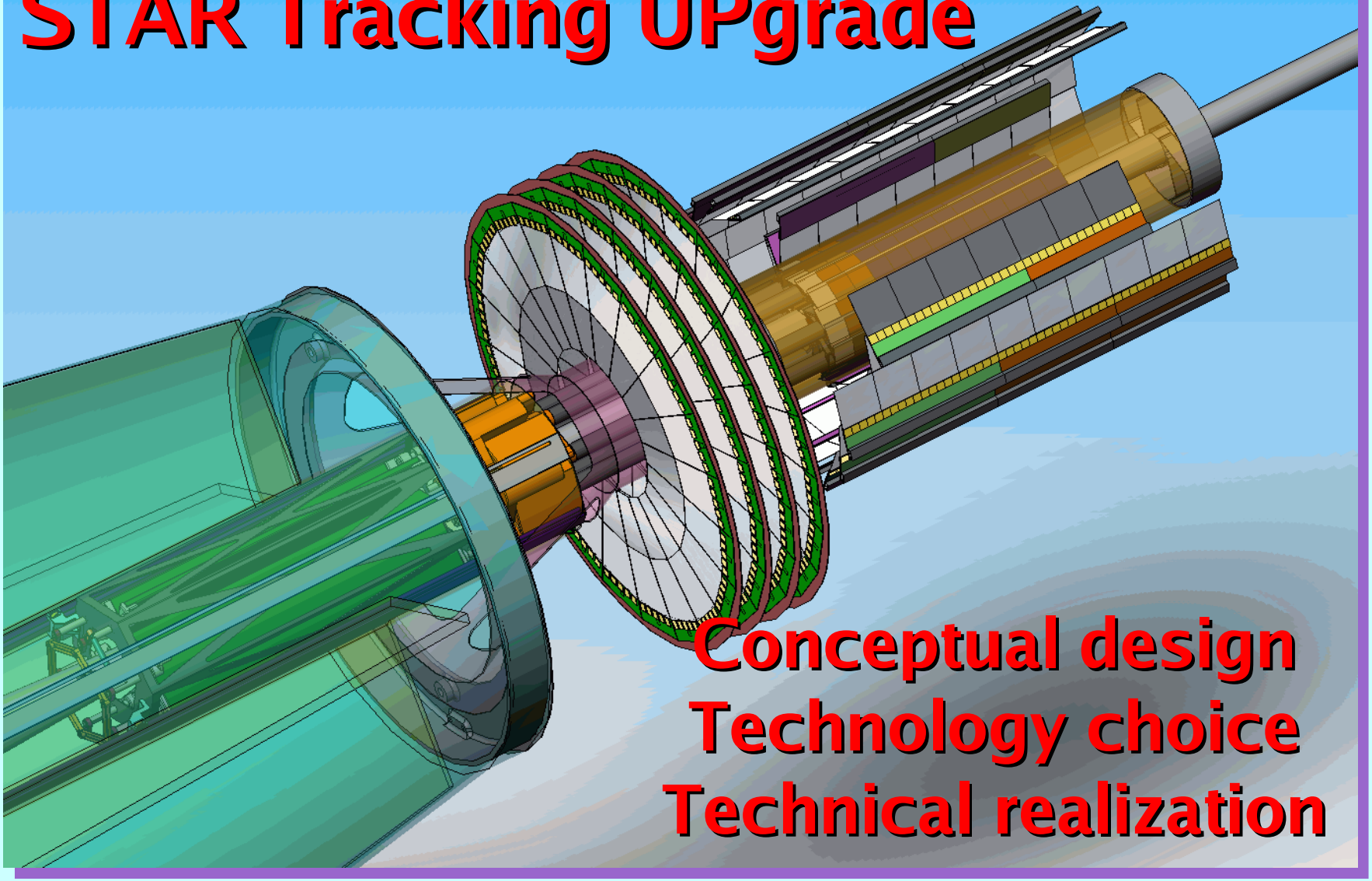
STAR Tracking UPgrade



Conceptual design
Technology choice
Technical realization

LOA

-1 < η < +1

TUP

HFT

IST

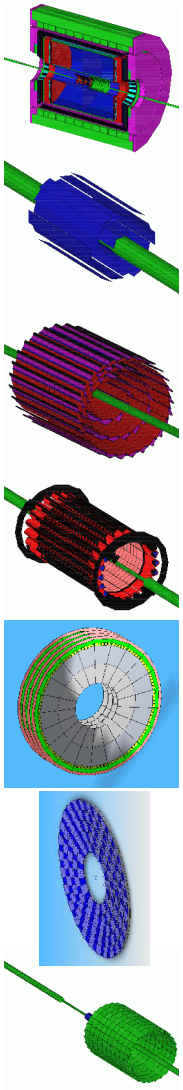
SSD

+1 < η < +2

FST

FGT

IGT



List Of Acronyms

Tracking UPgrade

Heavy Flavor Tracker

Inner STAR/Silicon Tracker

Silicon Strip Detector — existing

Forward STAR/Silicon Tracker

Forward GEM Tracker — option A

Inner GEM Tracker — option B

Technology choices

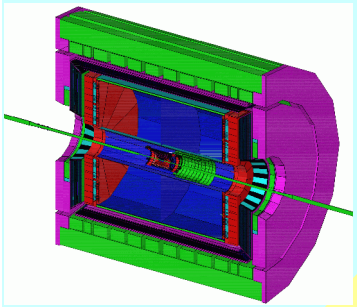
- Conservative approach to minimize risk
- 1 cutting edge technology is enough -> HFT
- Build upon existing expertise

- Single sided silicon from commercial vendor
  - proven reliable technology
  - MIT-LNS silicon labs (PHOBOS)

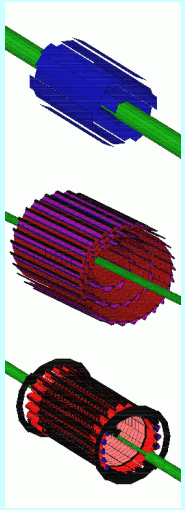
- Gas Electron Multiplier detectors
  - order of magnitude cheaper than silicon
  - proven reliable in COMPAS

- Off the shelf readout chip, CMS APV25-S1

TUP Overview



Inner

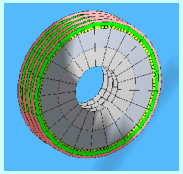


HFT

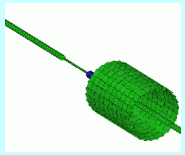
IST

SSD

Forward

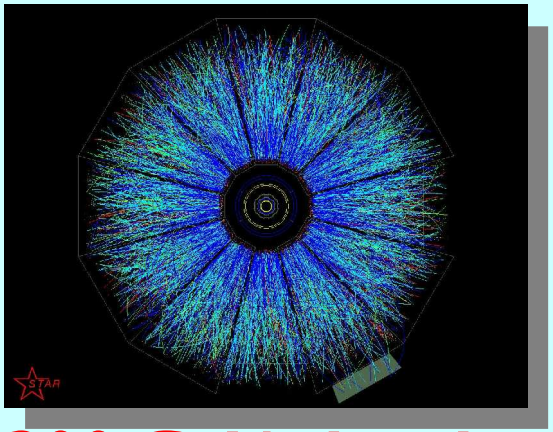


FST



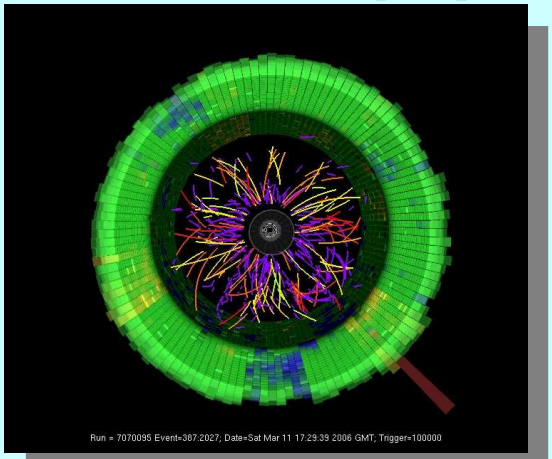
IGT

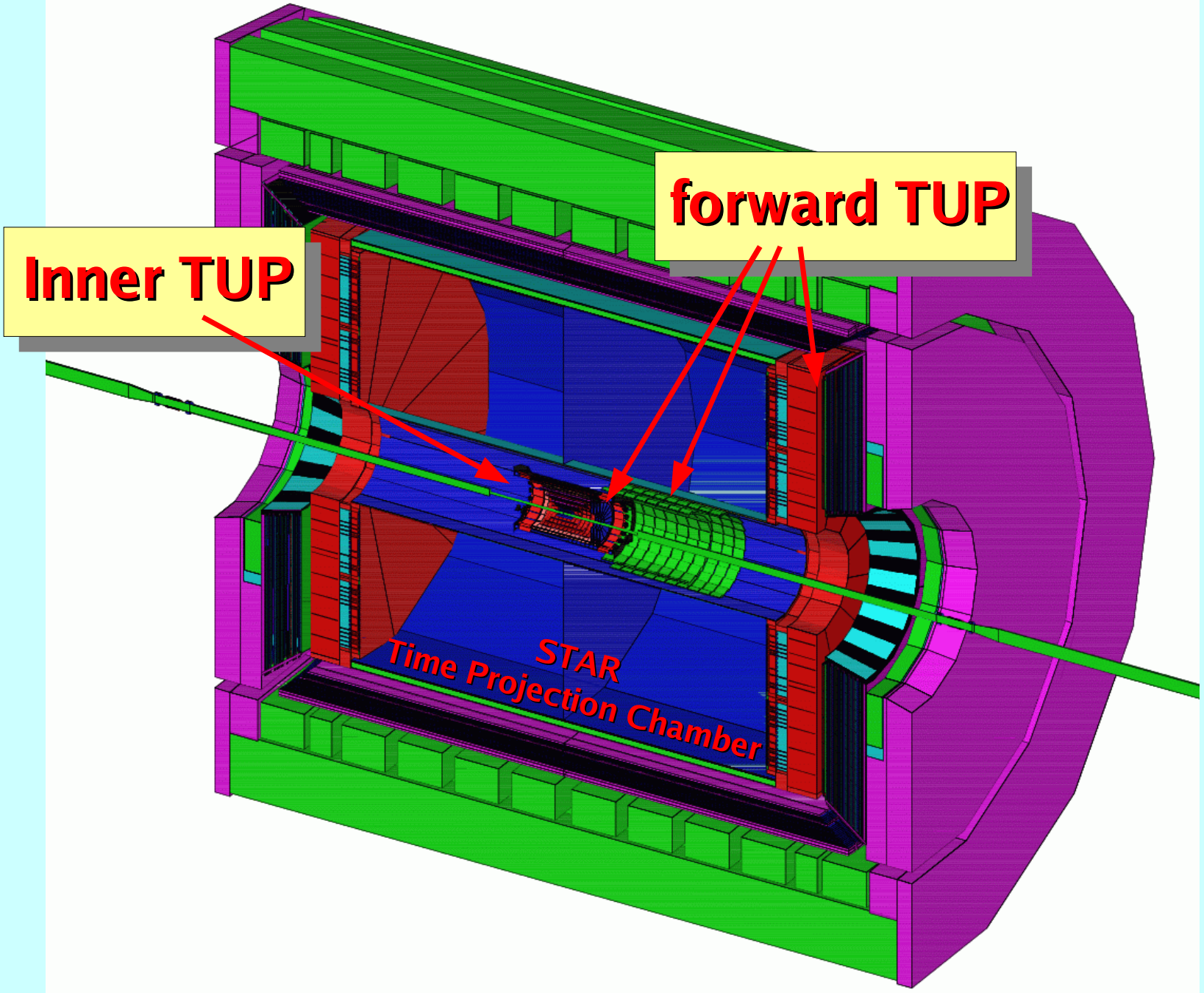
FGT

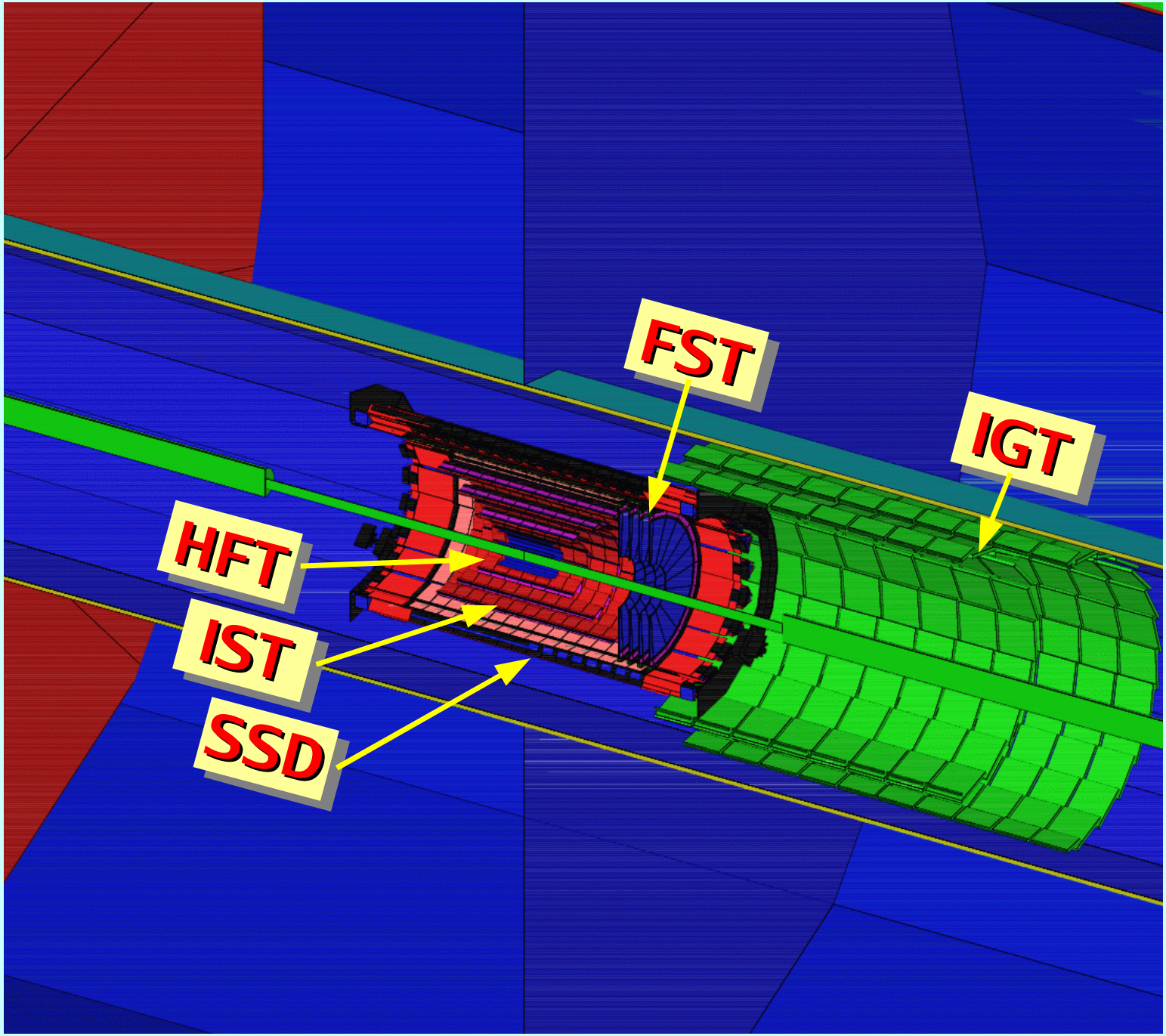


200 GeV Au+Au

200 GeV p+p




forward TUP
Inner TUP
STAR
Time Projection Chamber


FST
IGT
HFT
IST
SSD

Inner STAR Tracker requirements

- Fits in between HFT and SSD $-1 < \eta < +1$
- Material budget $\leq$ 1.5% X_o per layer
- Resolve individual beam bunches (213 ns)
- Handles RHIC II luminosities
  (AA: $90 \cdot 10^{26}$ cm^{-2} s^{-1} pp: $4 \cdot 10^{32}$ cm^{-2} s^{-1})
- Handles central 200 GeV Au+Au occupancy
  (2 particles per cm^2 at first layer)
- Minimize hit ambiguities, i.e. ghosts
- Good pointing accuracy to HFT
  ($\leqslant$ 150 μm for 750 MeV Kaons)
- Good vertex resolution for 500 GeV p+p

Inner TUP Geometry

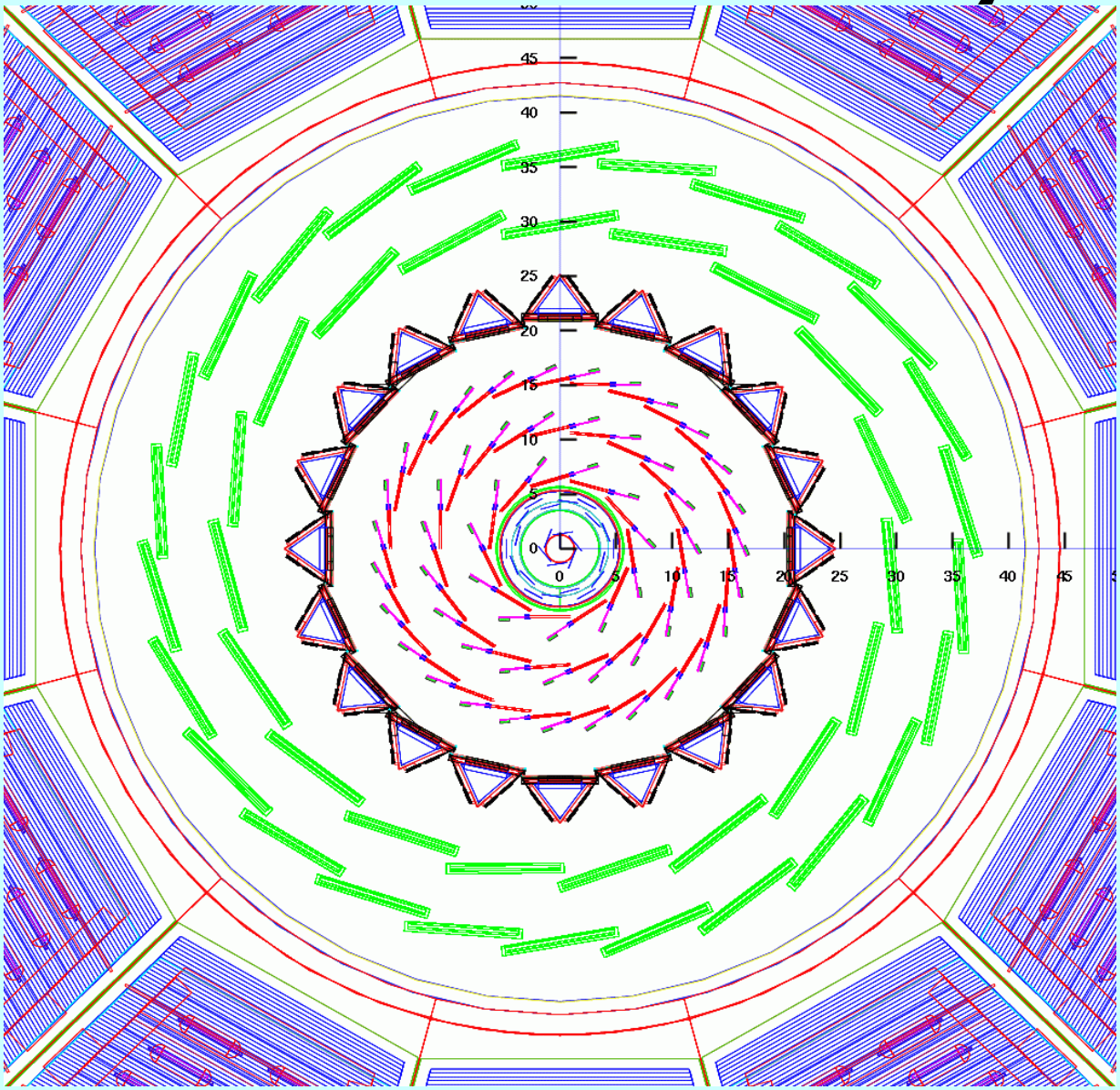
TPC

IGT

SSD

IST

HFT



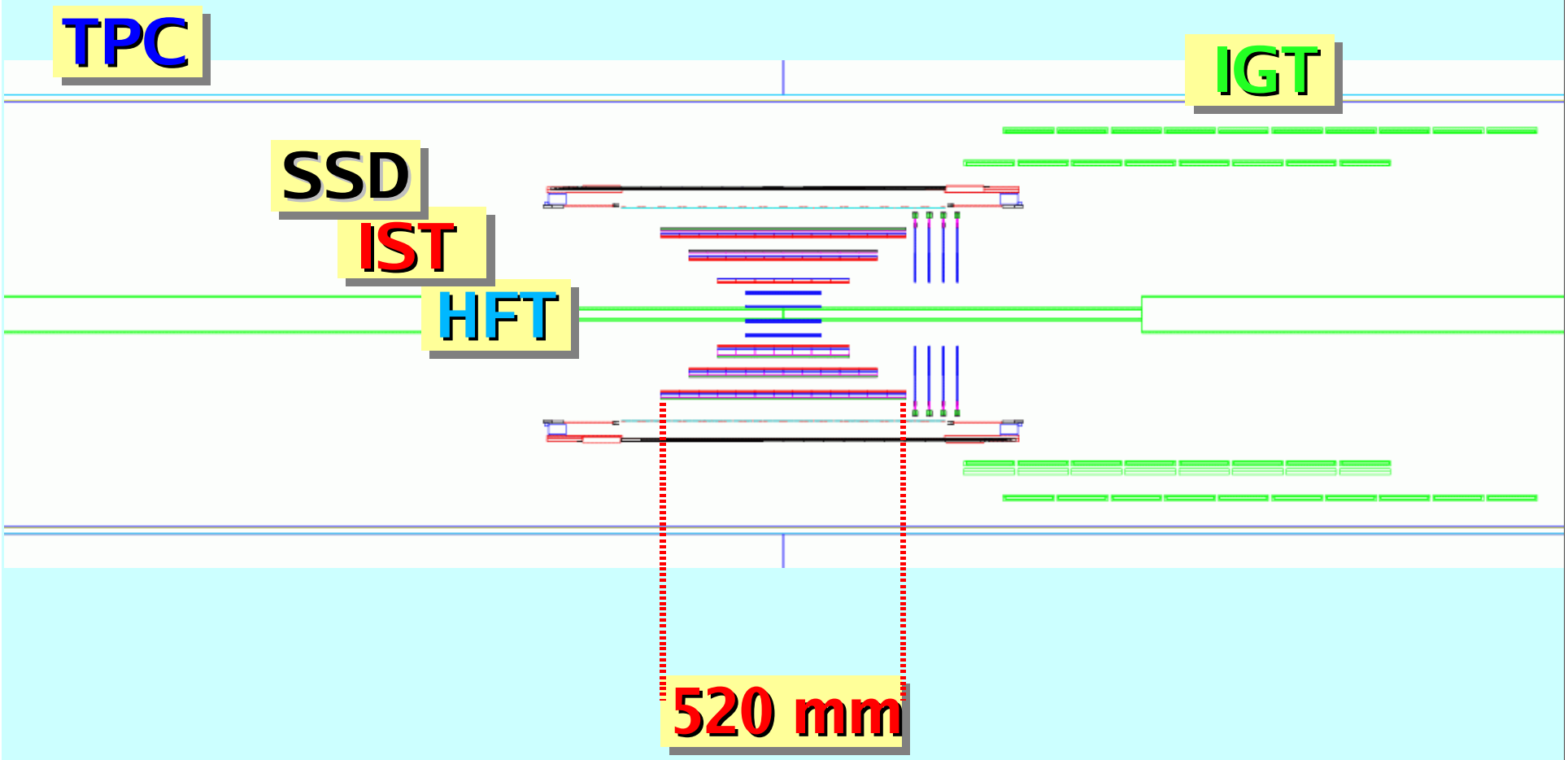
R_{IST} =

170 mm

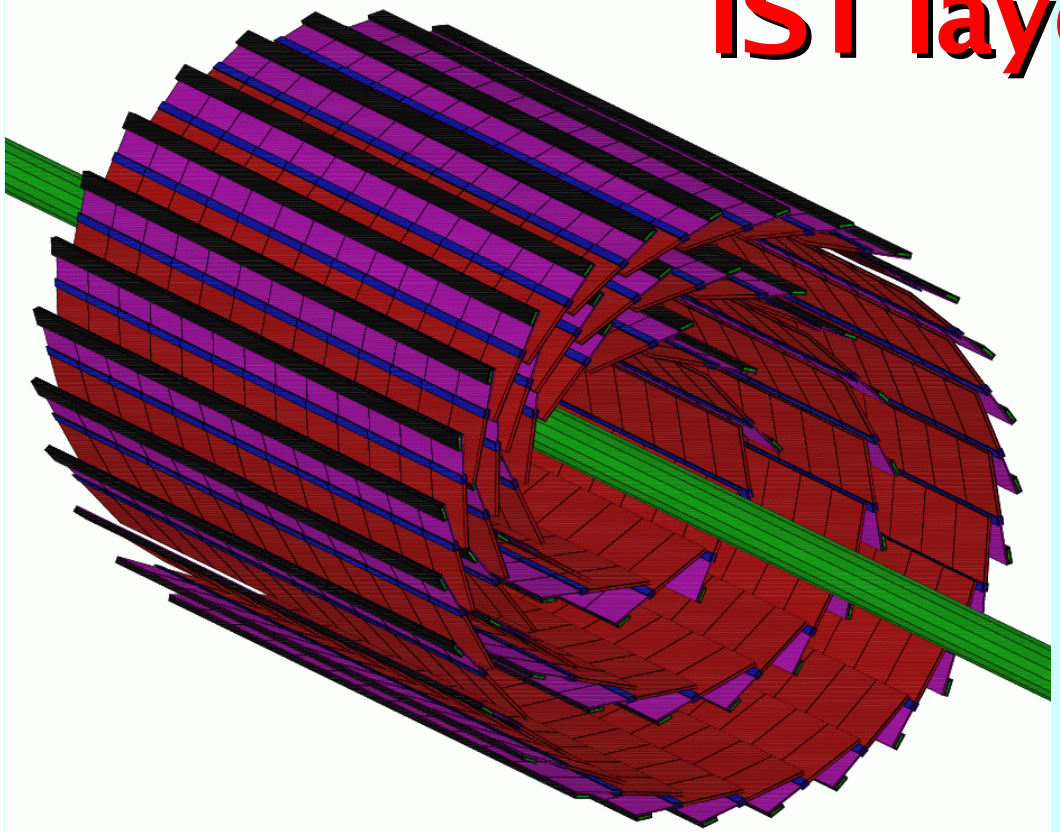
120 mm

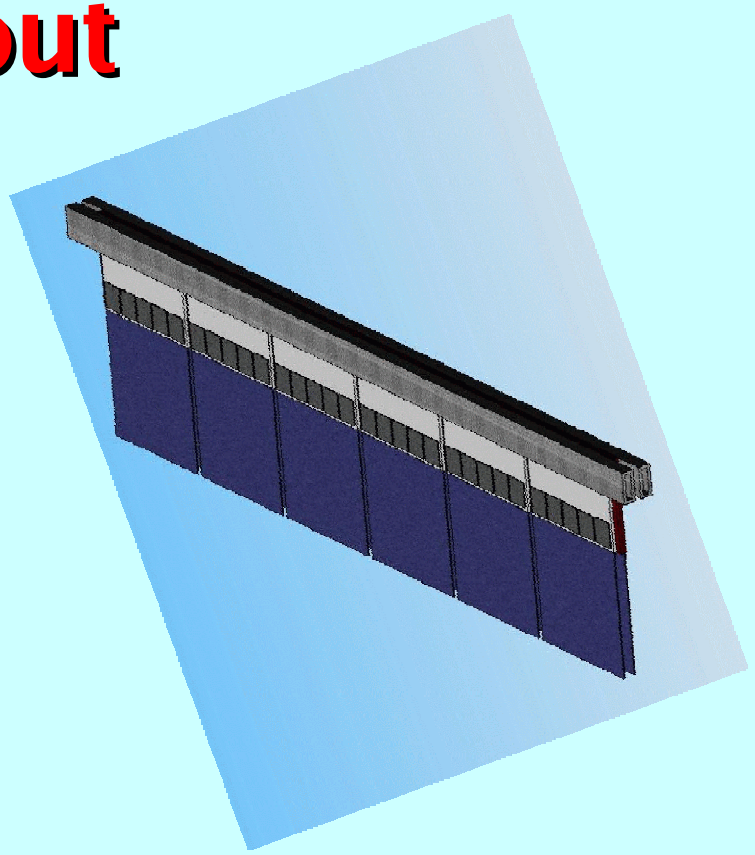
70 mm

Inner TUP Geometry



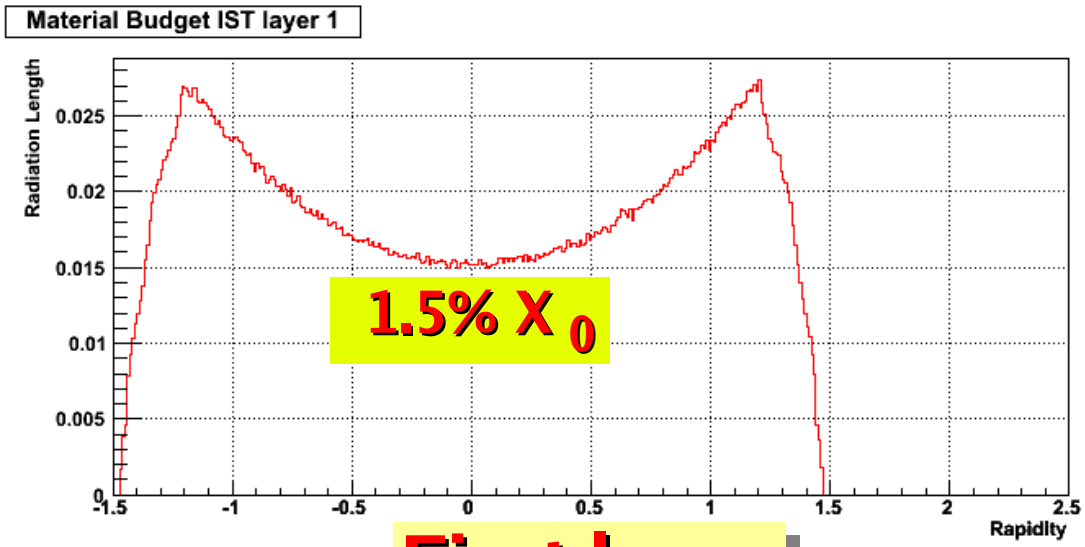
IST layout



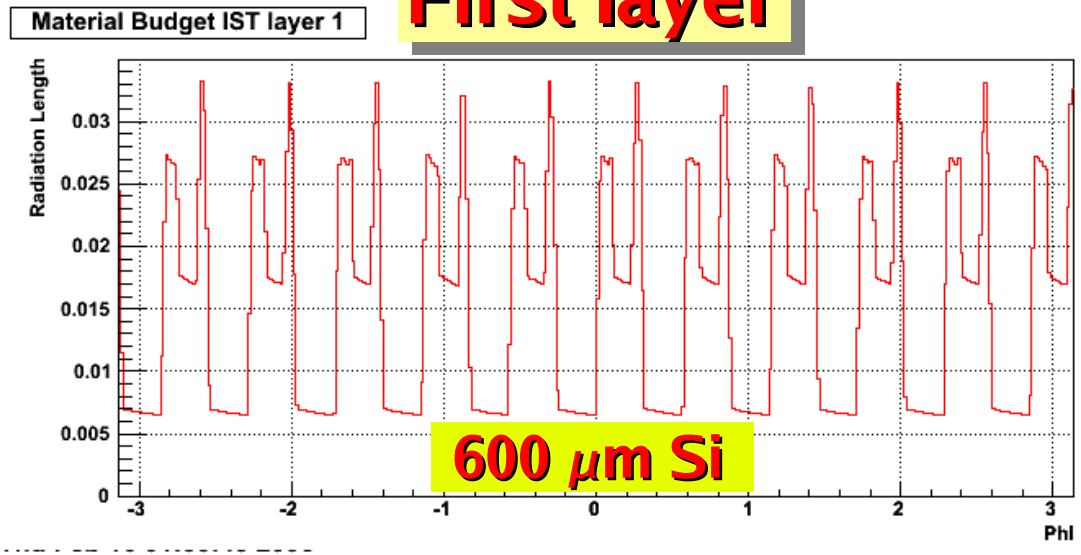


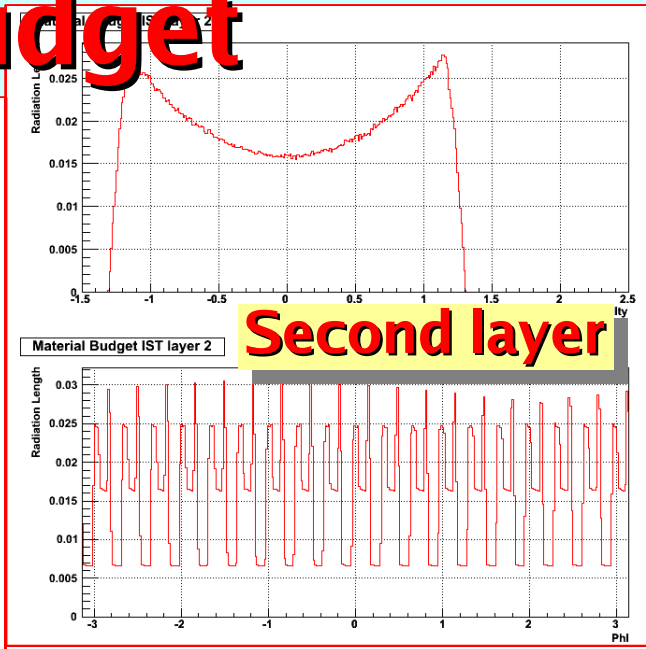
	Layer 1	Layer 2	Layer 3	Total
Radius [mm]	70	120	170	
No. Sensors per ladder	14	20	26	
No. Ladders	11	19	27	
No. Sensors	154	380	702	1236
No. Readout chips	770	1900	3510	6180
No. Channels	98560	243200	449280	791040

IST material budget

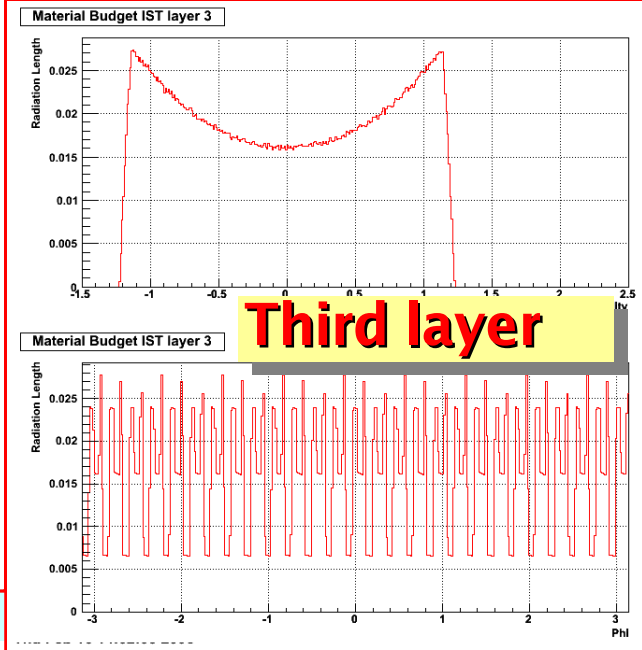


First layer



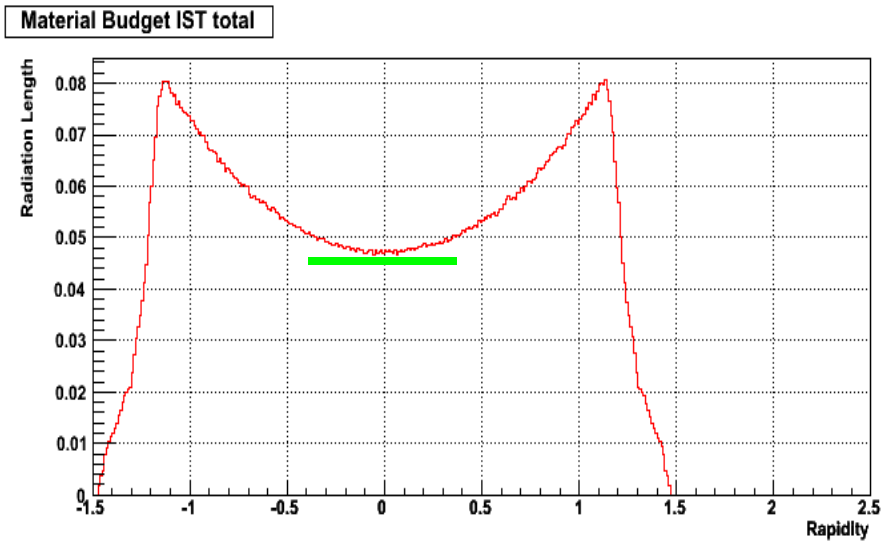


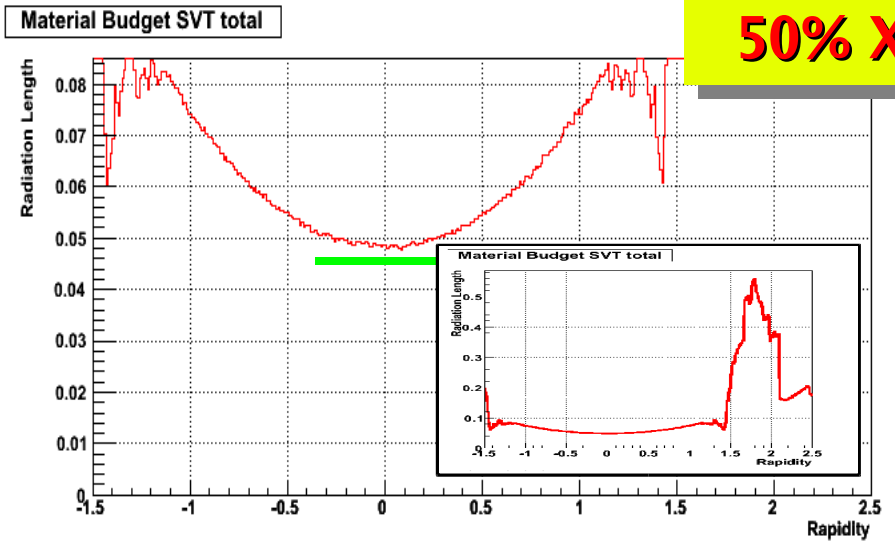
Second layer



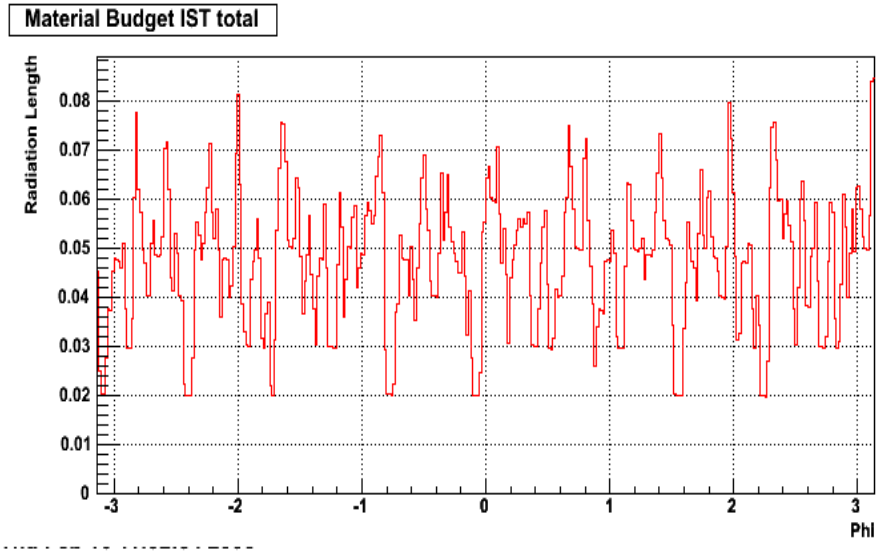
Third layer

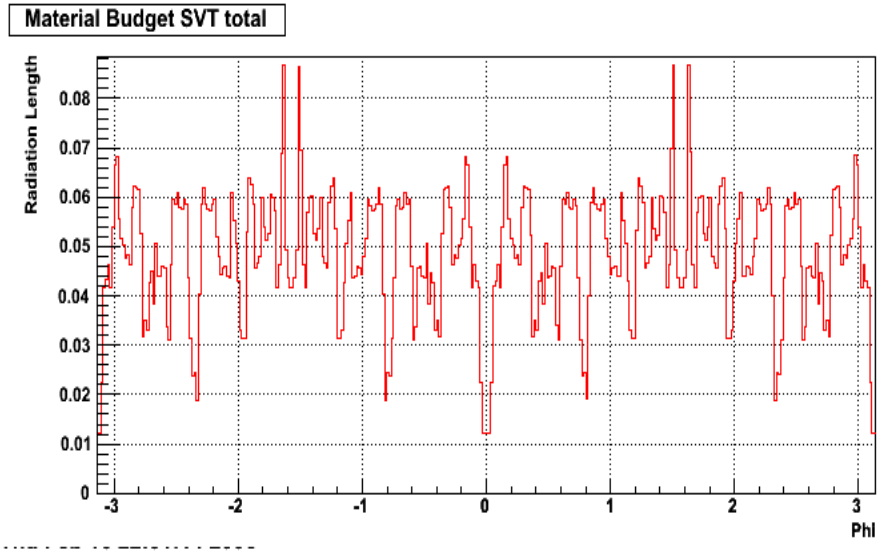
IST vs existing SVT material budget



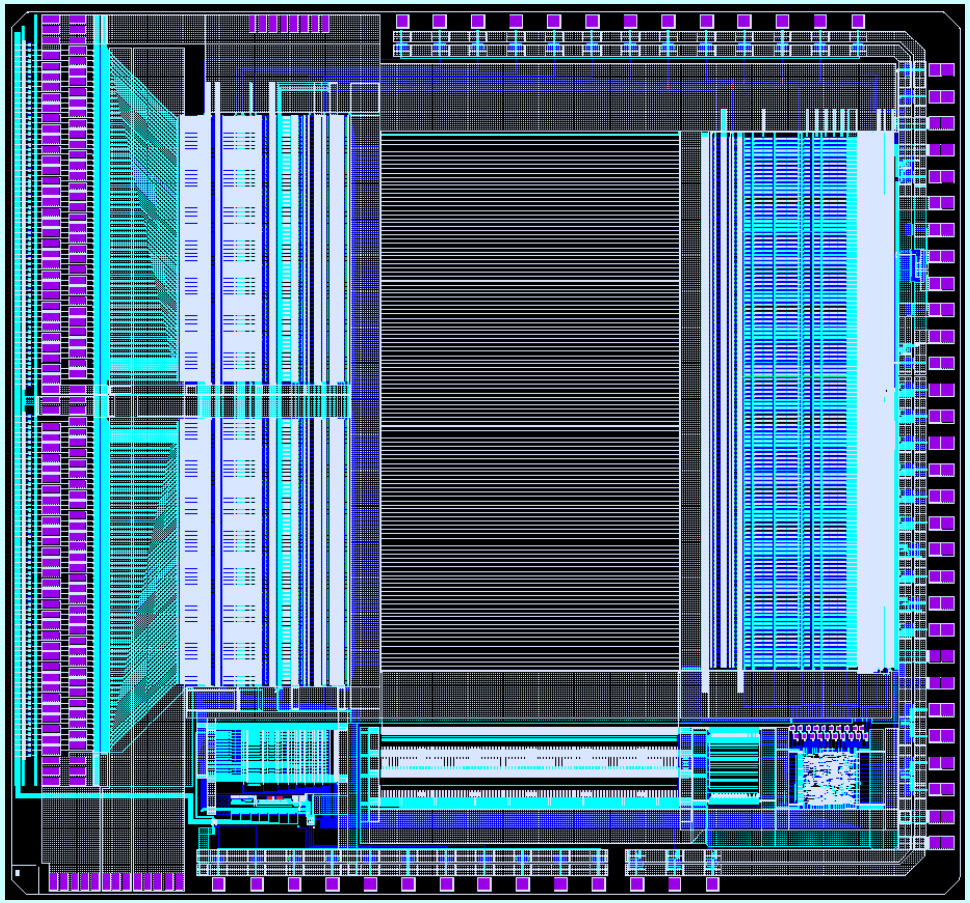


50% X_0





APV25-S1 readout chip



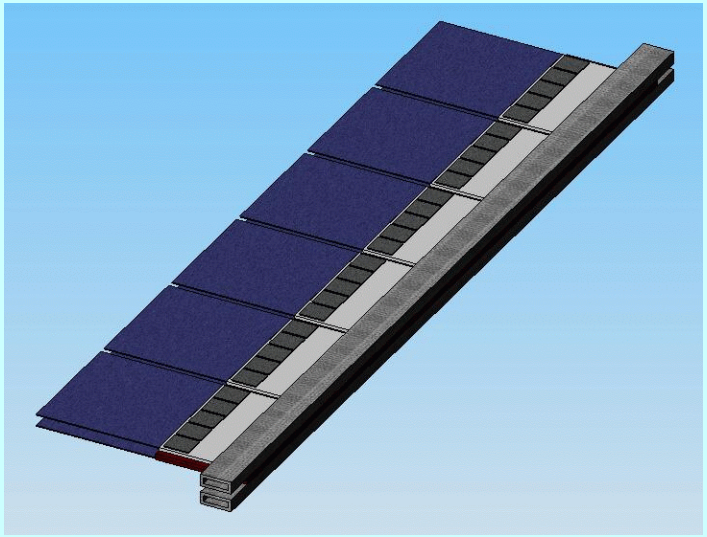
- developed for CMS
- 75000 in CMS tracker
- 128 channels
- 40 Mhz sample rate
- 4 us analogue pipeline
- < 2000 e ENC
- 11:1 signal/noise
- 0.25 Watt/chip
- 0.25 um CMOS
- rad hard
- SEU resilient

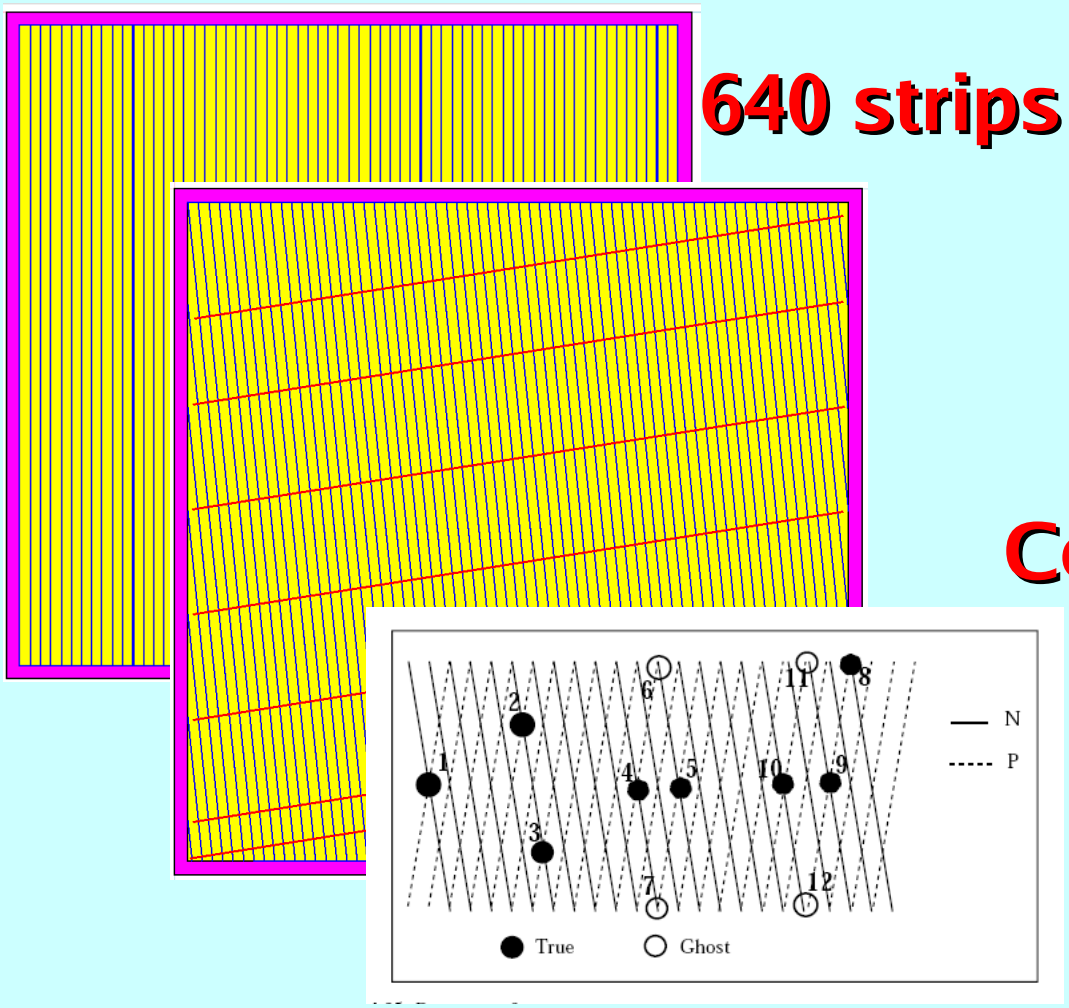
To be used in IST, FST, IGT, FGT -> 1 readout!

IST sensors I: Stereo strip pairs?

40 x 40 mm^2

640 strips

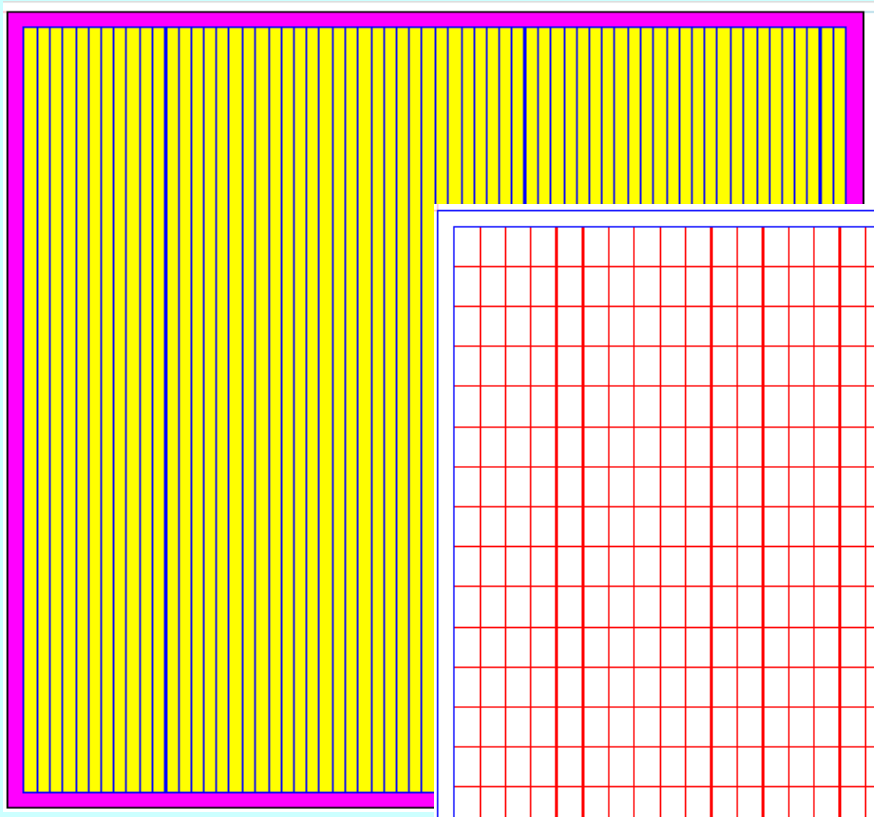




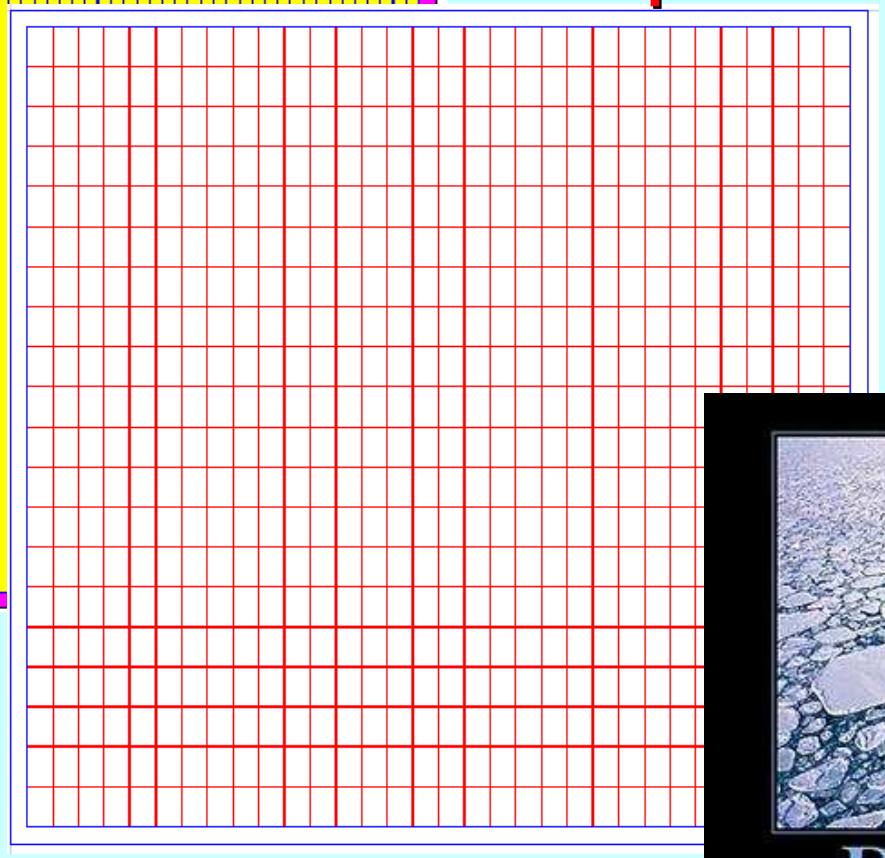
Central 200 GeV Au+Au

- first layer
- 30 hits per sensor
- occupancy OK
- > 100% ghosts

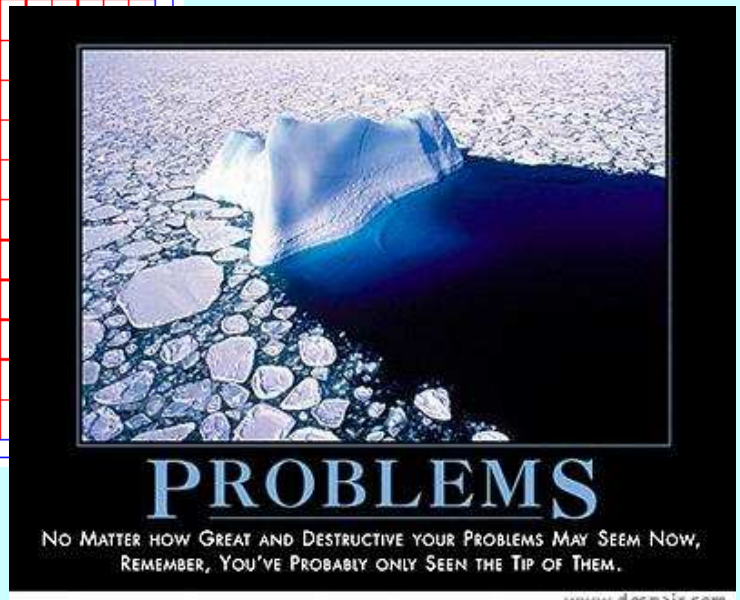
IST sensors II: Strip-pad pairs



4 cm X 4 cm
640 strips
60 um pitch

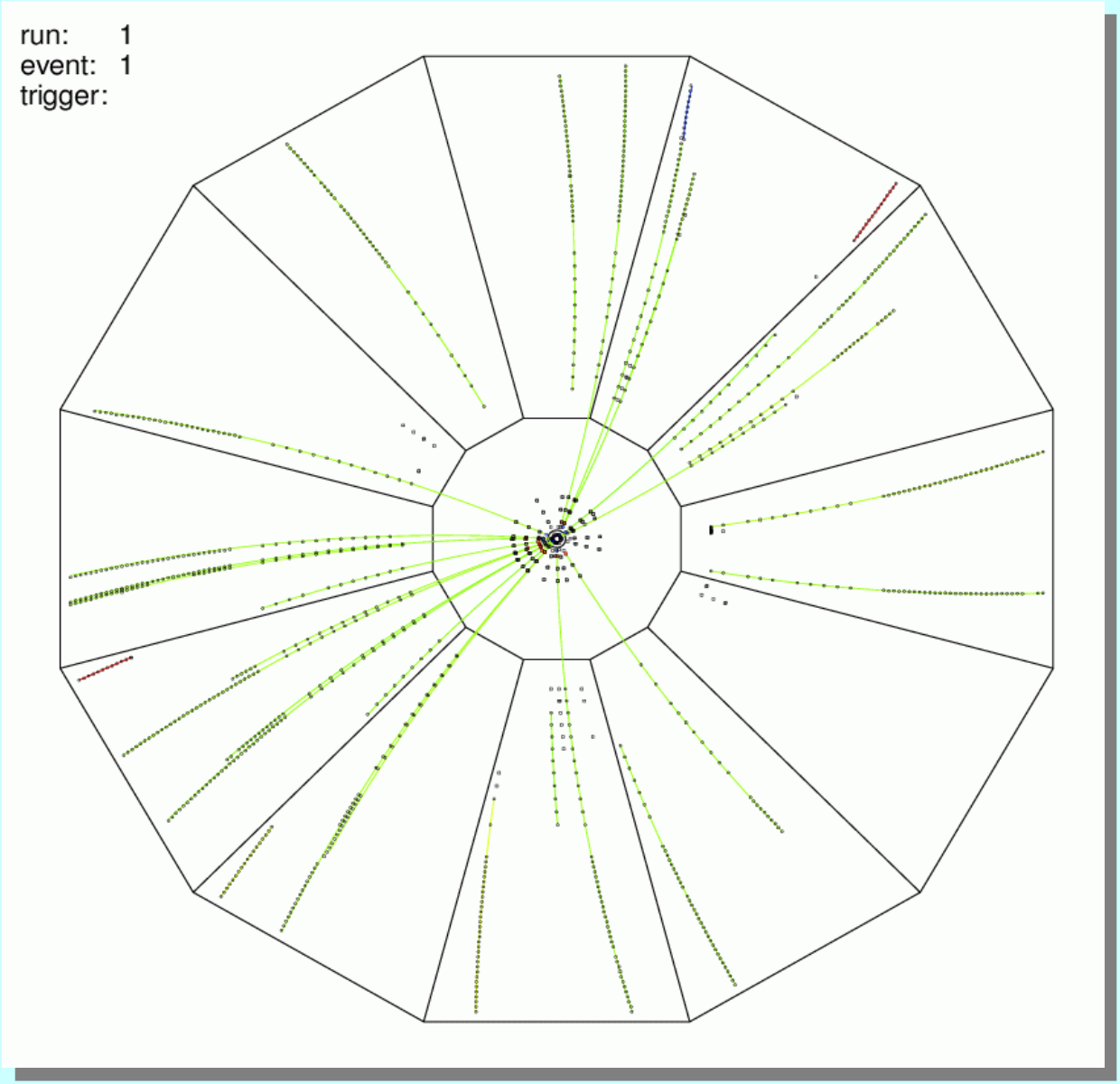


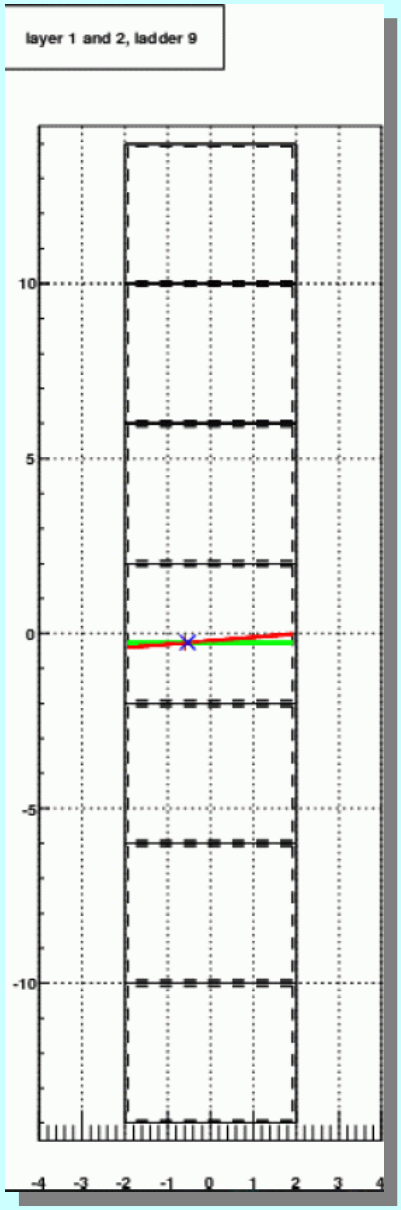
4 cm X 4 cm
30 X 21 pads
1.3 mm x 1.8 mm



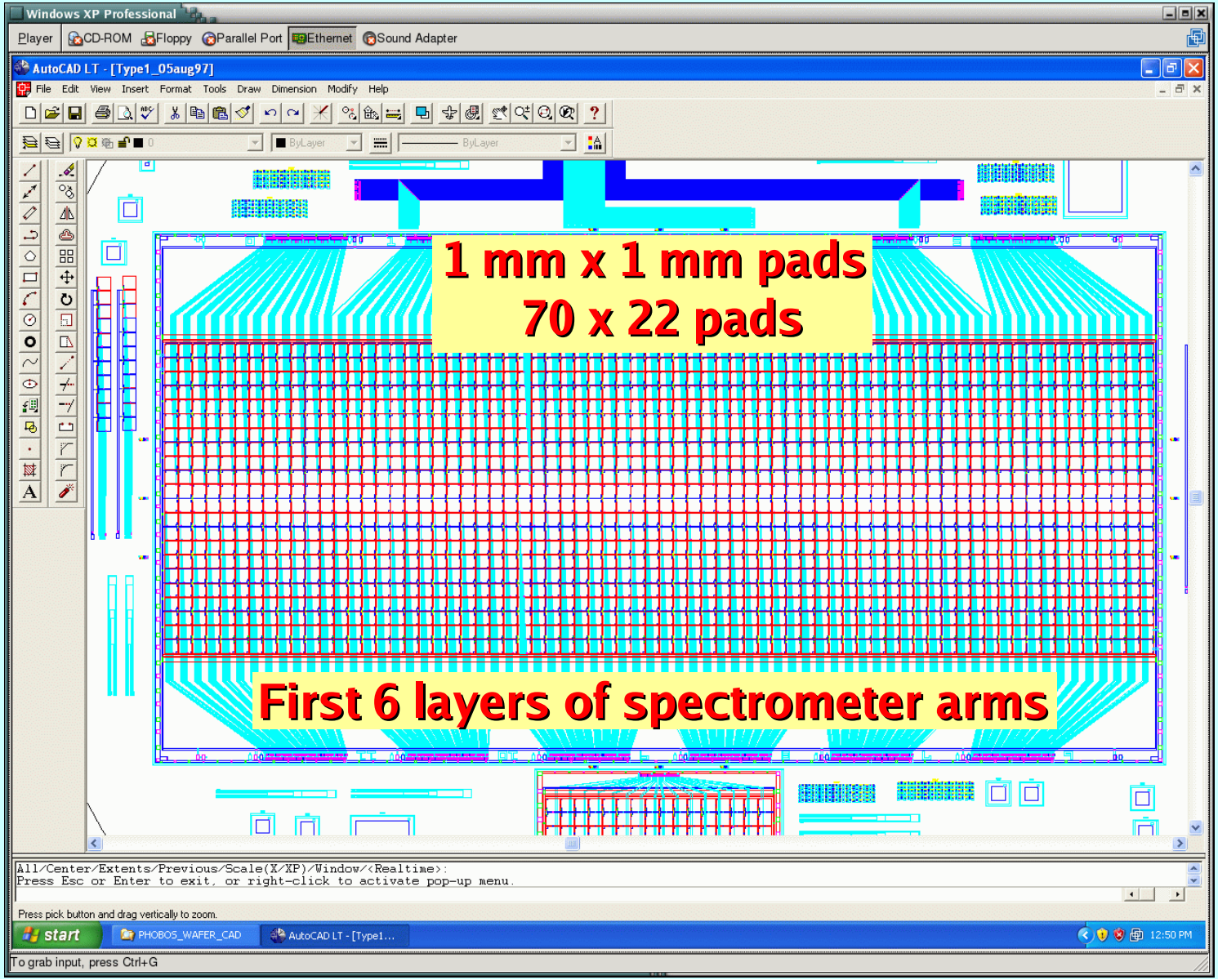
NOT final layout, needs simulations

Tracking simulations just started

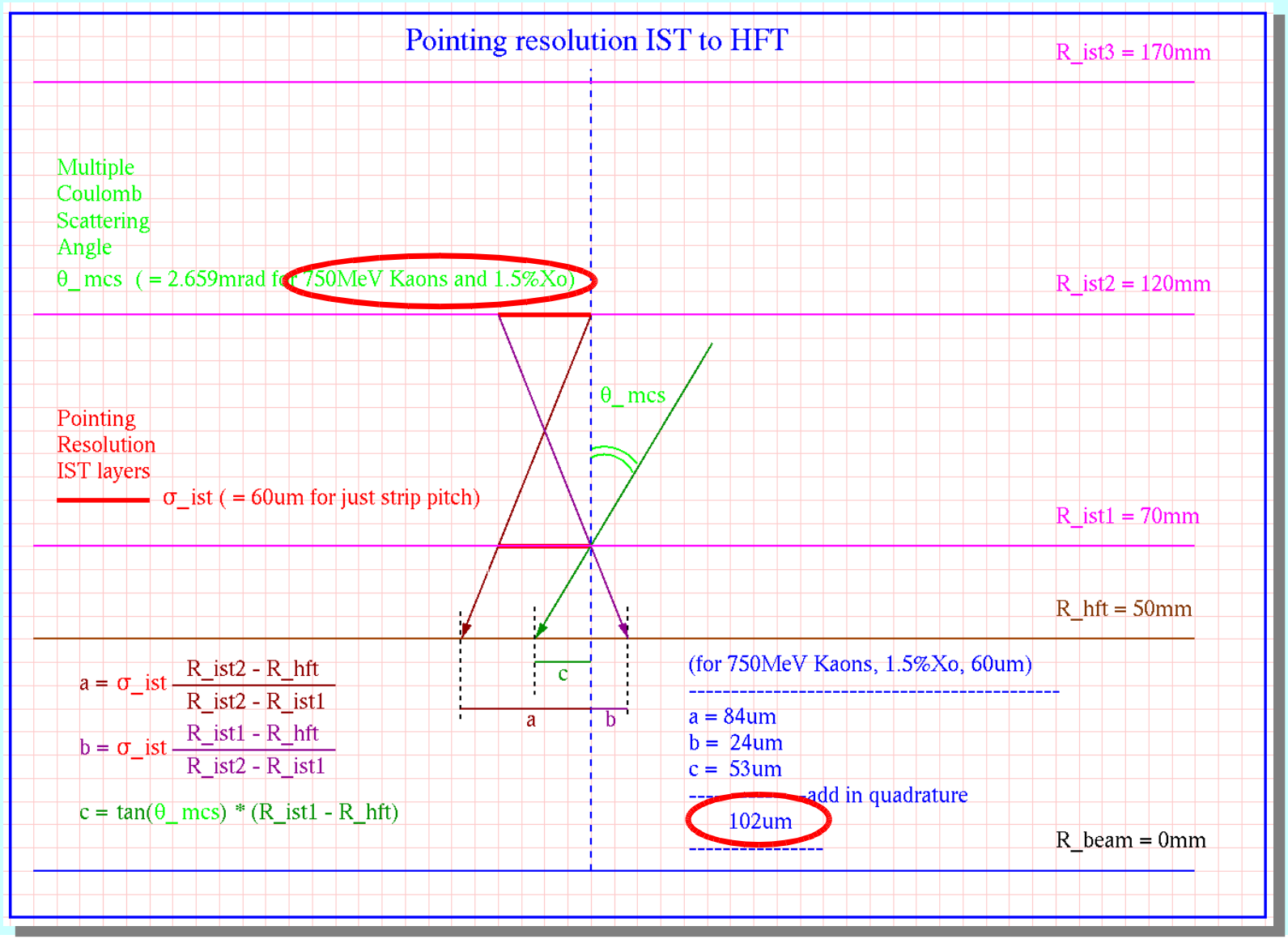




PHOBOS Silicon Pad Sensors



Pointing Resolution Strips to HFT



Vertex Resolution

```
root [0] .x Pointing1.C
------------------------------------------------
theta = 90.002657
beta  = 0.835121
MCS angle = 0.002659
---------------HFT--------------------------------
PosZ    Res at HFT = 87.361319
PosPhiZ Res at HFT = 1456.021978
MCS     Res at HFT = 53.186802
Total   Z pointing resolution at HFT = 102.278229
Total Phi pointing resolution at HFT = 1456.993042
--------------DCA---------------------------------
PosZ    Res    DCA = 166.709328
PosPhiZ Res    DCA = 2778.488798
MCS     Res    DCA = 186.153813
Total   Z pointing resolution    DCA = 249.890457
Total Phi pointing resolution    DCA = 2784.717773
```

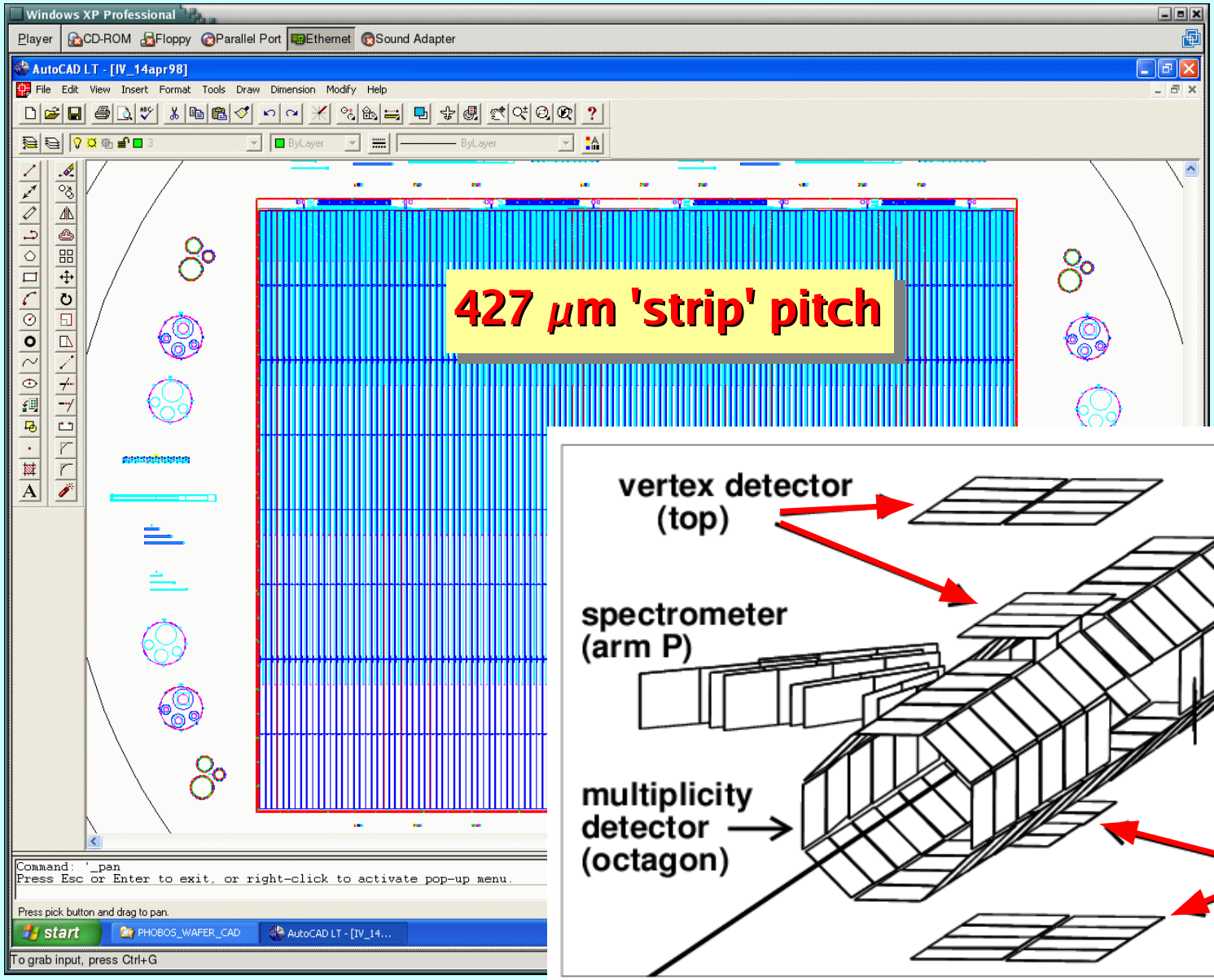
60 μm strip pitch

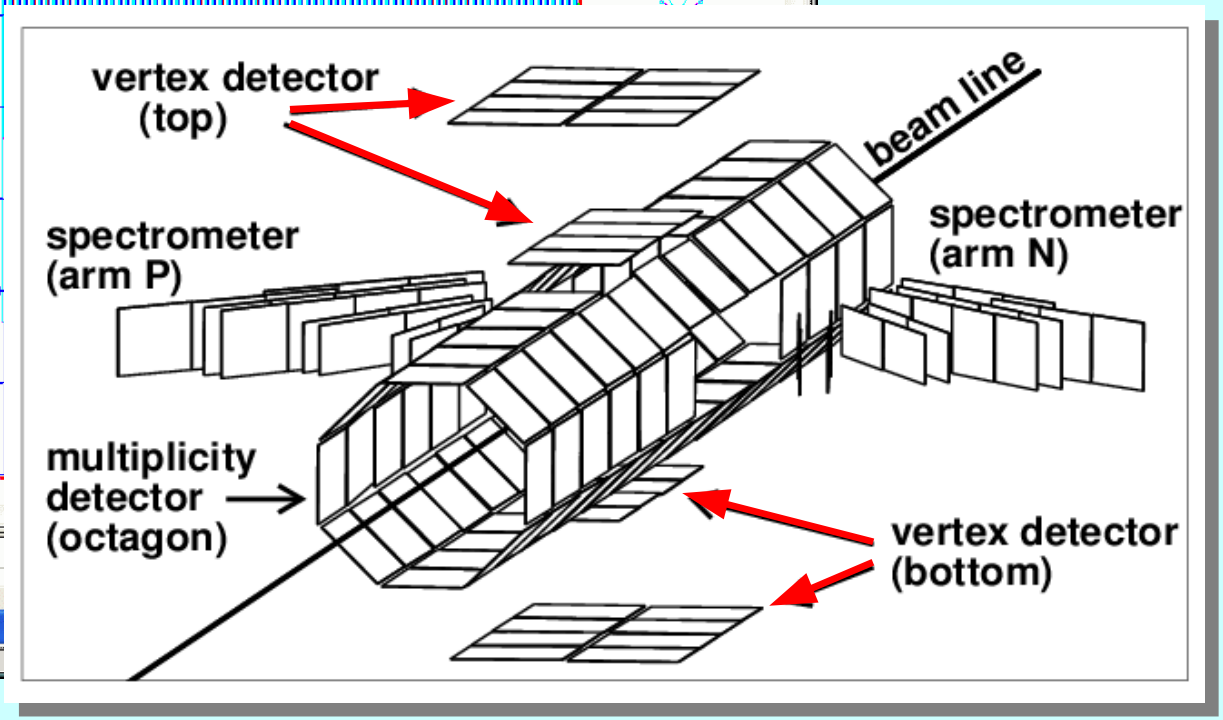
```
ot [0] .x Pointing1.C
------------------------------------------------
eta = 90.002657
ta  = 0.835121
S angle = 0.002659
-------------HFT--------------------------------
sZ    Res at HFT = 43.680659
Res at HFT = 1456.021978
Res at HFT = 53.186802
 pointing resolution at HFT = 68.824677
 pointing resolution at HFT = 1456.993042
------DCA---------------------------------------
Res    DCA = 83.354664
Res    DCA = 2778.488798
Res    DCA = 186.153813
 pointing resolution    DCA = 203.963821
 pointing resolution    DCA = 2784.717773
------------------------------------------------
```

30 μm strip pitch

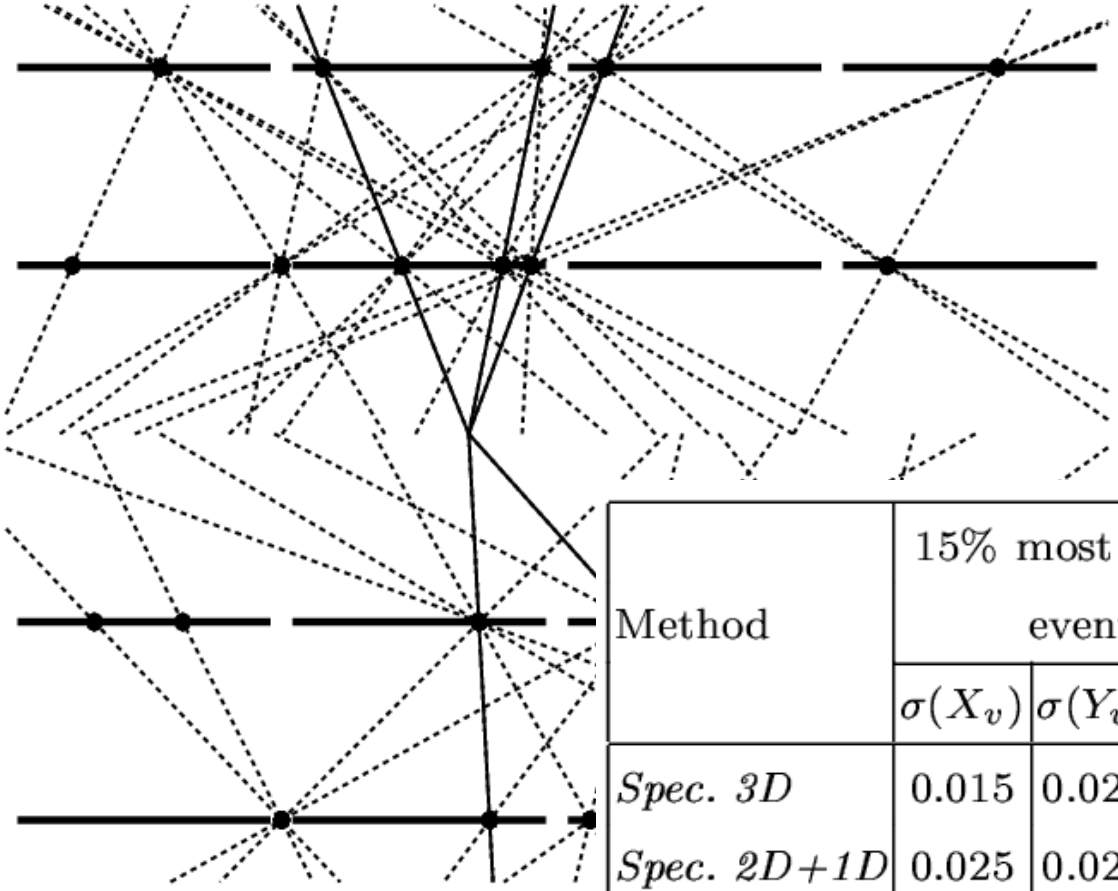
particle	daughters	cτ (μm)	Mass (GeV)
D^0	$K^-\pi^+$ (3.8%)	123	1.8646
$D^\pm$	$K^-\pi^+\pi^+$ (9.2%)	312	1.8694
D_s	$K^+K^-\pi^+$ (4.4%) $\pi^+\pi^+\pi^-$ (1.0%)	147	1.9683
Λ_c	$p\,K^-\pi^+$ (5.0%)	59.9	2.2849
B^0		460	5.2794
$B^\pm$		501	5.2790

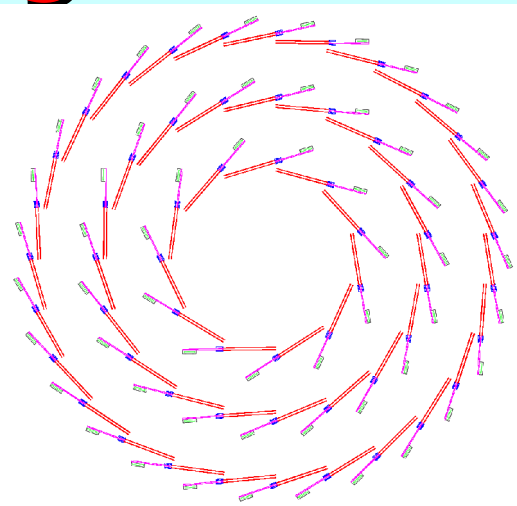
PHOBOS Vertex Sensors



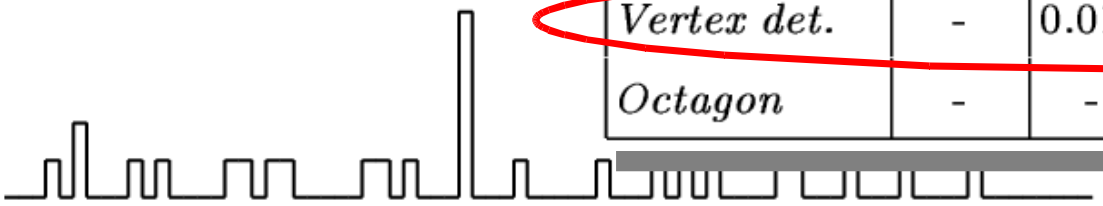


PHOBOS Vertexing

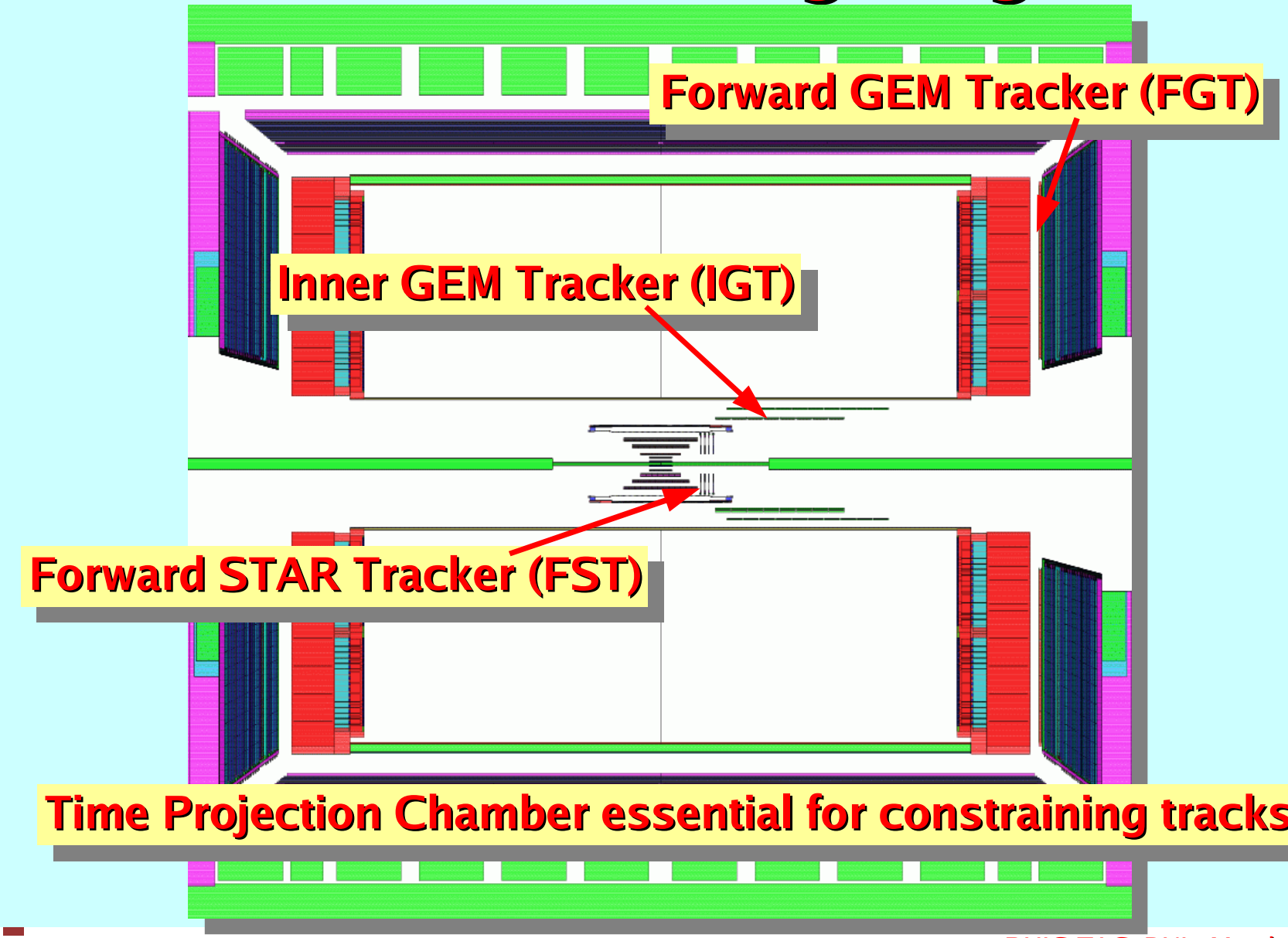




Method	15% most central events			30% most peripheral events			
	$\sigma(X_v)$	$\sigma(Y_v)$	$\sigma(Z_v)$	$\sigma(X_v)$	$\sigma(Y_v)$	$\sigma(Z_v)$	eff.
Spec. 3D	0.015	0.022	0.020	0.350	0.100	0.300	4%
Spec. 2D+1D	0.025	0.022	0.030	0.150	0.150	0.250	7%
Vertex det.	-	0.015	0.006	-	0.030	0.023	28%
Octagon	-	-	0.500	-	-	1.100	85%



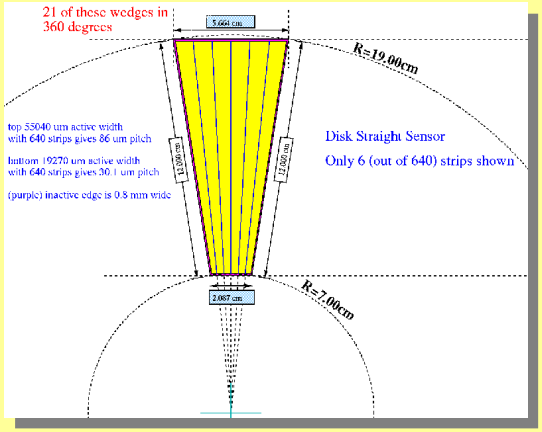
Forward Tracking UPgrade

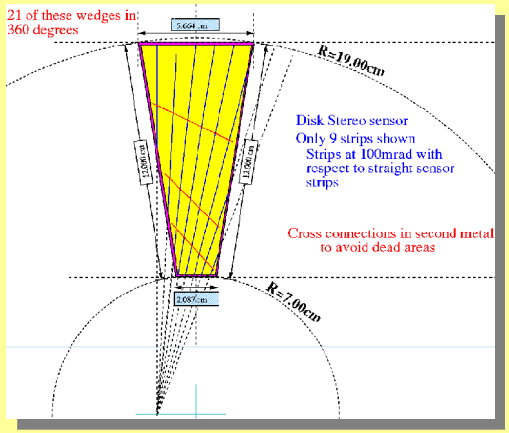


Time Projection Chamber essential for constraining tracks !

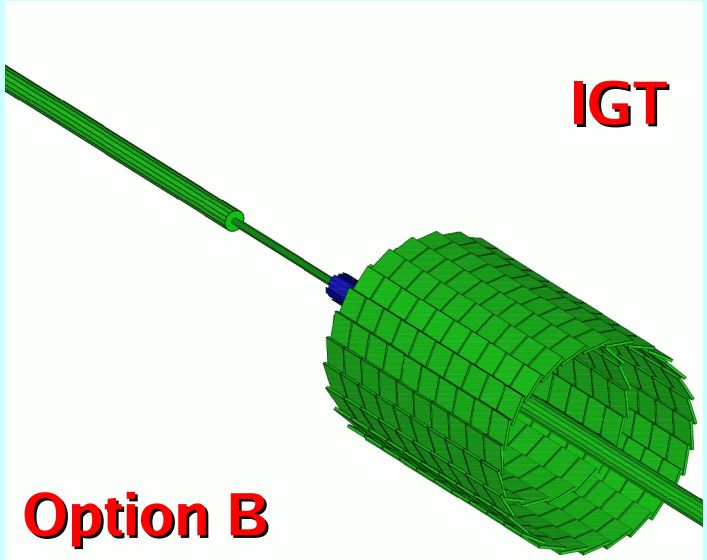
Forward STAR Tracker requirements

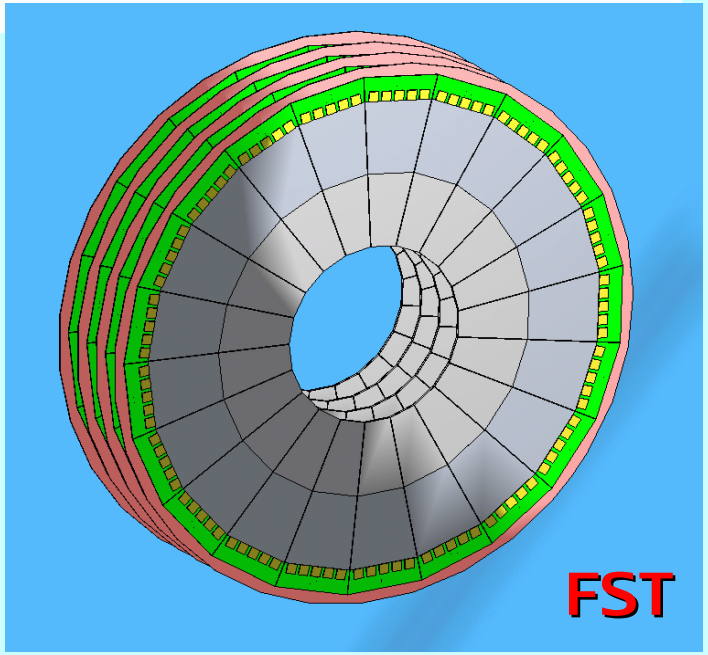
- Fits in whatever space is left $+1 < \eta < +2$
- Resolves individual beam bunches
  (213 ns)
- Handles RHIC II luminosities
  (AA: $90 \cdot 10^{26}$ cm^{-2} s^{-1} pp: $4 \cdot 10^{32}$ cm^{-2} s^{-1})
- e^+ e^- charge discrimination
  (sagitta of ~ 2.5 mm at 30 GeV/c

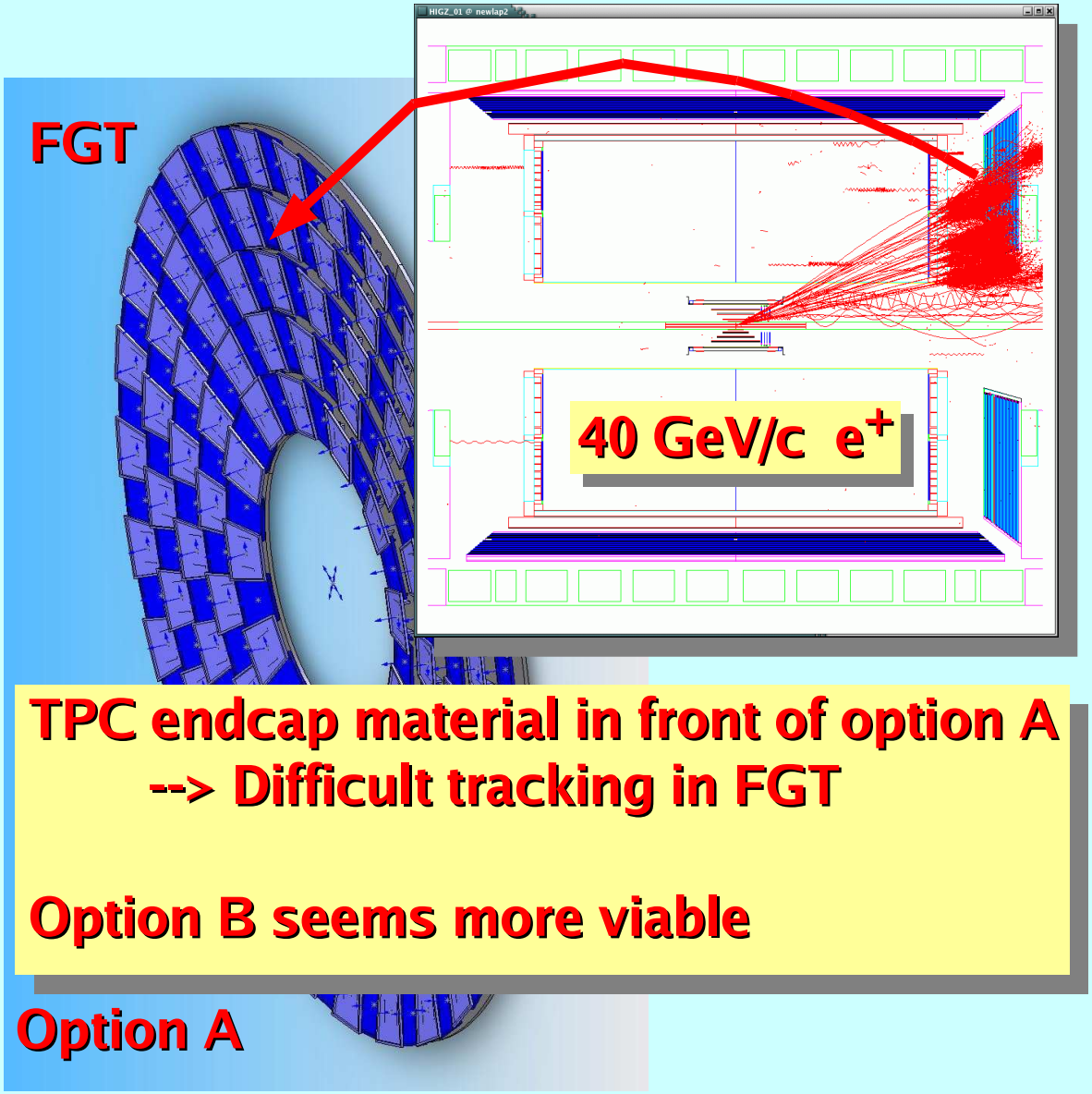




Forward STAR Tracking



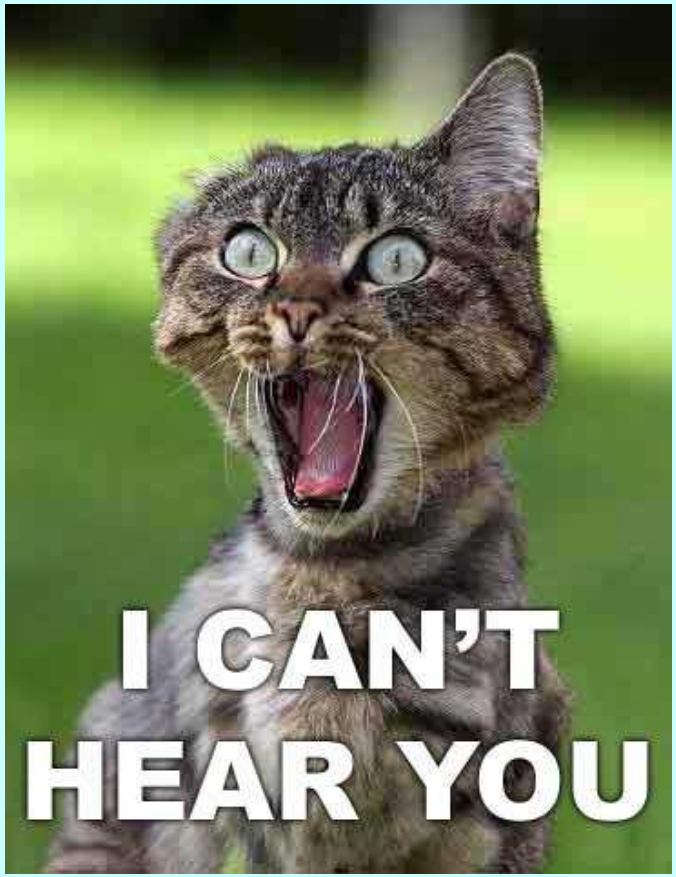




TPC endcap material in front of option A
--> Difficult tracking in FGT

Option B seems more viable

Summary



R&D

2006

- Simulation of IST and FST/FGT and FST/IGT
- Finalize design of IST silicon strip and pad sensors
- Mechanical design of light-weight IST mechanical support structure
- Design of IST hybrid chip readout system and STAR DAQ integration
- Triple-GEM R&D effort: Finalize GEM-foil characterization

2007

- Finalize design of FST silicon strip sensors
- Mechanical design of light-weight FST and IGT/FGT support structure
- Design of FST and IGT/FGT hybrid chip readout system and STAR DAQ integration
- Test of IST/FST silicon prototypes
- Design of light-weight triple-GEM prototype chambers
- Design of cables, cooling and alignment system

2008

- Finalize design of cables, cooling and alignment system
- Test of IST and FST silicon prototypes
- Test of triple-GEM light-weight prototypes
- Design of mechanical support structure