522, 252 (2004)**



…at very forward angles

$\Delta Z_{vtx} = (c / \sqrt{2})\ \Delta T_{side}$

$\Delta T_{side} = \Delta T_{singledet} / \sqrt{N_{det}}$ …this is the "Averaging effect"

if $\Delta T_{side} = 240ps$, then $\Delta Z_{vtx} = 5cm$ (at Level-0 in Au+Au, 1.and.1 earliest hits, no corrections)

if $\Delta T_{side} < 50ps$, then $\Delta Z_{vtx} < 1cm$ (A+A with corrections and the averaging effect)

How precise must this be?

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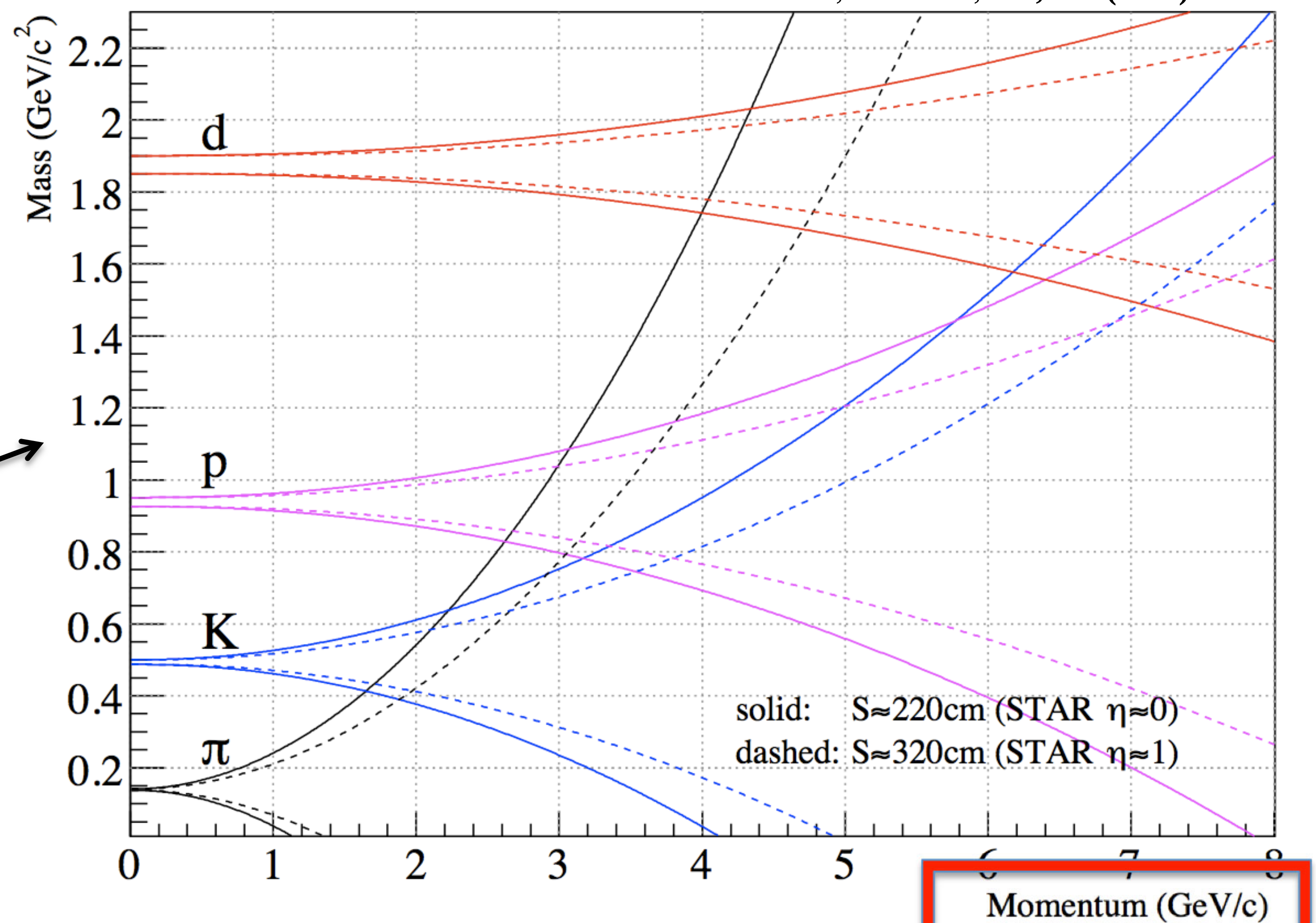

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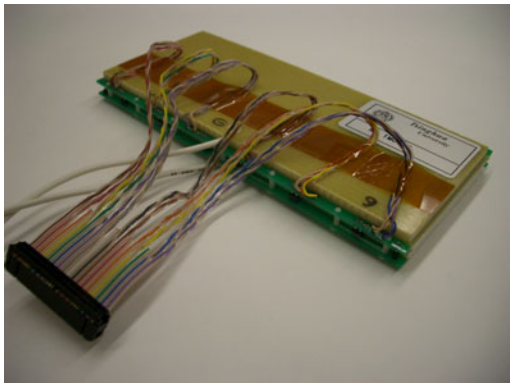
MOMENTUM, not P_T !!

How do we achieve this level of precision?

E. Cerron Zeballos, *et al*., NIM **A** 374, 132 (1996).
M.C.S. Williams, Nucl. Phys. **A** 698, 464 (2002).

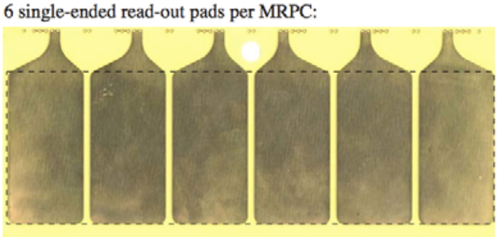
Multigap Resistive Plate Chambers (MRPCs)

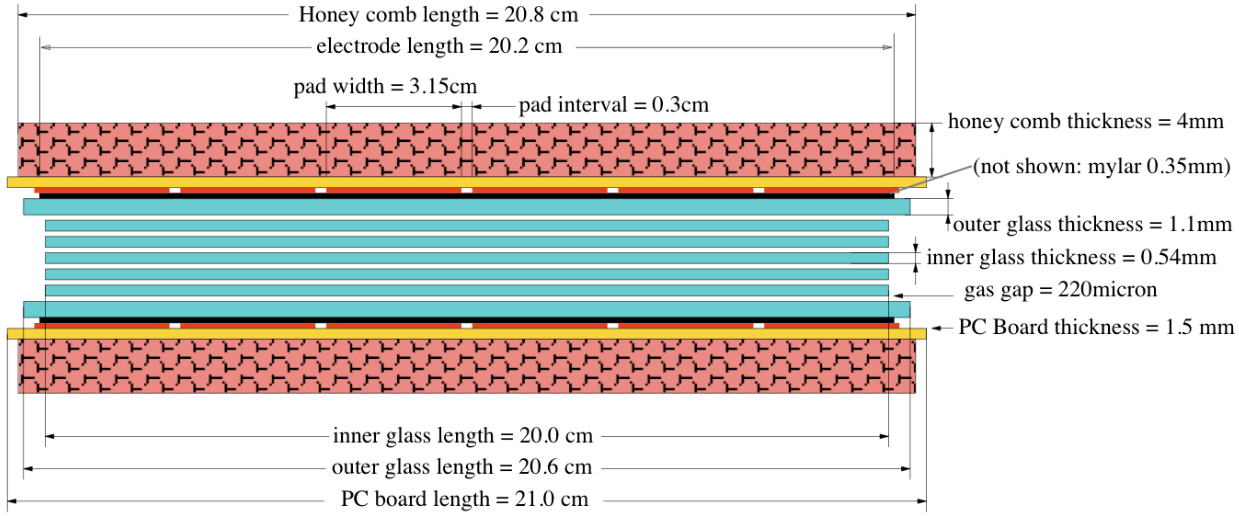
- cheap
- easy to build
- fast timing

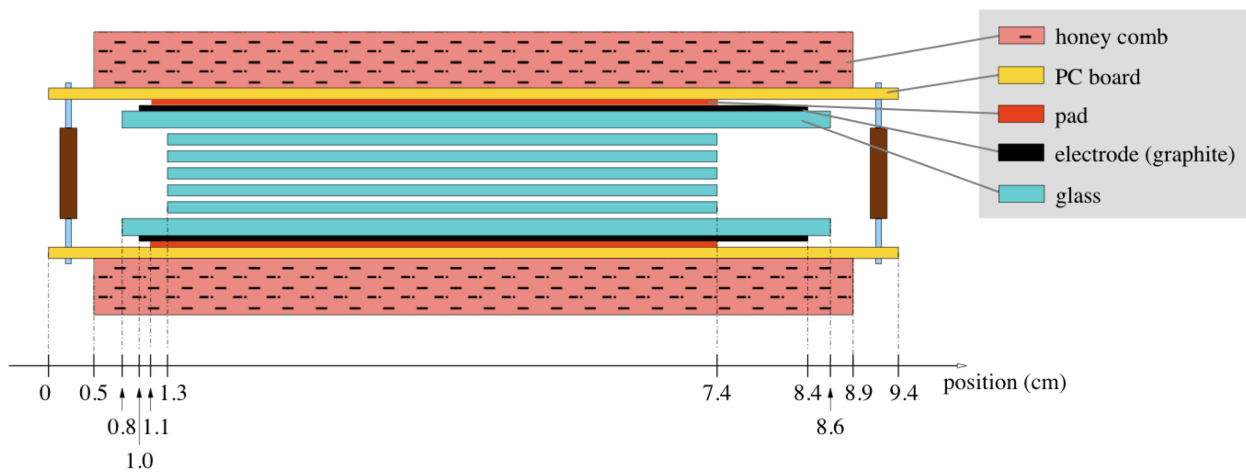


Tsinghua, Beijing
USTC, Hefei

6 single-ended read-out pads per MRPC:



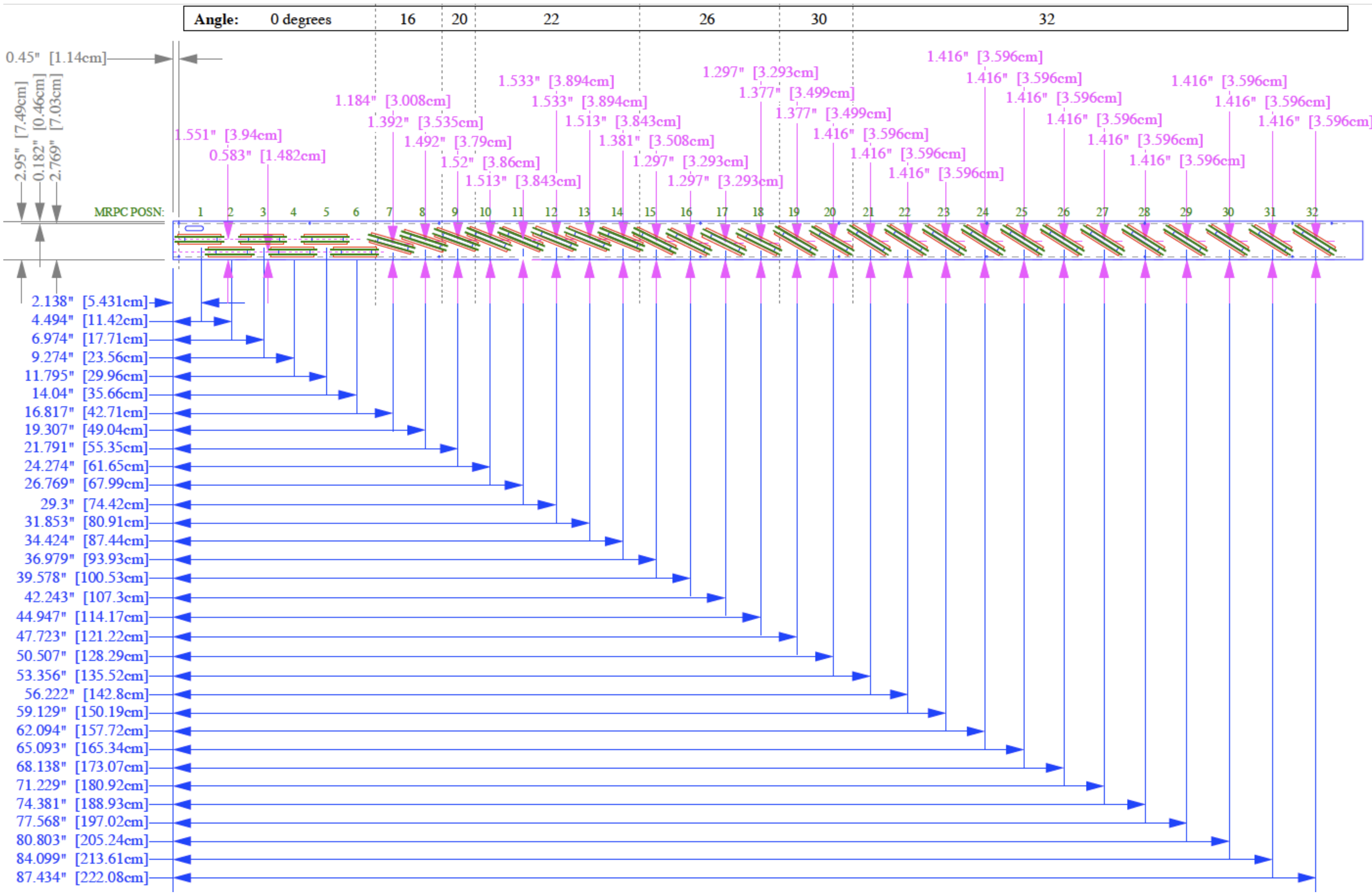




"Multigap RPCs in the STAR experiment at RHIC"
WJL for STAR, NIM **A**, in press, doi:10.1016/j.nima.2010.07.086.

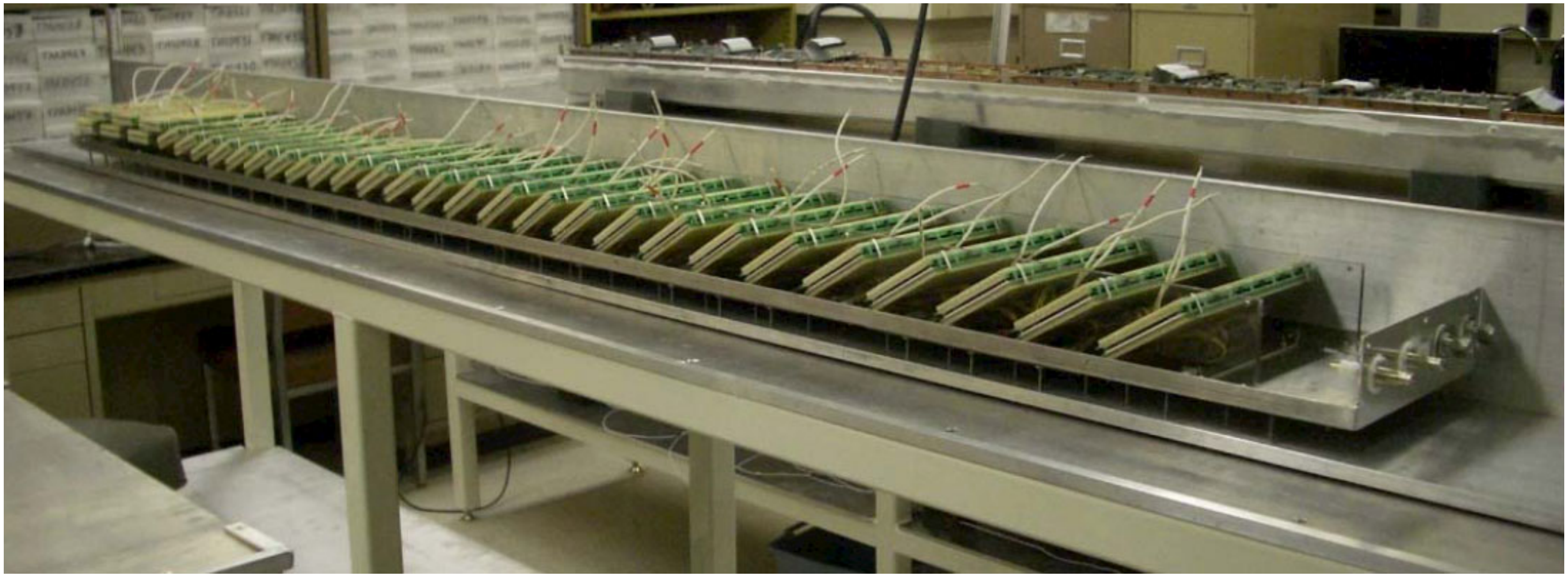
MRPCs in "Trays"

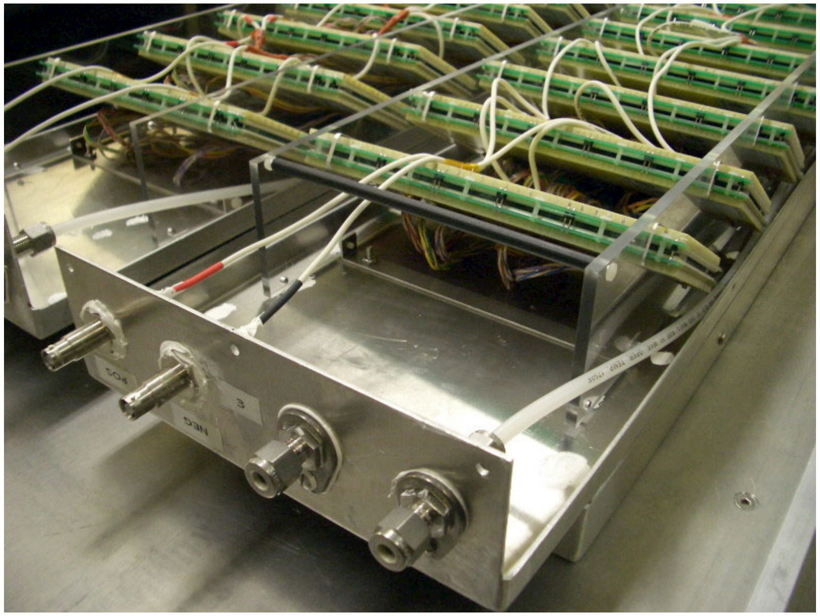
Put 32 MRPCs into each of 120 trays – surround these TPC with these trays in two rings…



- Z=0

TOF Trays



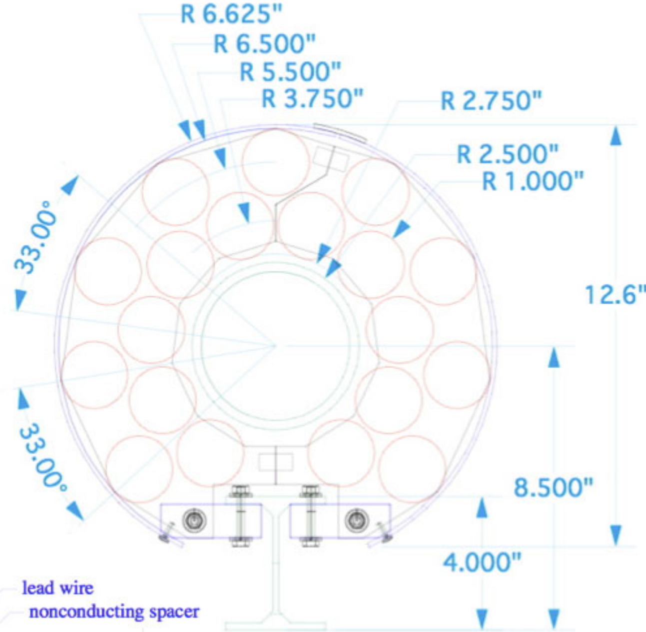


The “Start Side” (the very forward timing detector)

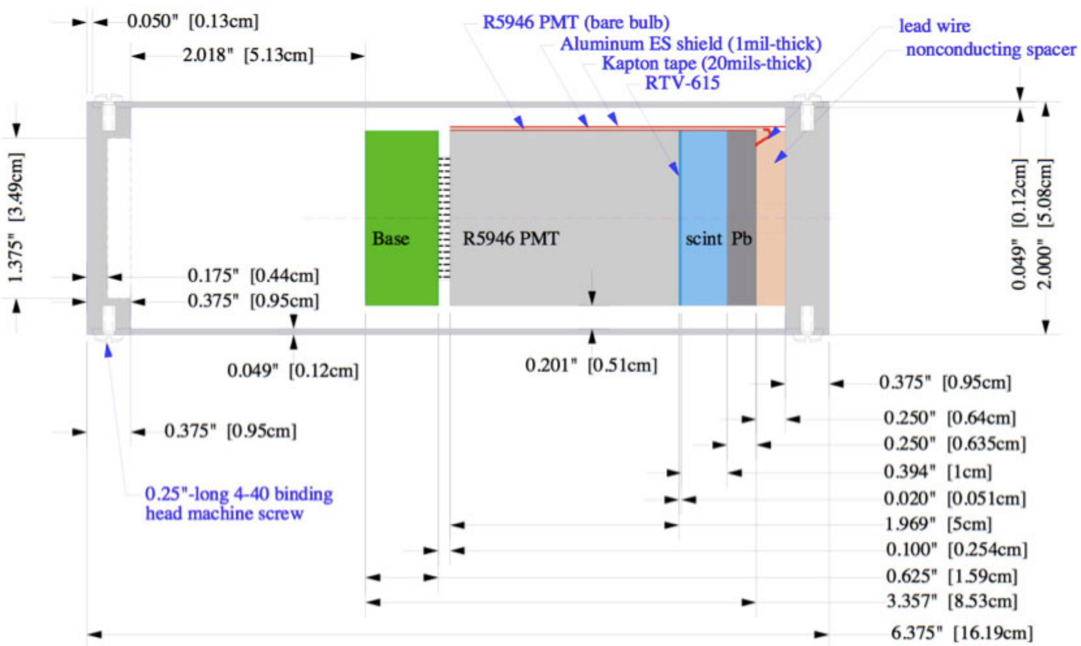
upVPD Mechanical Details

19 detector channels per side, 2.0” OD
in same integration volume as pVPD
no Steel or magnetic shielding, light-weight

Inner radius ~ 2.75” = 6.98cm
Outer radius ~ 6.50” = 16.51cm
STAR |Z| ~ 570 cm
$4.24 < |\eta| < 5.10$

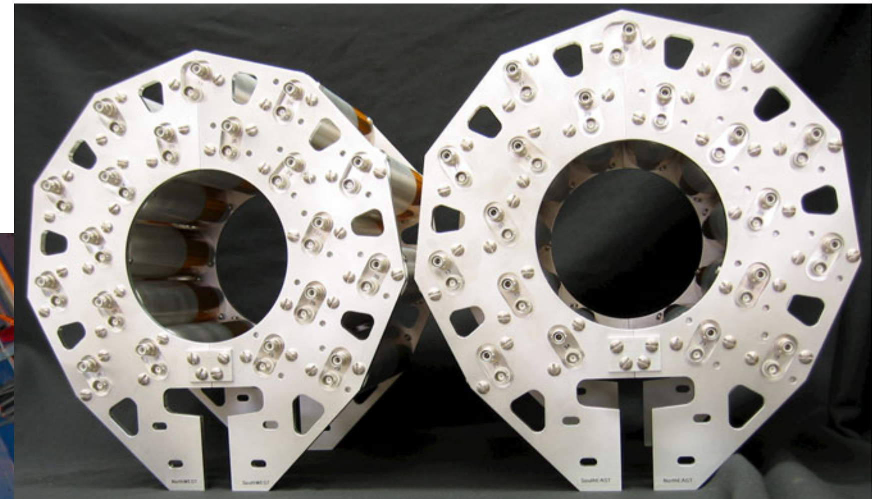


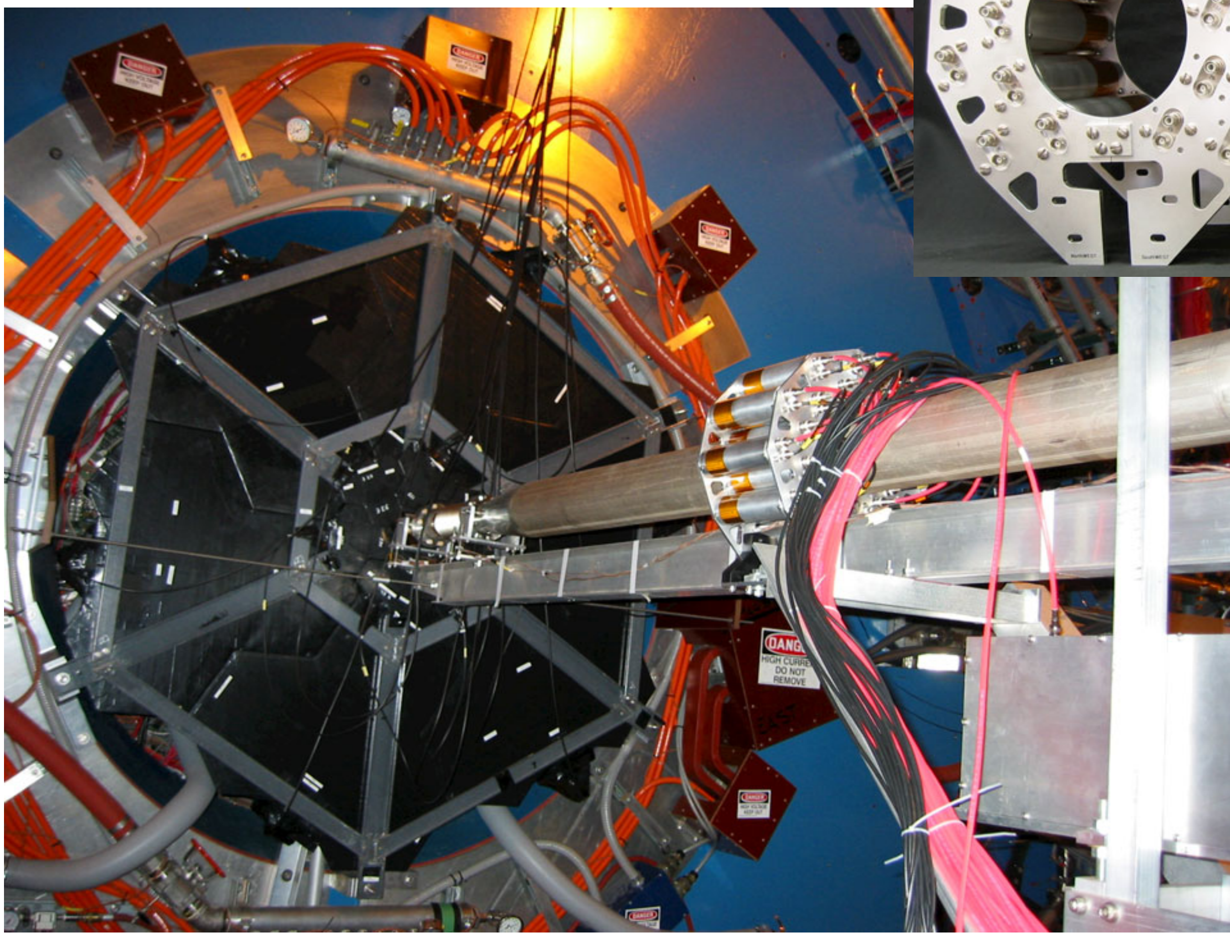
Pb converter, 1.5” OD, 1/4”-thick (1.13 radiation lengths)
inner ring converter min $|\eta| = 4.60$
inner ring converter middle $|\eta| = 4.79$
outer ring: ~1/3 of azimuth covered, $4.2 < |\eta| < 4.6$



The “upgraded pseudo Vertex Position Detector” (upVPD)

One on east, & one on west
|Z| ~ 5.7m
Digitized by TOF & TRG electronics…





Single Detector Resolution
p+p, d+Au ~130-140 ps
Au+Au ~100 ps

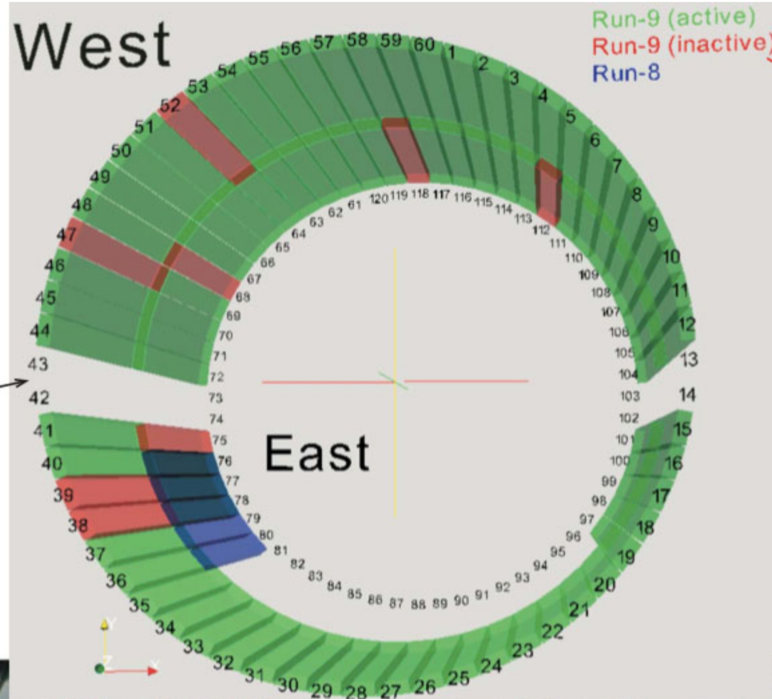
“Brief Introduction to the VPD and the TOF Start-Side
http://wjllope.rice.edu/~WJLlope/-myPublications/AnaMtg20100617_vpd.pdf

Coverage during Runs 8 through 10

Run-8 2008
5 trays
Run-9 2009
94 trays (86)
Run-10 2010
120 trays (119)

TPC support arms

...special jack used to support TPC for installation of these trays before present Run-10....



Run-9: 94 trays installed

Problems with 8 trays...

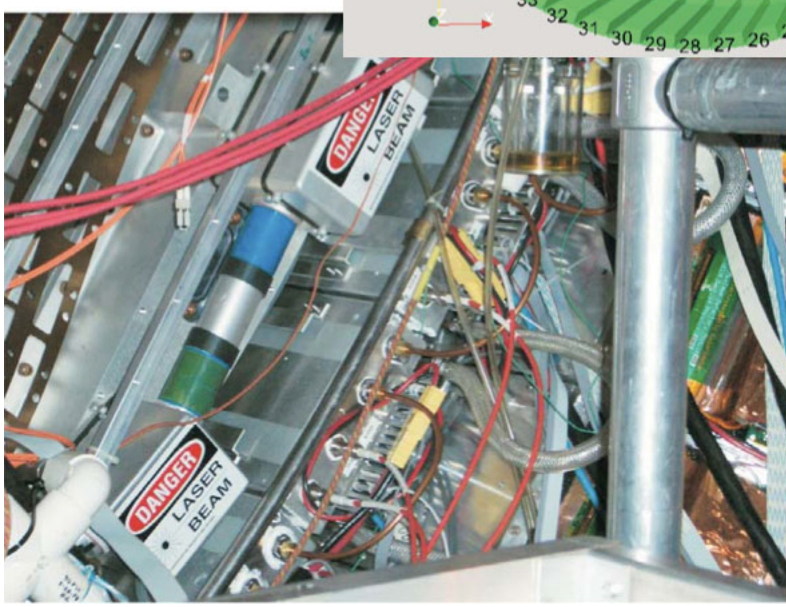
LV cabling: 2 trays
sense wires disconnected

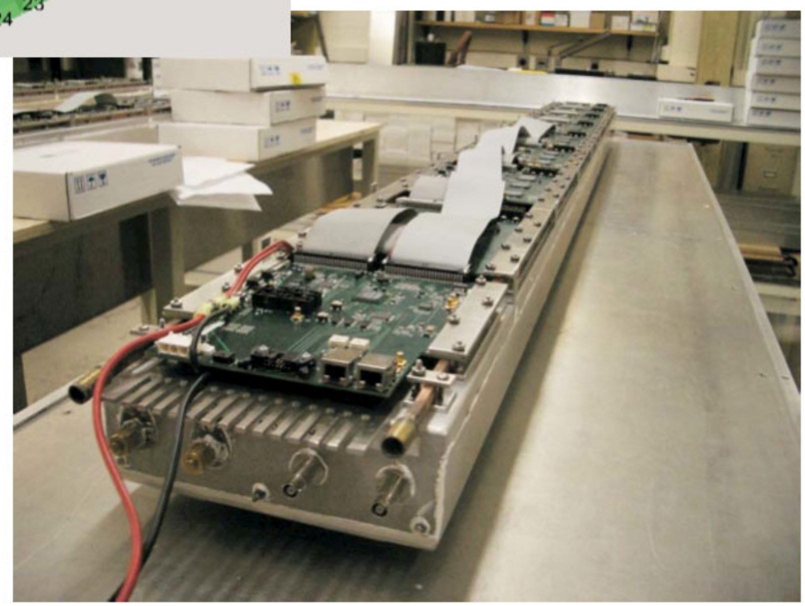
HV cabling: 5 trays
2 cables pinched by poletip
3 cables improperly connected

One bad TCPU board

86 trays collected good data...
All were fixed before Run-10...

but now 1 bad HV cable
(behind TPC support arms)



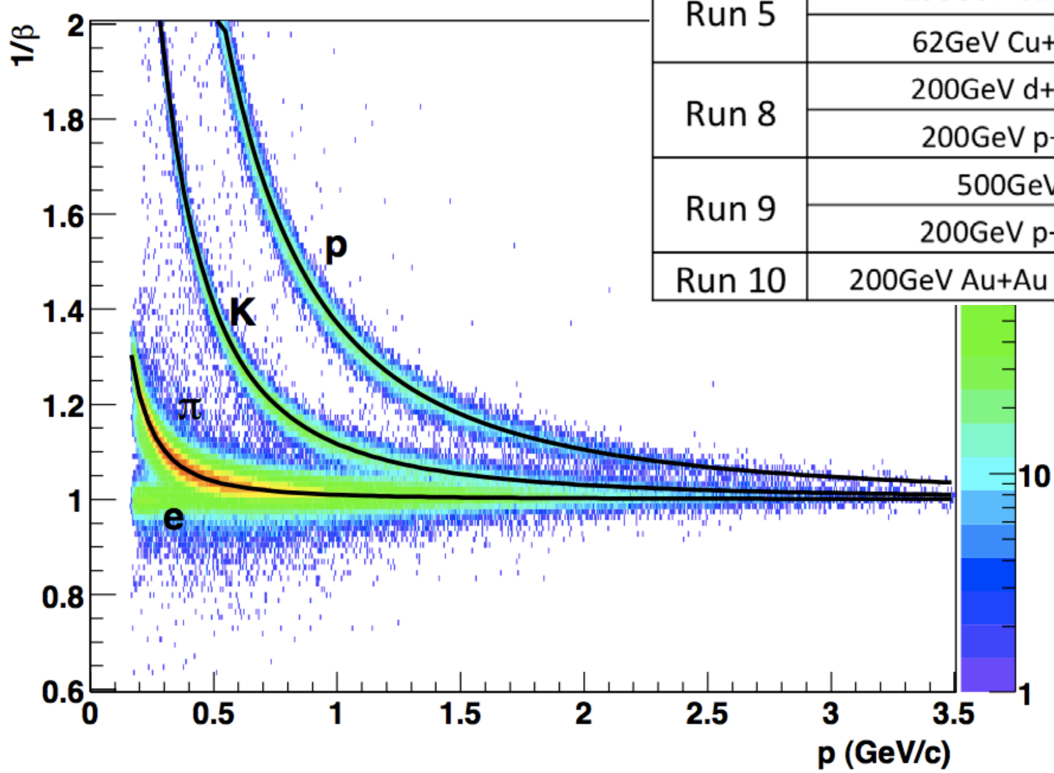


Performance

Start-time (and Zvtx) resolution highly dependent on beam species…

also see Frank and Xin's talks…

Run	Operating condition		Timing Resolution (ps): Start time	Overall	Stop time
Run 3	200GeV d+Au		85	120	85
	200GeV p+p		140	160	80
Run 4	62GeV Au+Au		55	105	89
	200GeV Au+Au	Full-field	27	86	82
		Half-field	20	82	80
Run 5	200GeV Cu+Cu (ToT)		50	92	75
	62GeV Cu+Cu (ToT)		82	125	94
Run 8	200GeV d+Au (ToT)		NA	NA	NA
	200GeV p+p (ToT)		83	112	75
Run 9	500GeV p+p		85	115	78
	200GeV p+p (RFF)		81	110	74
Run 10	200GeV Au+Au (preliminary)		30	87	82

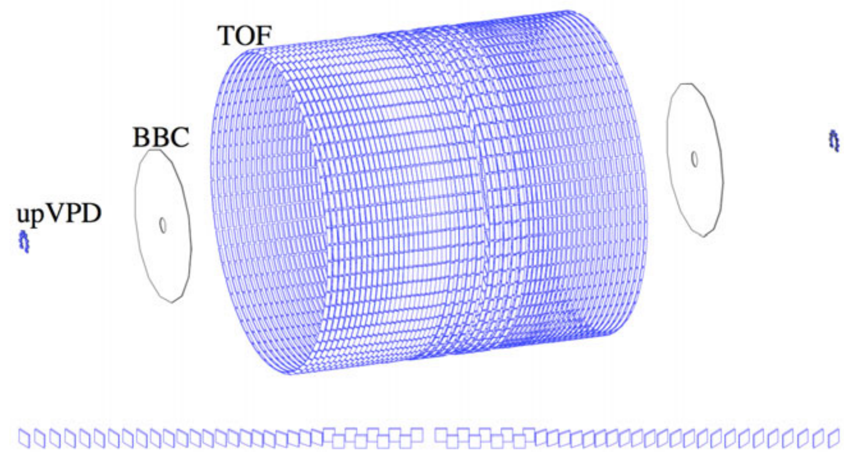


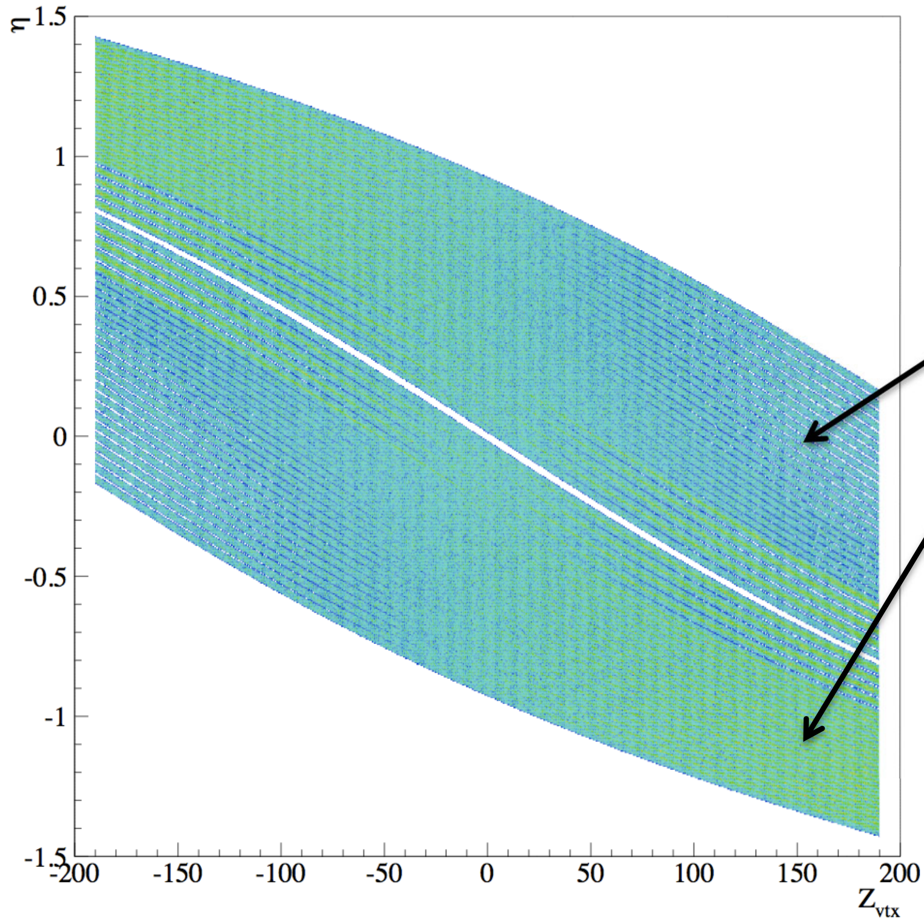
Stop-time resolution is stable across runs….

π vs K vs p direct PID up to ~1.6-1.7 GeV
(π+K) vs p direct PID up to ~2.8-3.0 GeV

Geometrical Acceptance

Installed Trays by Run:
Run 8: 4 (2.2%)
Run 9: 86 (71.6%)
Run 10: 118 (98.3%)
Run 11: 118 (98.3%)

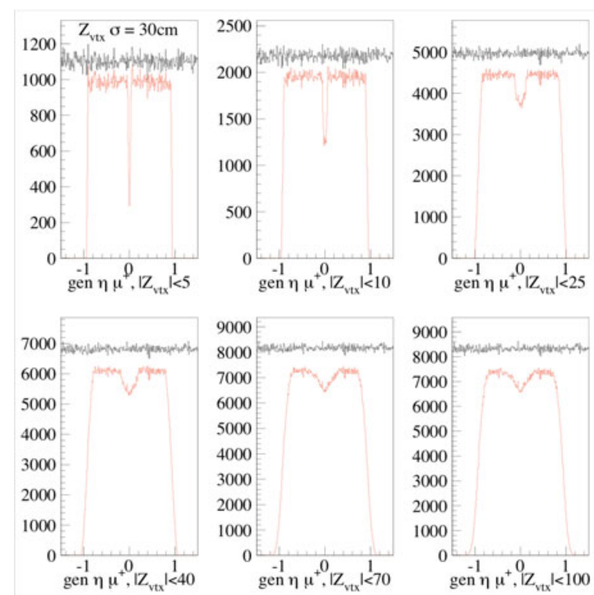




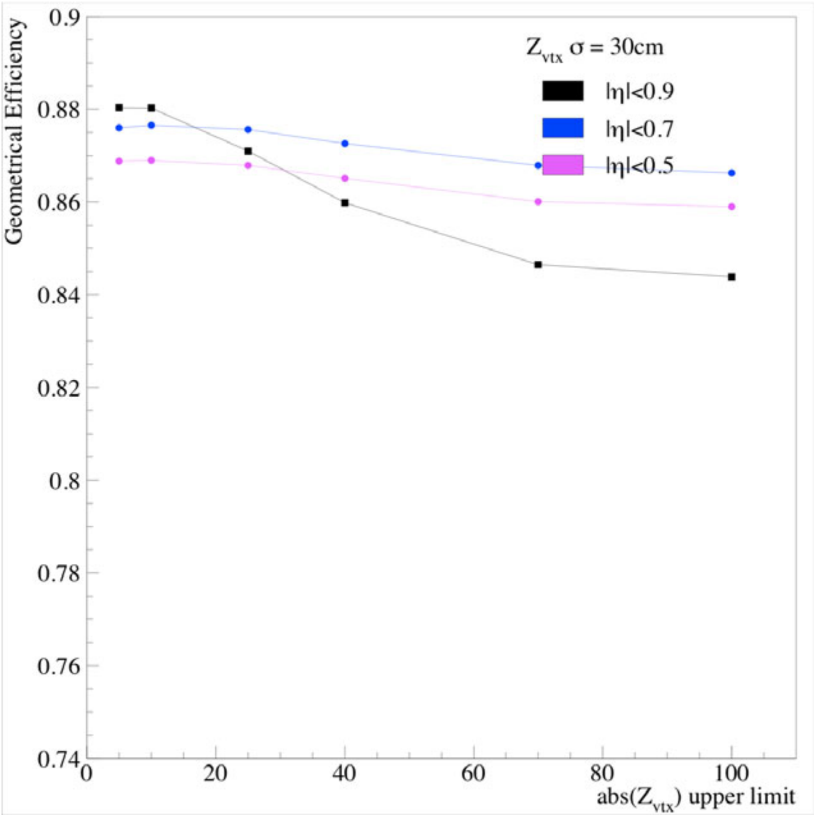
geometrical acceptance depends on Zvtx…

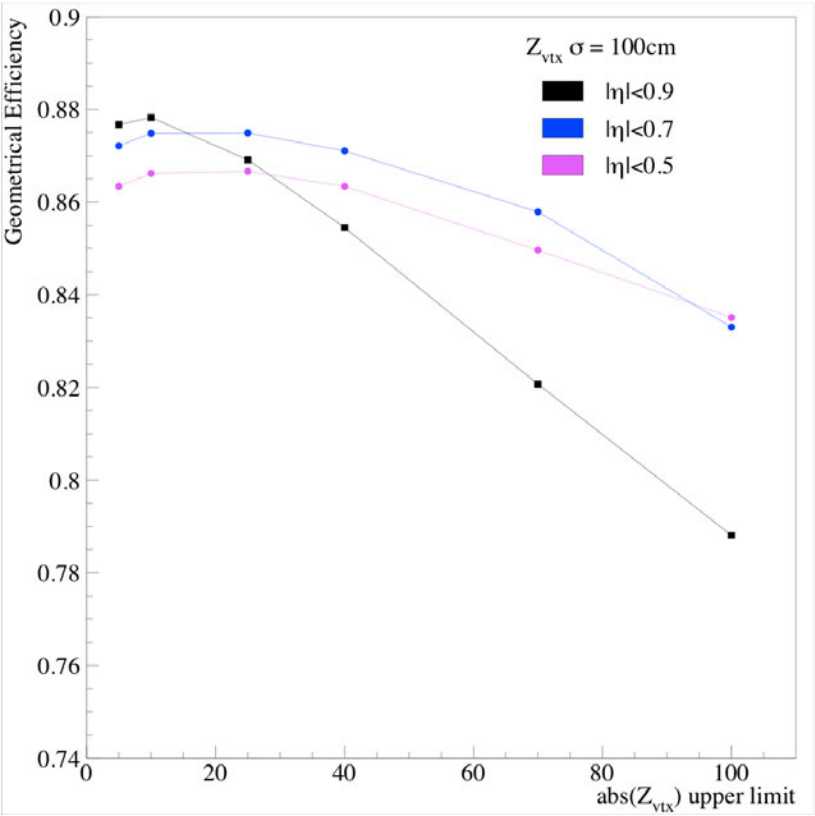
gaps if module and Vertex on same side of Z=0

Two hits per track otherwise



Geometrical Acceptance (continued)





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Geometrical Efficiency (out of 120 trays)

~84-88% for $\sigma(Z_{vtx})$ ~ 30cm & |Zvtx| < 50cm

~79-84% for $\sigma(Z_{vtx})$ ~ 100cm & |Zvtx| < 100cm

…depending on |η| window used

The end…

Have fun with it *!!*

…and always feel free to ask if you have any questions!