JLC Detector Overview

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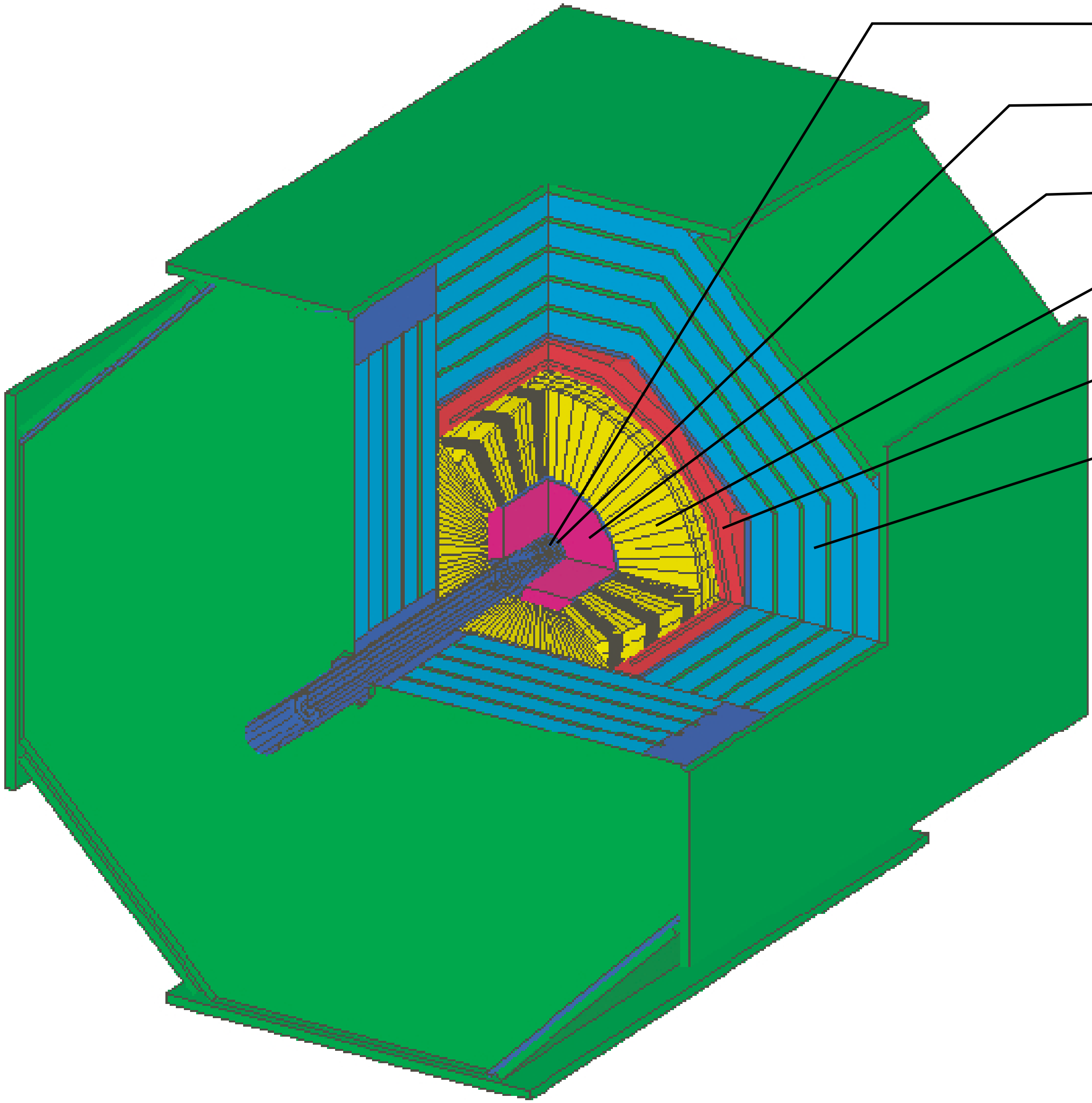
KEK

Contents:

R&D Status and Plan
- CCD Vertex Detector
- Central Drift Chamber
- Calorimeter

Machine Design and Detector Design
- Mask System
- New F.F. Optics

JLC Detector Model



Forward Region

(Forward Silicon Tracker)

Active Mask

Luminosity Monitor

Pair Monitor

Parameters of the JLC Detector Model

Detector		Configuration	Performances	Channels and Data Size
PM (3D Active Pixel)		θ = 11 - 48mrad (r=2-8.5cm) 300μm-thick x 2 layers pixel size=100μm	Under Study	Number of pixels = 8.6M Readout channel = 156ch Data size = 12k bytes/sec
LM (W/Si)		θ = 50-150mrad 43Xo x 16samplings Nr = 32, $N\phi$ = 16	Under Study	Number of pads = 16.4k Readout channel = 128ch Data size = 3.3k bytes/train
AM (W/Si)		θ = 150-200mrad 23Xo x 8samplings Nr = 10, $N\phi$ = 32	Under Study	Number of pads = 5.1k Readout channel = 16 Data size = 5.1k bytes/train
FT		TBD	Unknown	
VTX (CCD)		cosθ < 0.90 pixel size=25μm, thickness=300μm 4 layers at r = 2.4, 3.6, 4.8, 6.0cm	**σ = 4.0μm** **$\delta^2 = 7^2 + (20/p)^2/\sin^3\theta$ [μm]** **ε_b=50% @ purity=93%**	Number of pixels = 320M Readout channel = 2.4k Data size = 1.4M bytes/train
IT (Si-strip)		cosθ < 0.90 strip width=100μm, thickness=300μm 5 layers at r = 9, 16, 23, 30, 37cm	**σ = 40μm** Tracking Performance Under Study	Number of strips = 522k Readout channel = 1.0k Data size = under study
CDC (Mini-jet)	common	cosθ < 0.70 (full sample) cosθ < 0.95 (1/5 samples)	**σ_z = 1mm** **2-track separation = 2mm**	200MHz FADC depth = 1k words
	2Tesla	r = 45 - 230cm, L = 460cm N_{sample} = 80	**σ_x =100μm** **σ_{Pt} /Pt = 1x10^{-4}Pt + 0.1%**	Readout channel = 13k Data size = 5.2M bytes/train
	3Tesla	r = 45 - 155cm, L = 310cm N_{sample} = 50	**σ_x =85μm** **σ_{Pt} /Pt = 3x10^{-4}Pt + 0.1%**	Readout channel = 8.1k Data size = 3.3M bytes/train
Trackers Combined			**σ_{Pt} /Pt = 1x10^{-4}Pt + 0.1%**	
CAL (Pb/Sci)	common	EM = 27Xo (3sections) HAD = 6.5λo (4sections) $\Delta_{\theta,\phi}$ = 24mrad (EM), 72mrad (HAD)	**σ/E=15%/√E+1% (EM)** **σ/E=40%/√E+2% (Had)** **e/π ID = 1/1000**	Number of cells = 144k Readout channel = 5k Data size = 3k bytes/train
	2Tesla	cosθ < 0.985 (full thickness) r = 250 - 400 cm, z = +- 290cm		
	3Tesla	cosθ < 0.966 (full thickness) r = 160 - 340 cm, z = +- 190cm		
SHmax		scin.strip (1cm-wide) or Si-pad (1cm x 1cm)	**σ = 3mm/√E**	Readout channel = 5k Data size = 40k bytes/train
MU (SWDC/RPC/TGC)		cosθ <0.998 6 SuperLayers	**σ = 0.5mm** Muon ID under study	Readout channel = 10k
Yoke	2Tesla	r = 5.5m - 7.5m, Z = 5.0m - 7.9m		
	3Tesla	r = 4.5m - 7.0m, Z = 3.9m - 6.5m		

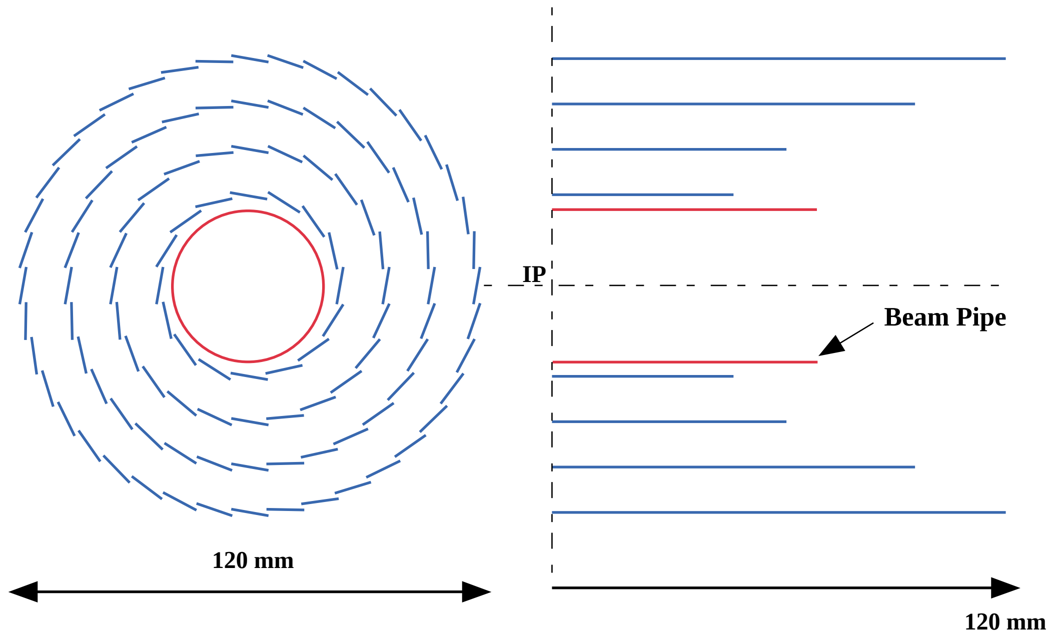
R&D Status of Sub-detector Components for JLC

- Vertex Detector
- Central Drift Chamber
- Calorimeter

Vertex Detector

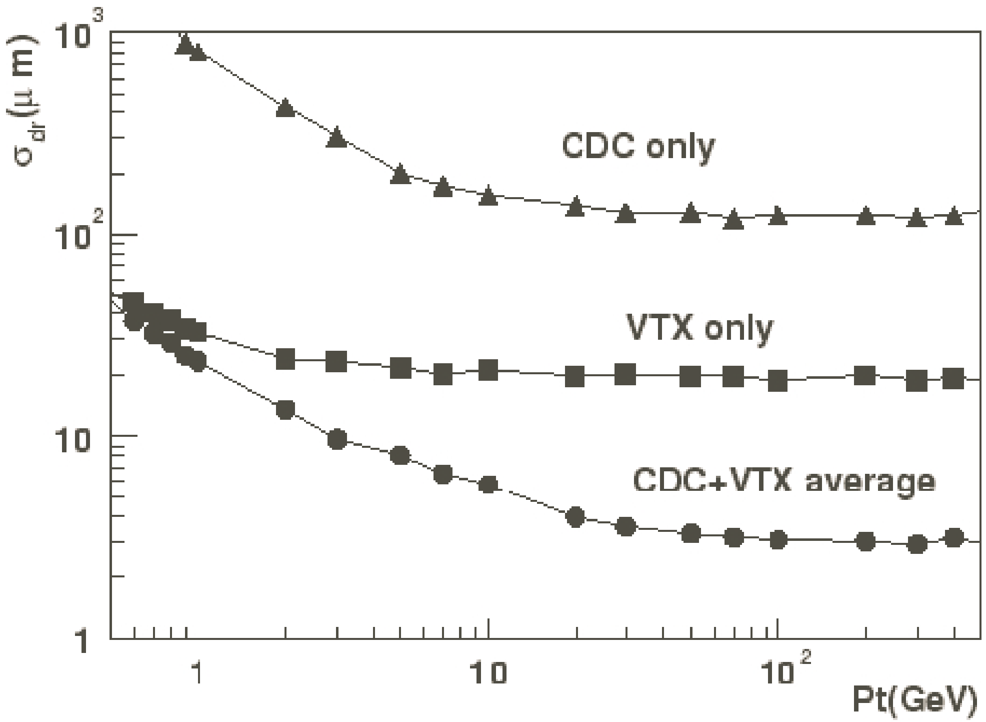
Present Design Parameters in JIM (JLC full Simulator)

- **4 layers of CCDs at r = 24, 36, 48, 60 mm**
  - **--Another layer at smaller r ?**
- **Angular coverage of $|\cos\theta|<0.9$**
- **Wafer thickness of 300 μm**
  - **-- Thinner wafer ?**
- **Pixel size of 25 μm^2**
- **σ = 4 μm**
- **$\delta^2=7^2+(20/p)^2/\sin^3\theta$ [μm]**

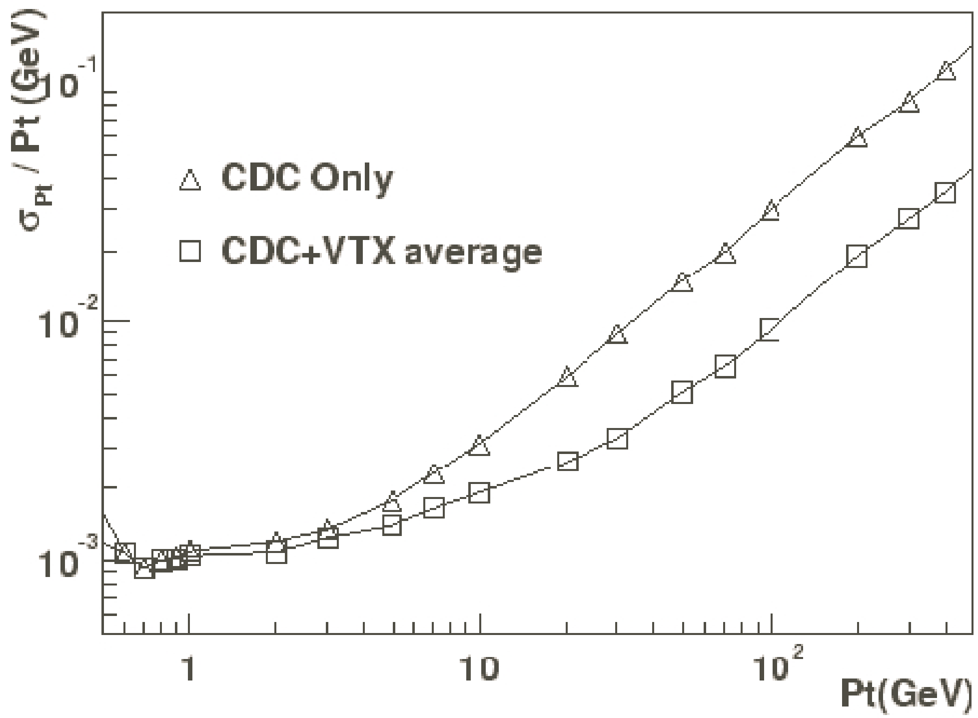


Expected Performance of CCD Vertex Detector

Impact parameter (2D) resolution



Momentum resolution



Better than 7μm expected by VTX alone at large Pt due to high resolution CDC

$$\sigma_b = \frac{\sigma_{in} r_{out}}{r_{out}-r_{in}} \oplus \frac{\sigma_{out} r_{in}}{r_{out}-r_{in}} \oplus \frac{0.014 r_{in}}{p\beta}\sqrt{\frac{Xr}{\sin^3\theta}}$$

R&D Status & Plan of CCD Vertex Detector

1) Spatial resolution

- **Resolution of <3µm has been confirmed with test beam**
- **Laser beam (1064 nm) scanner with 2µm spot size (Niigata Univ.)**

2) Study of distortion of CCD wafers

Thinner wafer is desireble
--- 20µm is enough for particle detection
--- but how to support?
Thermal distortion shoud be reasonably small and has repeatability

Idea of C.Damerell's group: 50µm wafer stretched from both ends
-> proposed in TESLA TDR
Another idea: Partially thinned wafer like SHOJI in traditional Japanese house

System of distortion measurement has been constructed

3) CCD radiation hardness

The result of our study so far using ^{90}Sr irradiation is;

CCD can survive > 3 years with

B = 2T
Rmin = 24 mm
Machine parameter "A" (Standard Luminosity)

But it is preferable to have

Rmin < 24 mm
High Luminosity ("Y") Option

-> Study of radiation hardness should be continued

Issues to be studied:

- Effect of readout speed
  -> Fast readout (~10MHz) is needed

- How to inject the “Fat Zero Charge”

- Radiation damage effect on the spatial resolution
  -> @Niigata Univ.

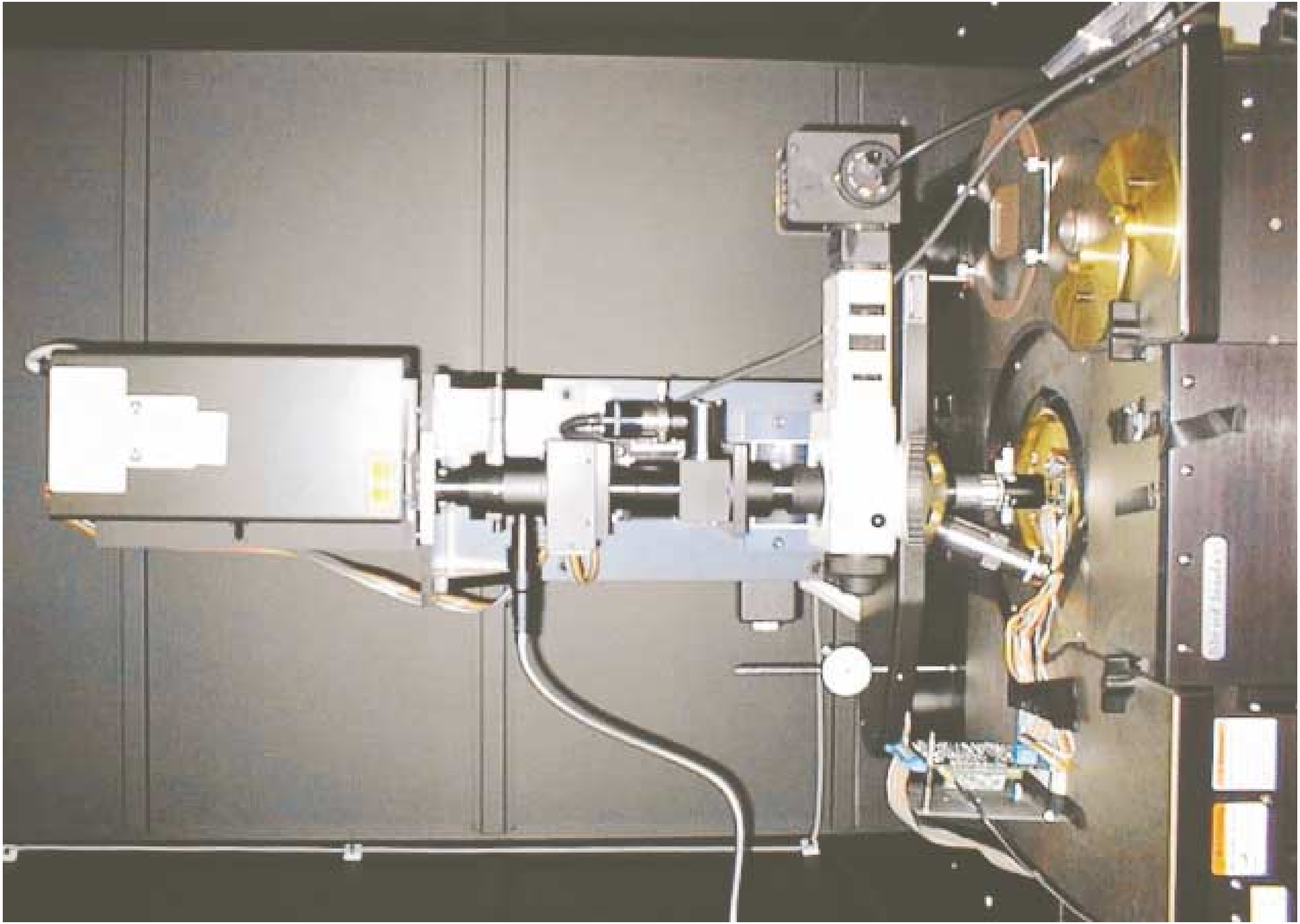
- Radiation damage by high energy (>10MeV) electrons
  -> Sooner or later

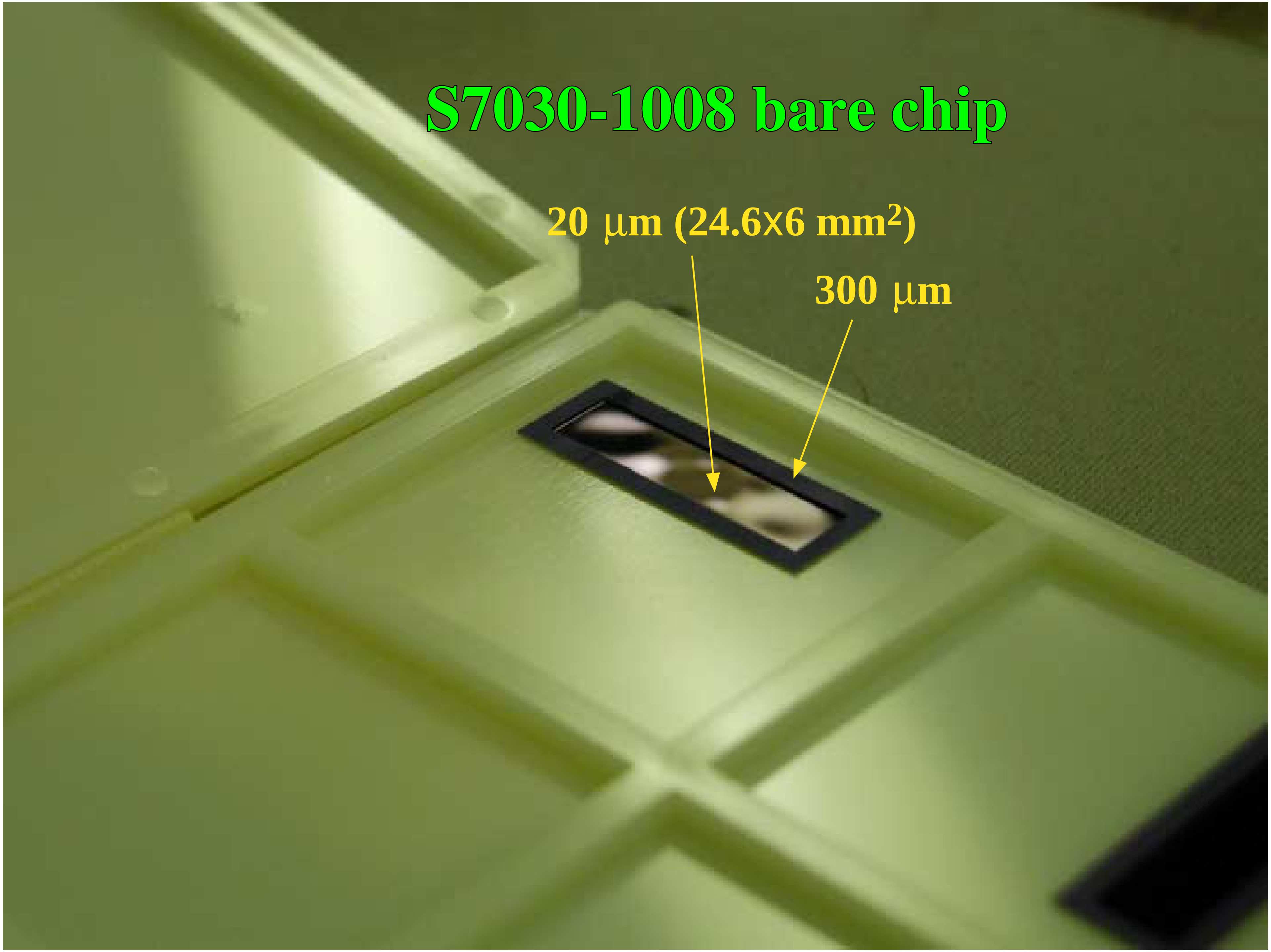
4) Fast readout electronics

CCD Signal Processor chip for Digi-Cam

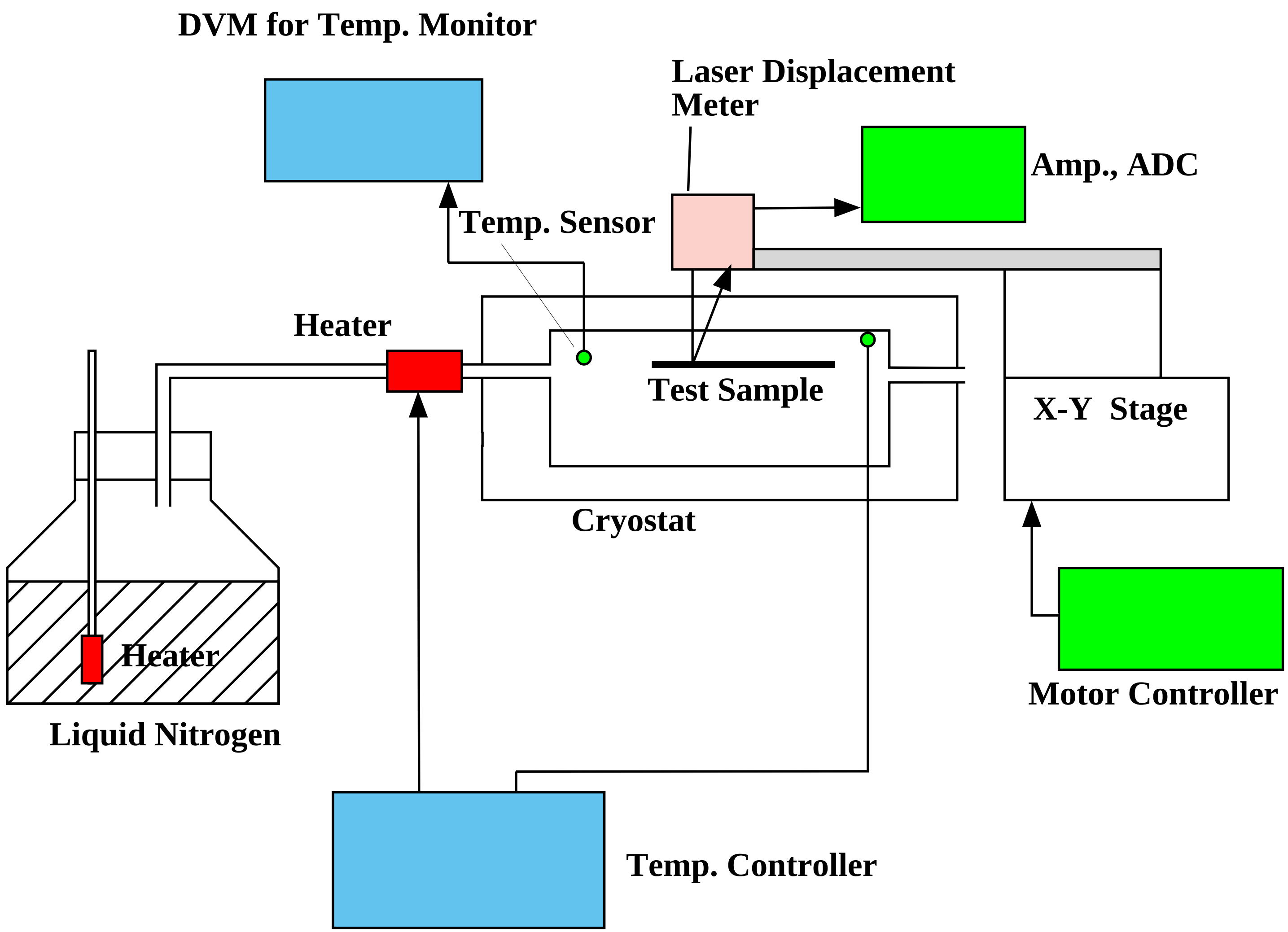
- **Correlated double sampler**
- **Variable gain amp**
- **10bit/40MHz or 12bit/20MHz ADC**

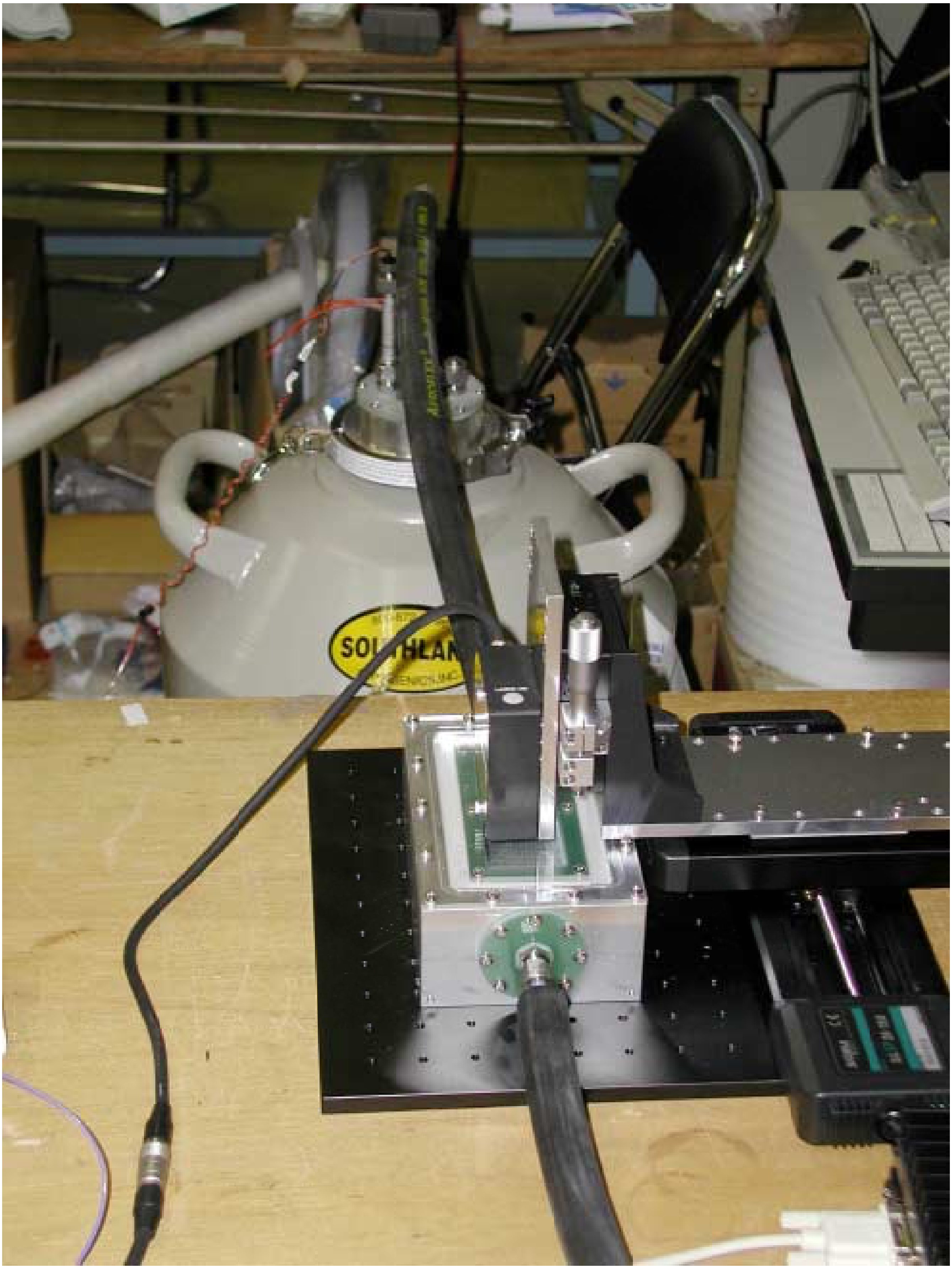
These functions in 9x9 mm^2 chip size by $6/chip

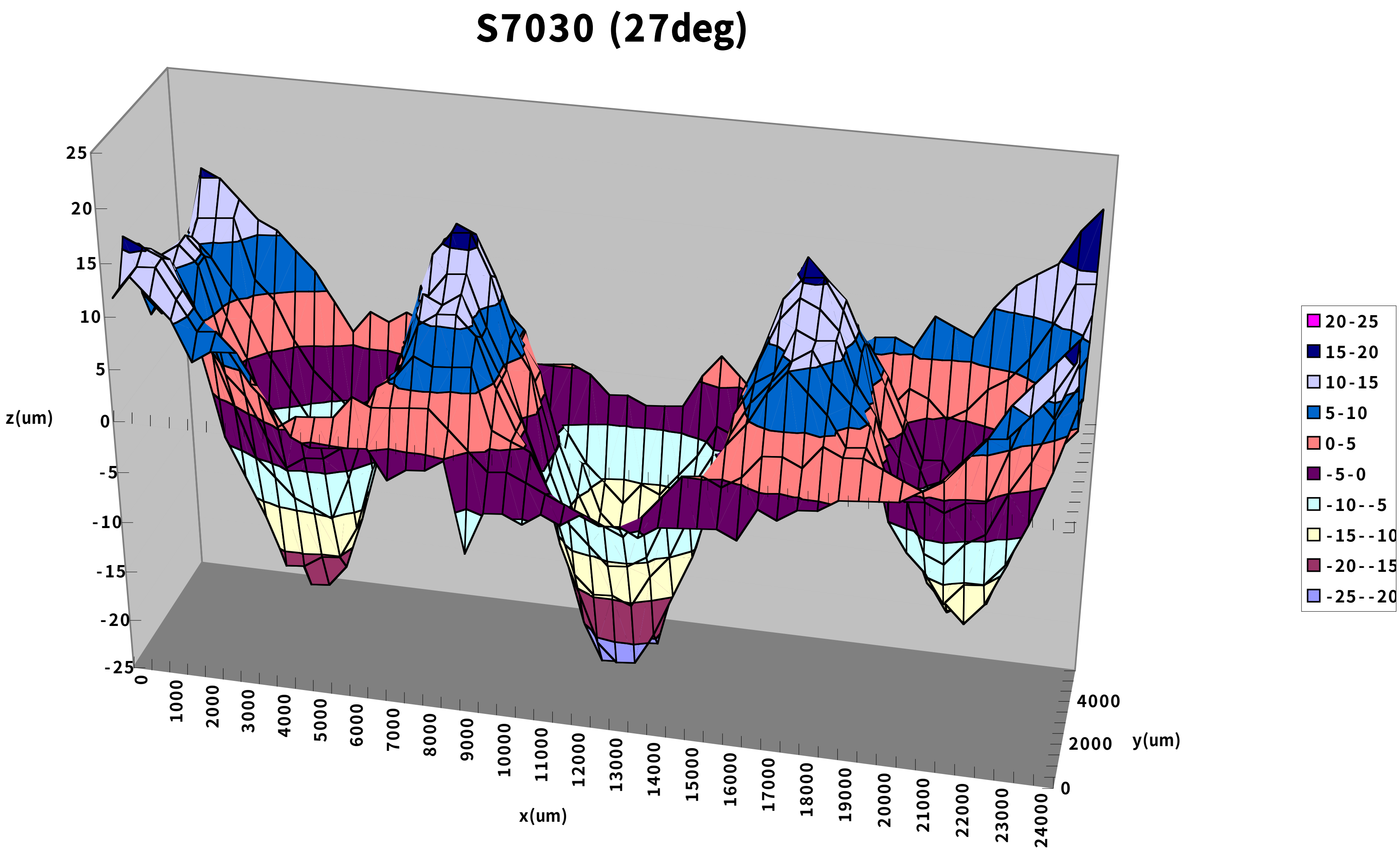



S7030-1008 bare chip
20 μm (24.6x6 mm²)
300 μm

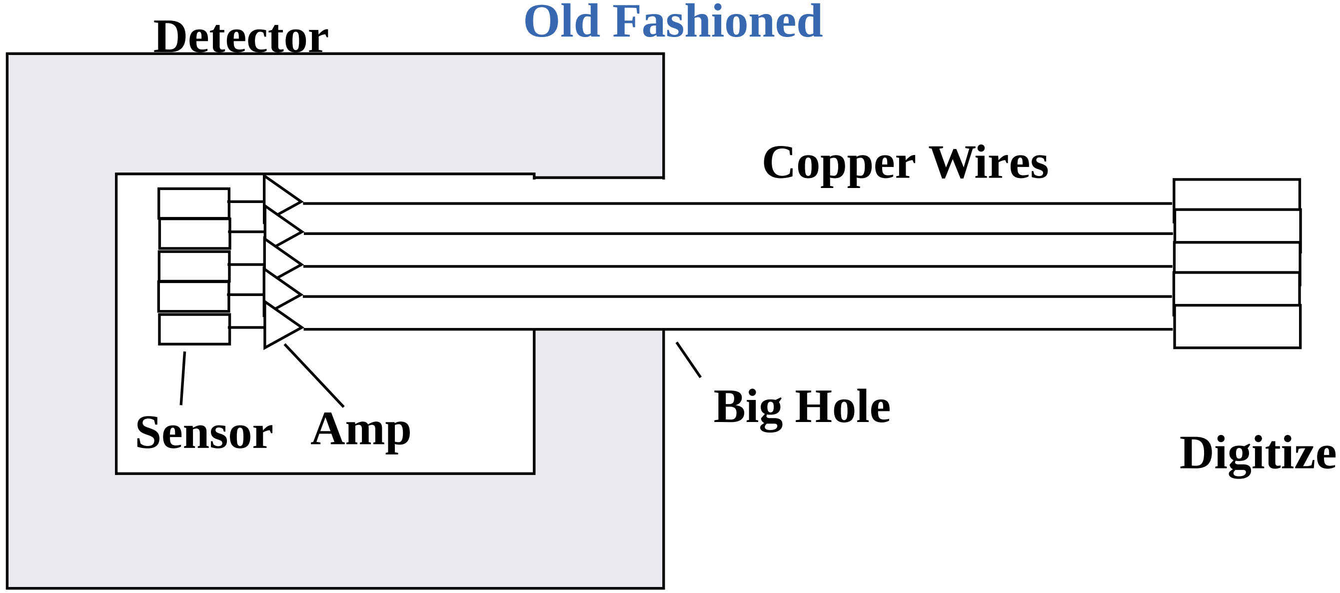
Measurement System



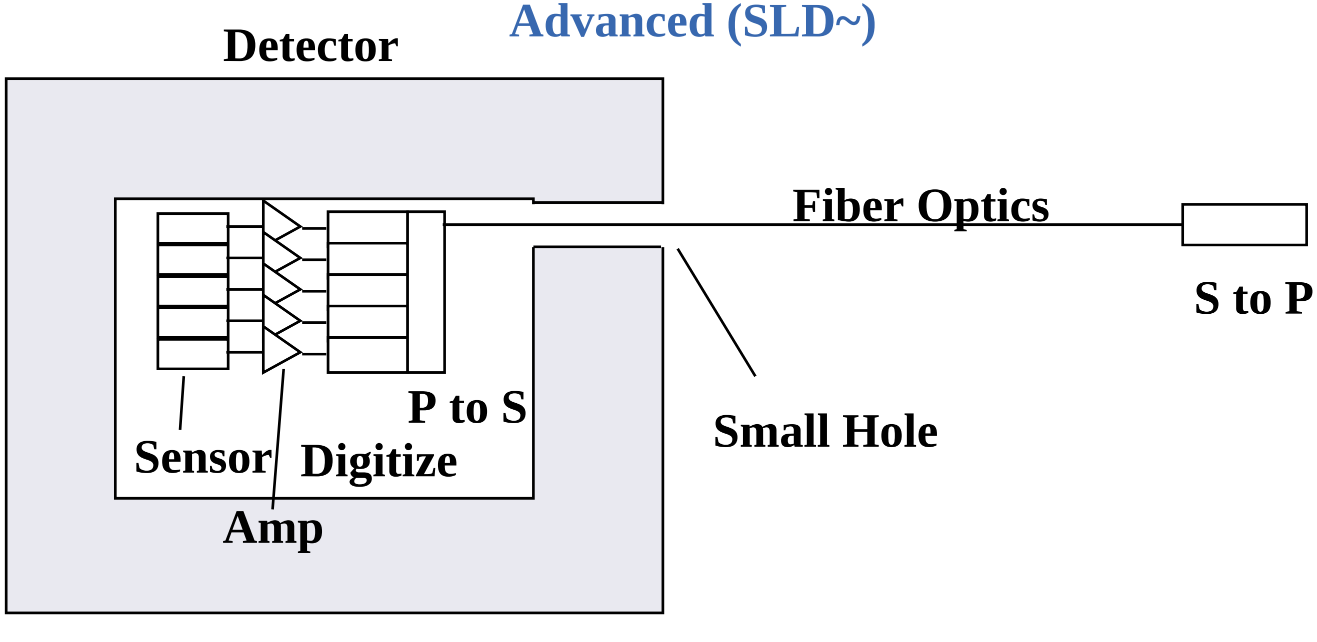

SOUTHLAN


S7030 (27deg)
z(um)
25
20
15
10
5
0
-5
-10
-15
-20
-25
x(um)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000
18000
19000
20000
21000
22000
23000
24000
y(um)
0
2000
4000
20-25
15-20
10-15
5-10
0-5
-5-0
-10--5
-15--10
-20--15
-25--20

Old Fashioned



Advanced (SLD~)



	SLD (VTX3)	JLC
# of pixels	307 M	> 320 M
Readout time	200 ms	6 ms
R.O. frequency	5 MHz	20 (40) MHz
# of r.o. ch	384	> 2600 (1300)
Throughput	15 Gbps	> 500 Gbps
Fiber Optics	960Mbps x 16	3.4 Gbps (IEEE1394b) x 150 ??

Current CDC Parameters (R&D)

Mini− jet cell structure (5 anode wires /cell)

Gas mixture CO_2 (90%) − C_4H_{10} (10%)

$\sigma_{xy} = 85\ \mu m$

2−Tesla option

$R_{in} = 45$ cm

$R_{out} = 230$ cm

$L = 460$ cm (Length of the chamber)

$B = 2$ T

$n = 80$ (Number of sampling points)

3−Tesla option

$R_{in} = 45$ cm

$R_{out} = 155$ cm

$L = 310$ cm (Length of the chamber)

$B = 3$ T

$n = 50$ (Number of sampling points)

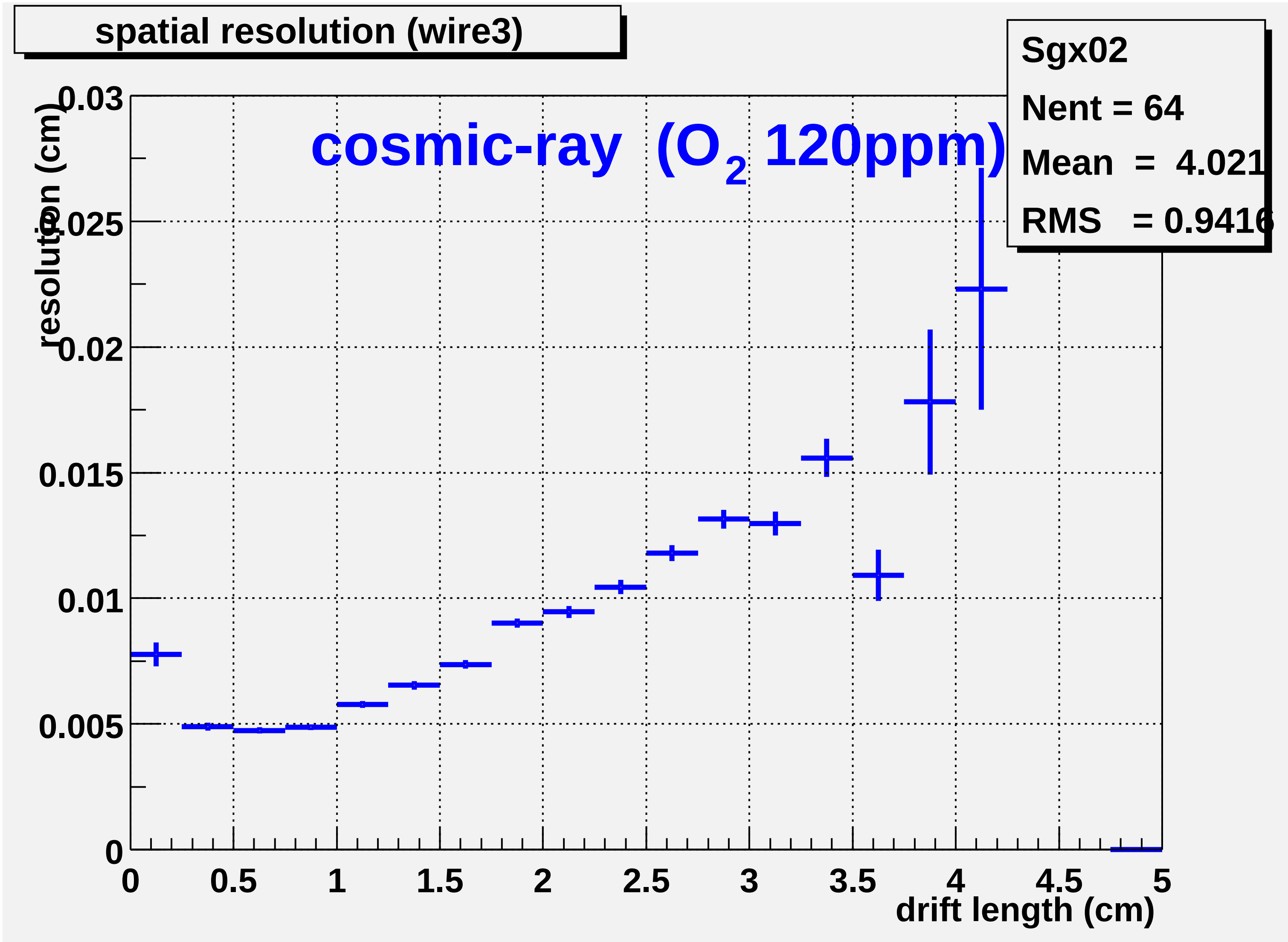
Progress after last ACFA meeting

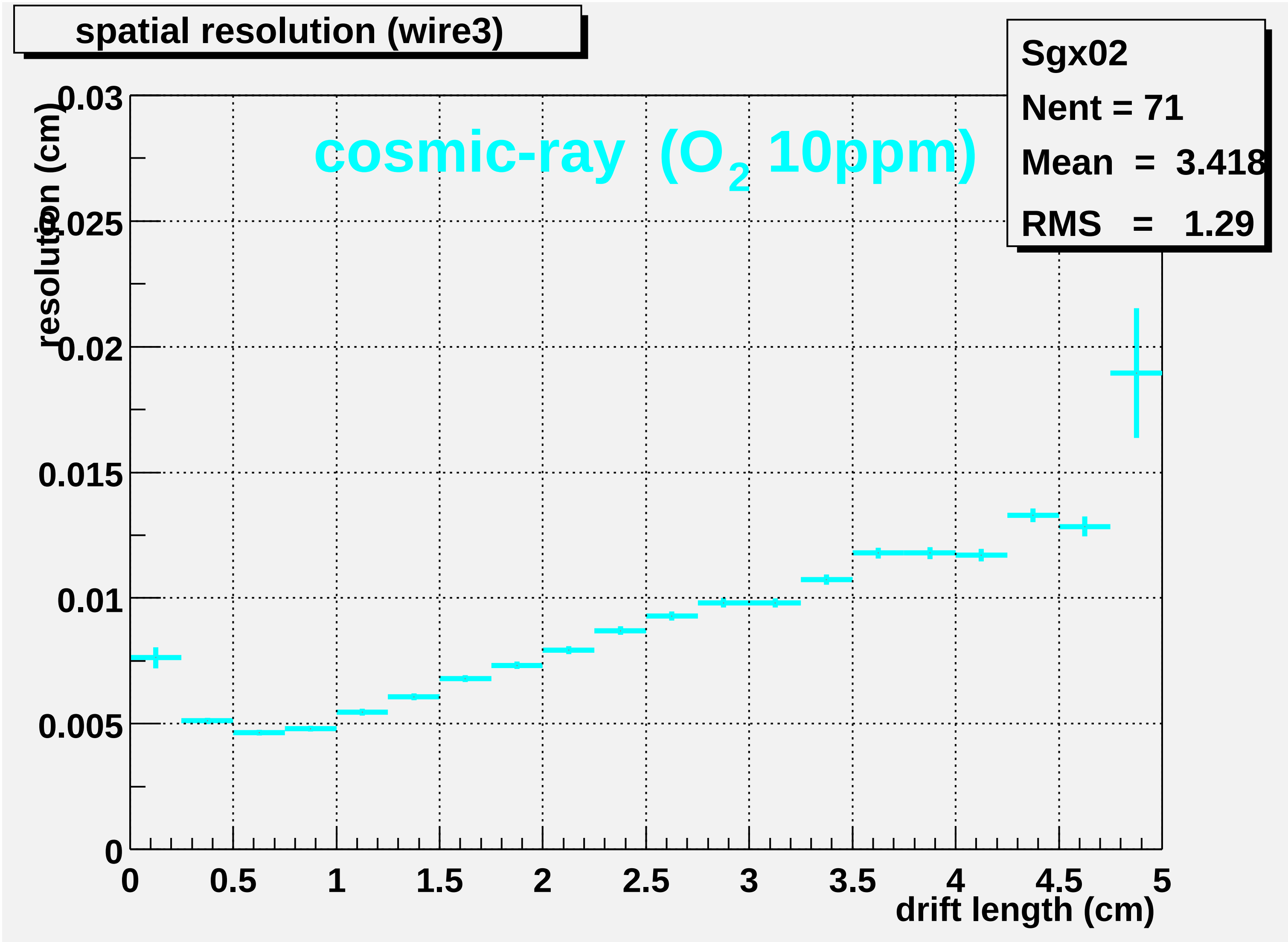
Past

- **Gas Gain Measurement ...**
  NIM, A447 (2000) 459.
- **Lorentz Angle Measurement ...**
  Subm. to NIM.

Present status and future plan

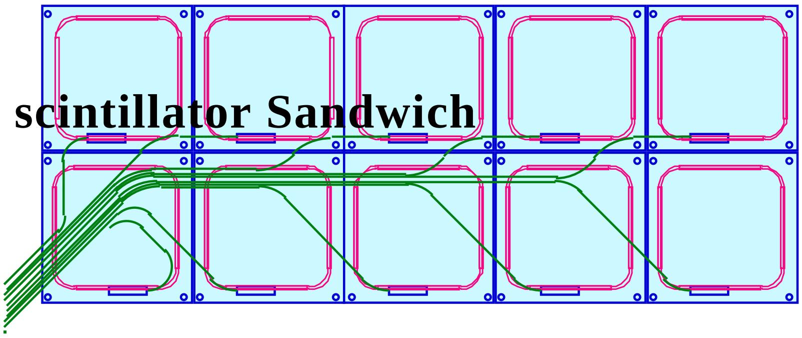
- **dE/dx Measurement ...**
  Draft − in preparation.
- **Oxygen Contamination Study ...**
  Draft − in preparation.
- **Single Track Study (space resolution etc.) ...**
  Draft − in preparation.
- **Space charge effect study...**
  in progress.
- **Two−track separation study ...**
  in progress.
- **Signal shape study (GARFIELD, experiment)...**
  in progress.
- **Wire material study (tension problem)...**
  in progress.
- **GEANT4 development (3T option) ...**
  in progress.
- **Neutron background study ...**


spatial resolution (wire3)
Sgx02
Nent = 64
Mean = 4.021
RMS = 0.9416
cosmic-ray (O2 120ppm)
resolution (cm)
0.03
0.025
0.02
0.015
0.01
0.005
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
drift length (cm)


spatial resolution (wire3)
Sgx02
Nent = 71
Mean = 3.418
RMS = 1.29
cosmic-ray (O2 10ppm)
resolution (cm)
0.03
0.025
0.02
0.015
0.01
0.005
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
drift length (cm)

Calorimeter

Baseline Design



- **Structure : Lead/Plastic scintillator Sandwich**

  EM : Pb/Sci=4mm/1mm

  had : Pb/Sci=8mm/2mm

- **Scheme : Tile/Fiber**

  with hardware compensation

- **Granularity : as small as reasonably achievable**...under study

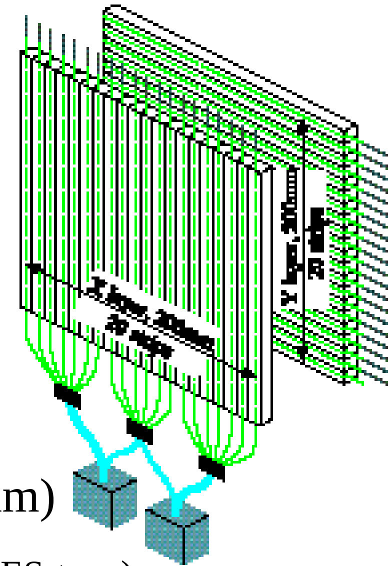
  Baseline Rect-Tile

  EM : 4cm x 4cm (24mrad) x 3 longitudinal samplings

  had : 14cmx14cm (72mrad) x 4 longitudinal samplings

  Strip-EM option

  1cm-wide strip-array (x-y layers) x ~20 longitudinal samplings



- Shower Max Detector

  Baseline : 1cm-wide strip-array (x-y layers)

  Option : 1cm x 1cm Si-pad

Performances

- Single-particle response (measrured with testbeam)

  $\sigma_E/E = 15.4\%/\sqrt{E} + 0.2\%$ for electrons (ZUES-type)

  $\sigma_E/E = 46.7\%/\sqrt{E} + 0.9\%$ for pions

  $\sigma_X = 2\sim3$mm even at over 50GeV

  pion rejection = 1/1400 at $\varepsilon_e = 98\%$

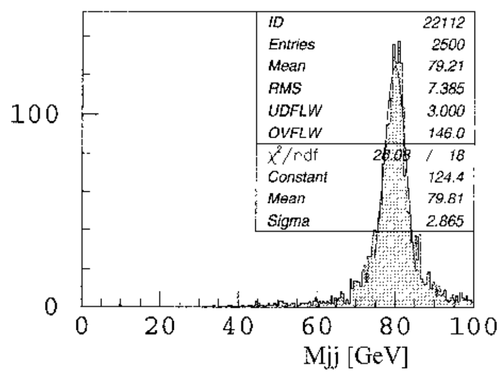
- **Jet response : under simulation study**

Recent Activities

[I] Granularity Optimization with Full Simulation

Analysis of quick-simulation data gives very good performance

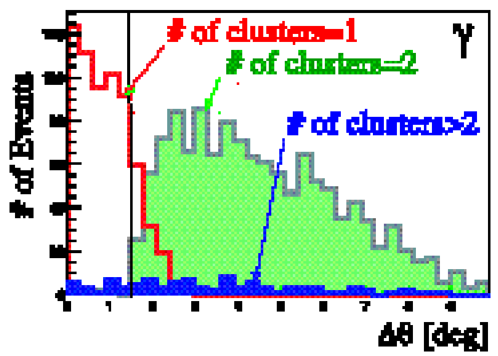
... but it is not the end of the story.

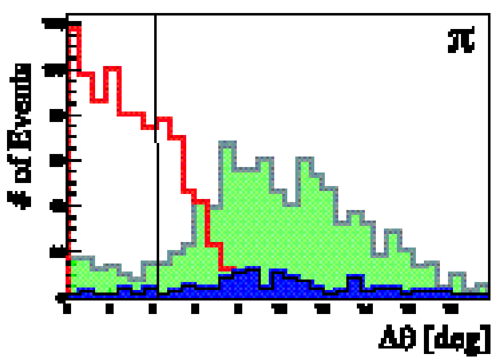


1) Construction of full-simulator

- Done for baseline design (Rect-Tile).
- not yet for optionl design (strip-EM).

2) Shower clustering ; in progress but very difficult

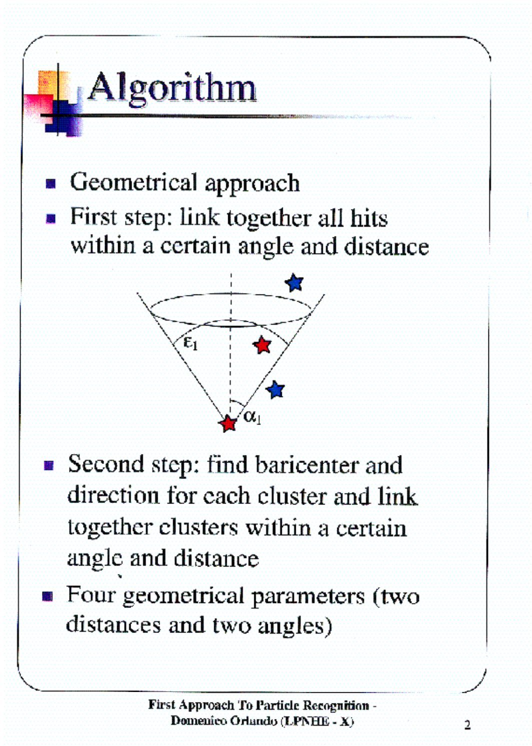




a) hadron shower clustering

<--- • 2D-JADE ; not successful yet

- 2D-contiguous ; not successful yet
- 3D-contiguous ; not successful yet
- **Super-cluster = French method not yet tried (below)**



b) decomposition of overlapping showers

under study including its necessity itself

c) track-cluster association

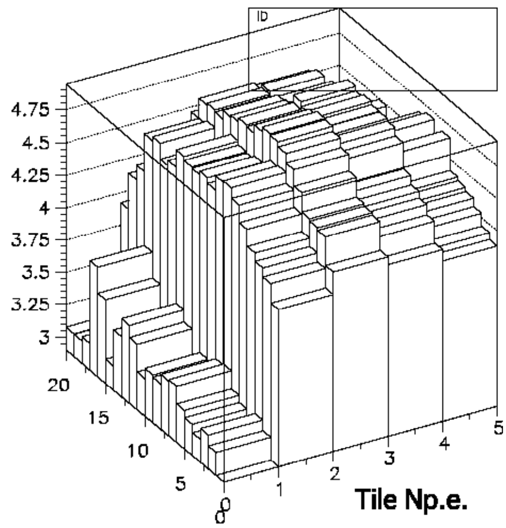
under study including 1st principle ;

whether one-to-one or plural-to-one

[II] Hardware Studies

1) Strip EM option

- Bench test on photon yield and uniformity in progress
- Simulator of above properties under construction



2) Small Rect-Tiles (4cm x 4cm x 1mm-thick)

- WLS-fiber shape, layout and die selection under desk-study
- Bench test on photon yield and uniformity under preparation

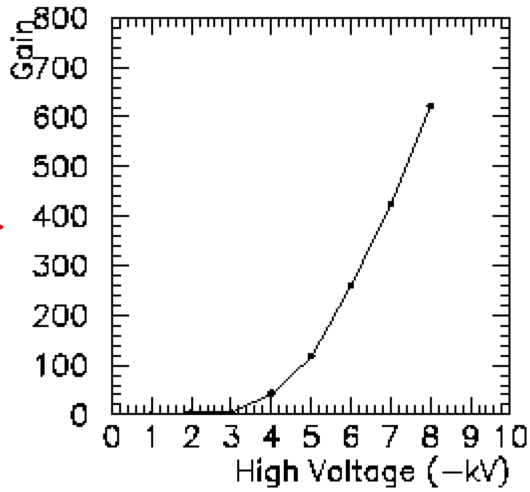
3) Direct-readout SHmax ; Bench test in progress

- PIN-Si ; gain too low
- APD ; under study ... might be operational but costy

4) Photon Detectors

- Multi-channel HPD ; toward $S_{ingle}P_{hoton}P_{eak}$
- Single-channel HAPD ; toward multi-ch
- EBCCD ; toward High Gain ------------------>
- High-QE photo-cathode (40%@540nm)

<---> WLS die optimization for Rect-Tile



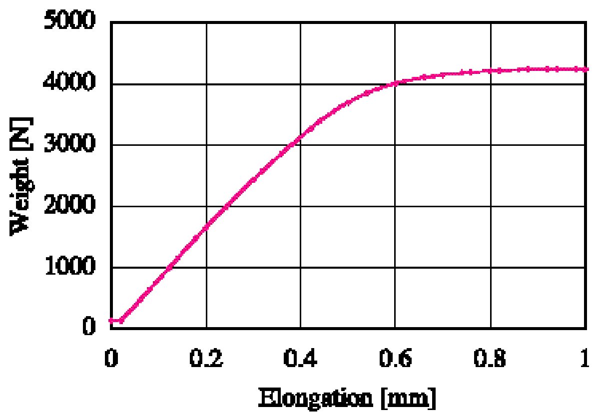
5) Lead Alloy

a) Measurement of Strength and Young modulus in progress

- dopants ; Sb, Ca/Sn ... in progress
  As ... hopeful but difficut
- treatment ; heat / mechanical
  in progress

b) Hybrid material

Paper-work in progress



Coming R&D plans

1) Further full-simulation studies on granularity optimization

2) Beam tests of fine-granularity EM module

includes

- Strip-EMC
- Rect-Tile EMC
- Direct-readout SHmax
- Optimum photon detectors for each

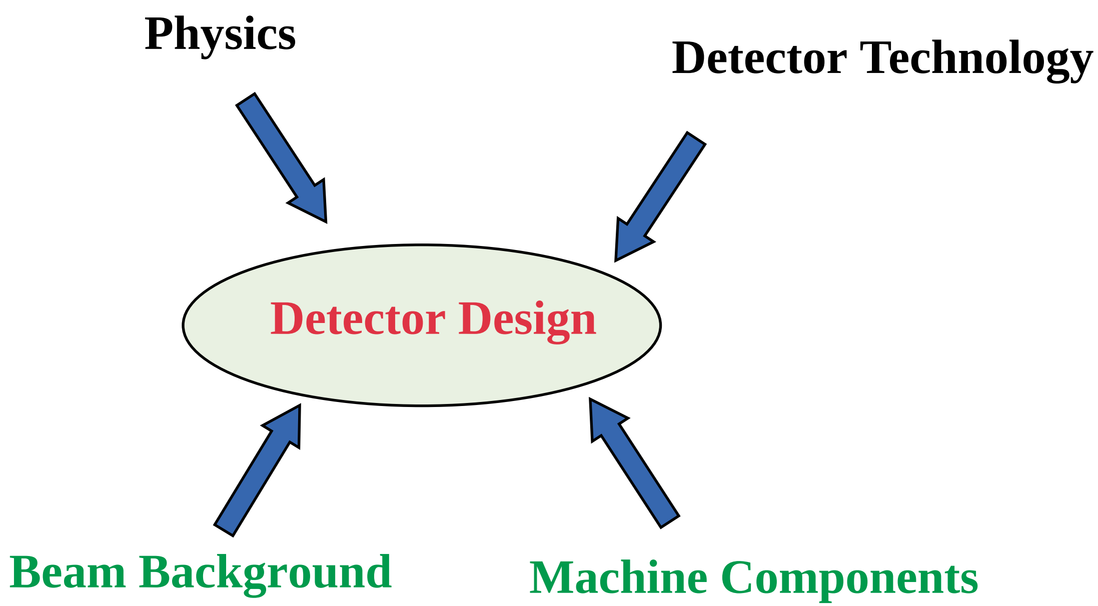
3) Lead alloy and structures

- Further studies on alloys and hybrid materials
  Make test pieces of SUS-Pb sandwich
- Engineering studies on structure

4) Mass production of tiles and fiber assemblies

- Tiles ; Design optimization for "moldable" tiles
  MEGA-tile structure, groove cross section, etc.
- Fiber assemblies ; low-cost heat-splicing, mirroring, etc.

Machine Design and Detector Design



Trend of the JLC Detector Model

2 Tesla Solenoid Magnet (JLC-I)

↓

3 Tesla Soleniod Magnet (ACFA Report)

- **Less beam background hits**
- **Smaller detector (CDC) size**

↓

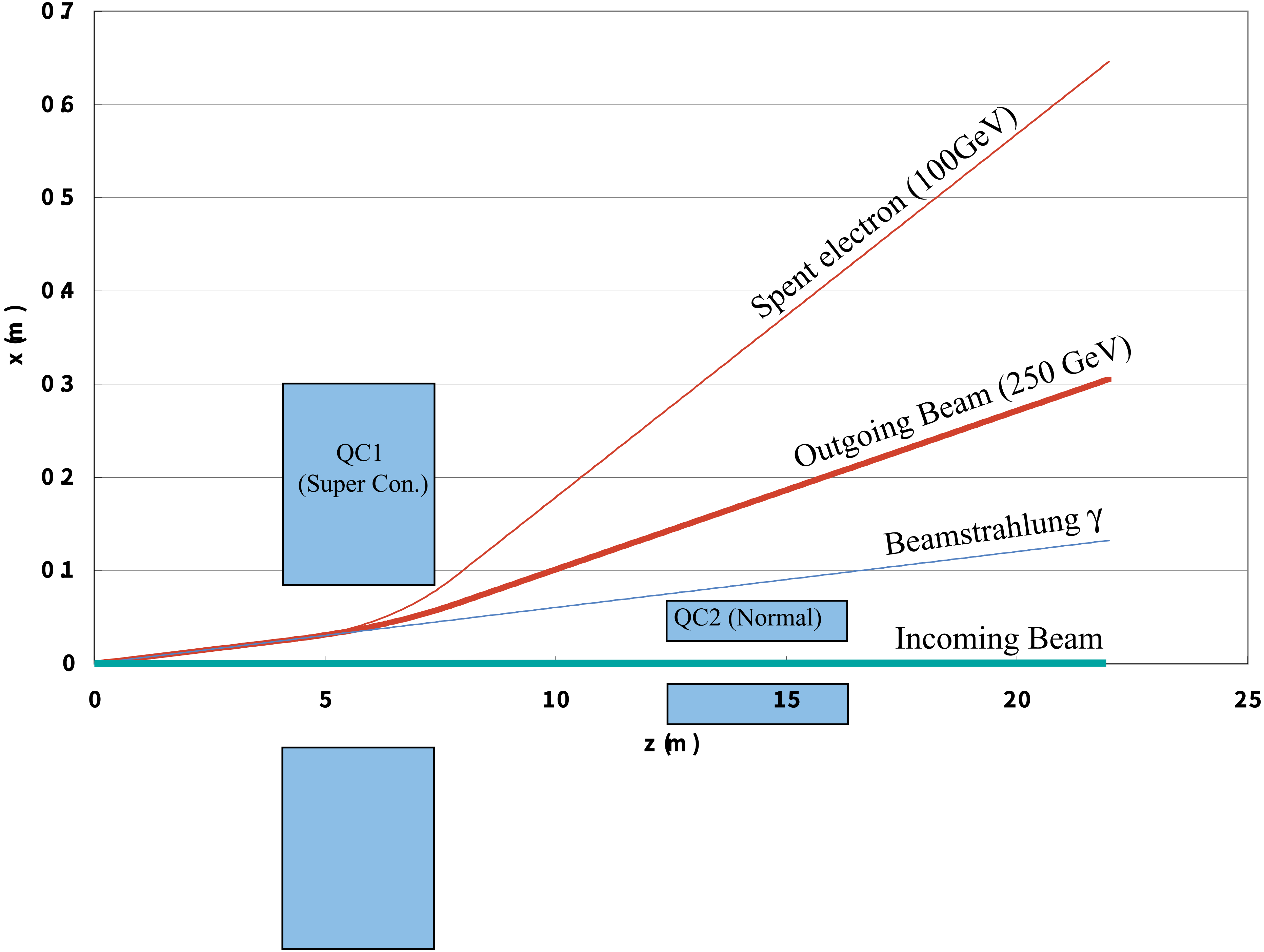
4 m *l -- New Final Focus Optics**

- **Still less beam background hits**
- **Smaller inner radius for CDC & ECAL**
- **Better forward coverage**

New Final Focus Optics

- Proposed by Pantaleo Raimondi & Andrei Seryi (SLAC)
- Length of the final focus section : 1800 m -> 500 m @E_b=500 GeV
- *l** (distance between IP and QC1) : 2 m -> 4.3 m

- Optimization for JLC has to be done
- Estimation of beam background (sync. rad. etc.) needed



0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
x (m)
0
5
10
15
20
25
z (m)
Spent electron (100GeV)
Outgoing Beam (250 GeV)
Beamstrahlung γ
Incoming Beam
QC1
(Super Con.)
QC2 (Normal)

Detector models and Mask system

Detector Model		QC1 surrounded by	Mask System
Old	B=2T *l**=2m	CDC	Long tungsten(W) mask inside support tube Low-Z (graphite/CH_2) mask in front of QC1
Now	B=3T *l**=2m	CAL	Long W Mask inside Support Tube (Short W mask is enough) Low-Z mask
Future	B=3T *l**=4.3m	Endcap Iron	Forward calorimeters (No W mask) Low-Z mask

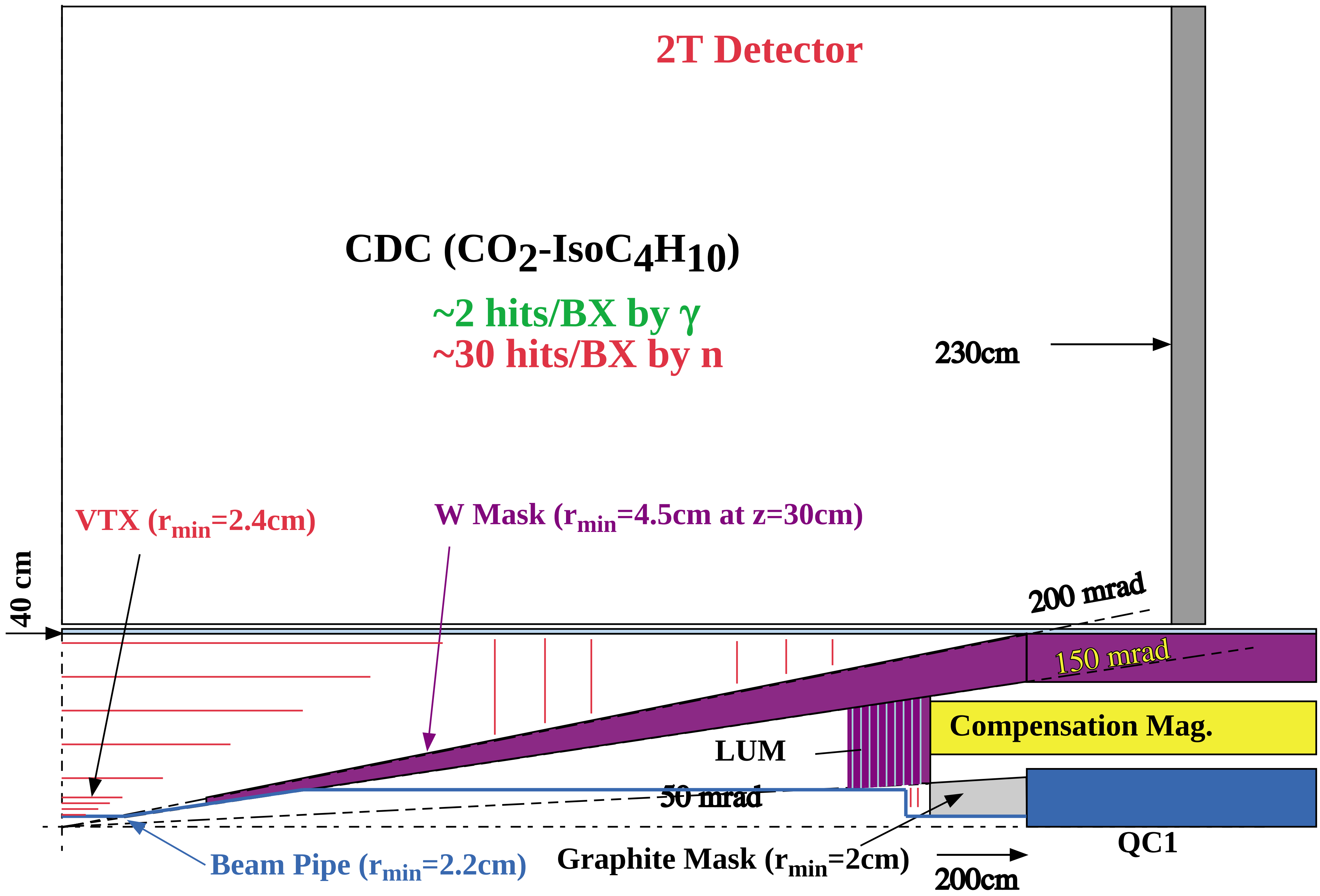
Simulation

Generation of pair background:

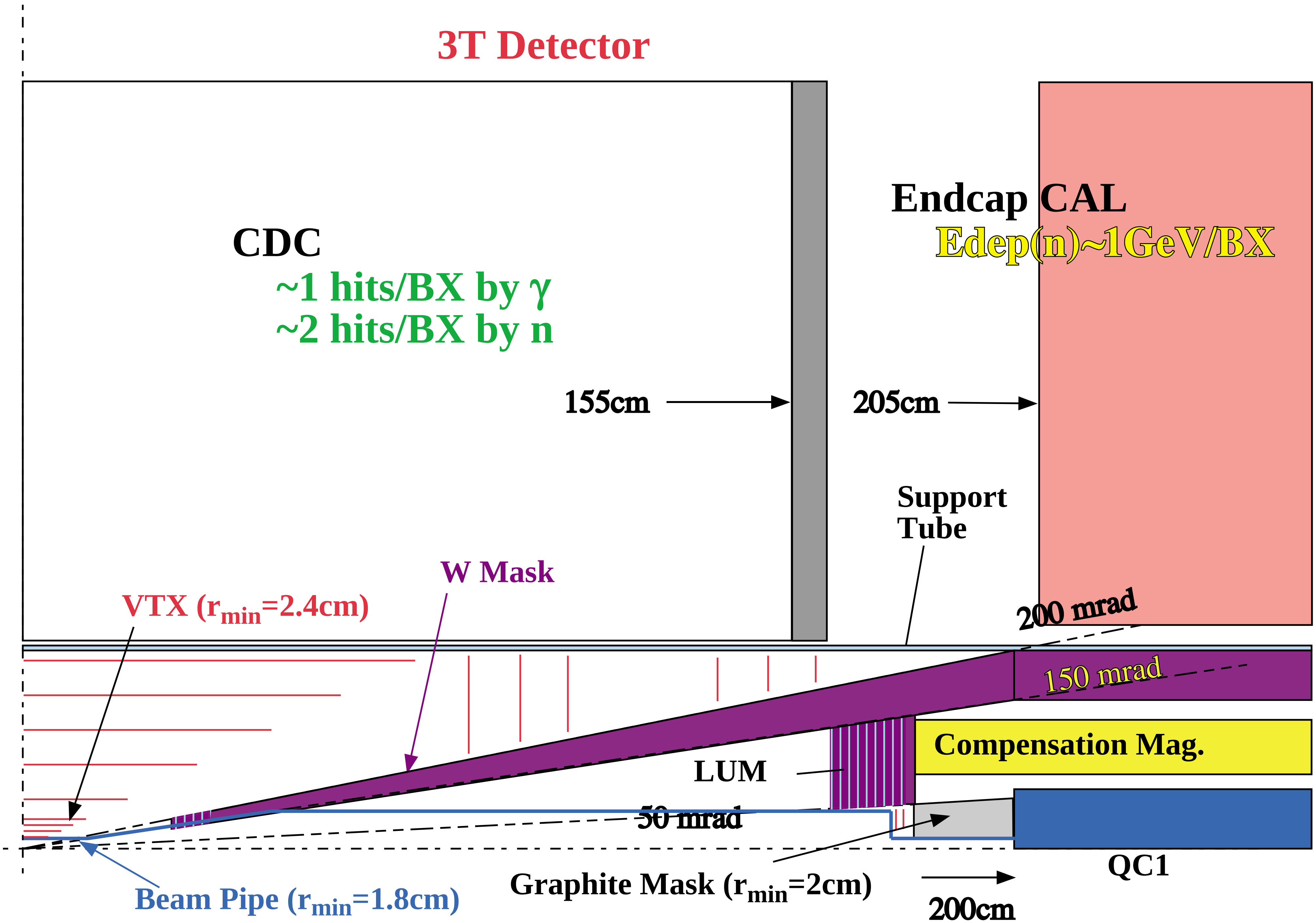
CAIN
Ebeam=250GeV
"A" option ("Y" option)

Detector Simulation:

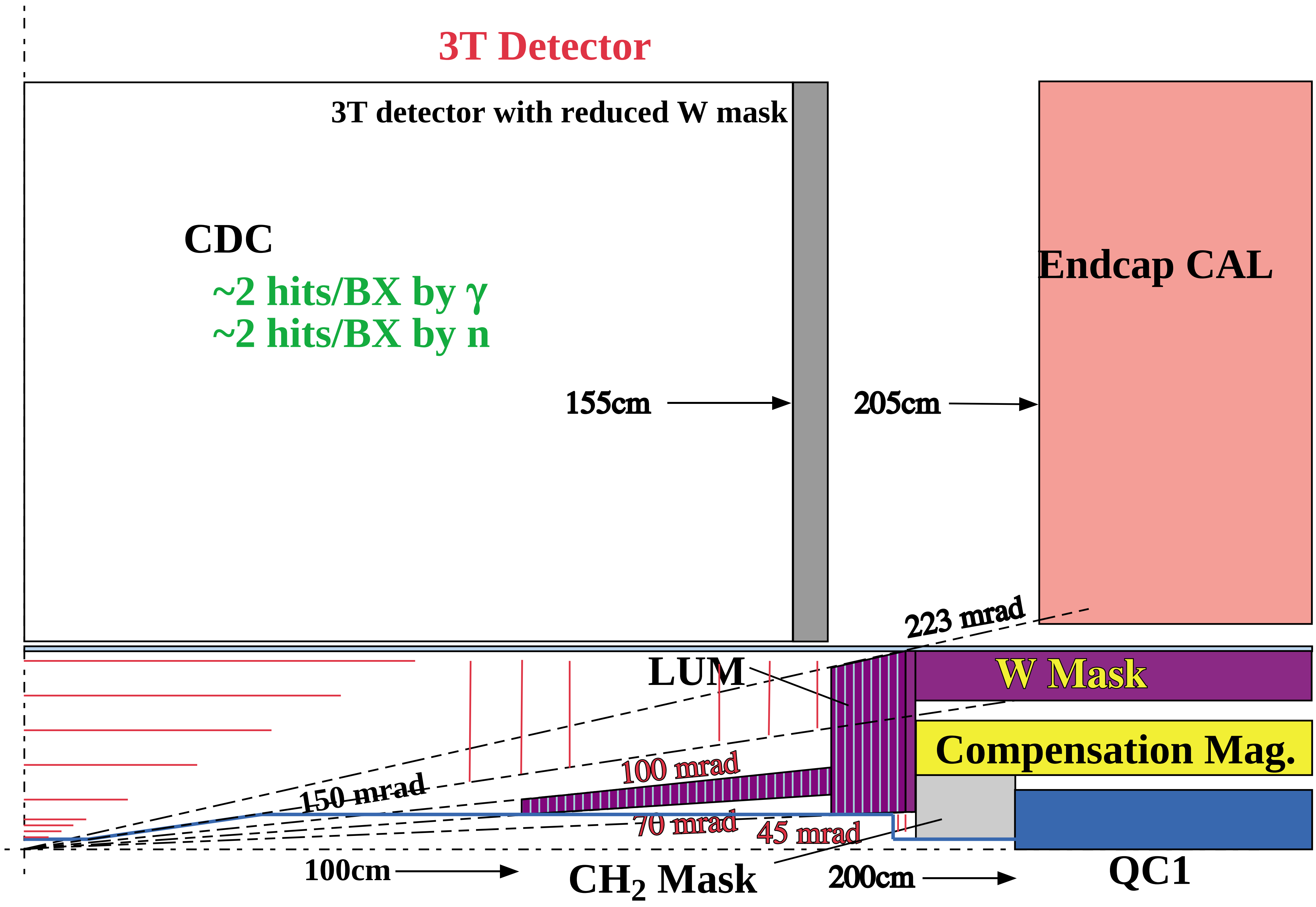
JIM (based on GEANT3)
Ecut for γ: 10 keV
Ecut for n: 1 keV
B field of compensatiom mag. & QC included



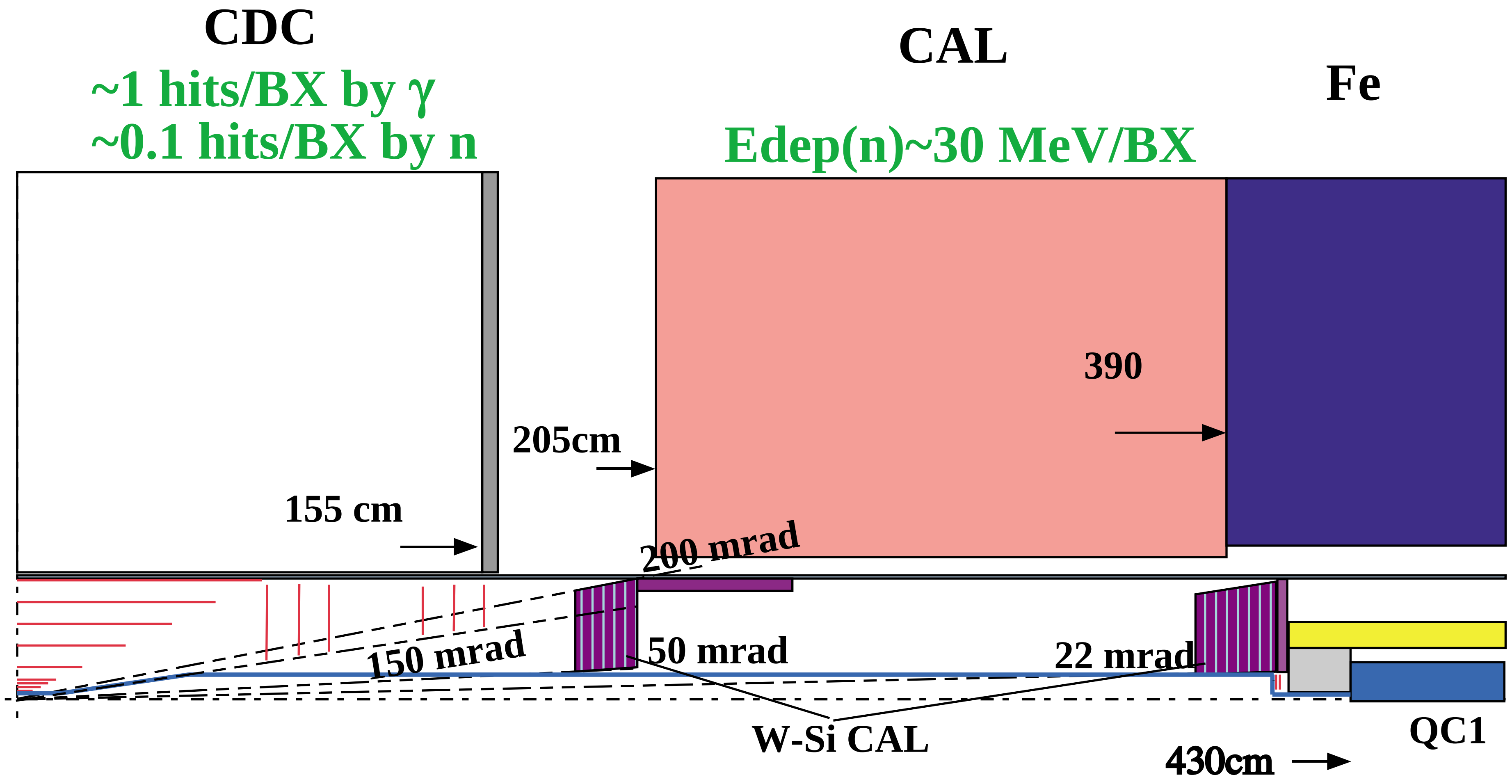
2T Detector
CDC (CO2-IsoC4H10)
~2 hits/BX by γ
~30 hits/BX by n
230cm
VTX (rmin=2.4cm)
W Mask (rmin=4.5cm at z=30cm)
40 cm
200 mrad
150 mrad
Compensation Mag.
LUM
50 mrad
QC1
Beam Pipe (rmin=2.2cm)
Graphite Mask (rmin=2cm)
200cm



3T Detector
CDC
~1 hits/BX by γ
~2 hits/BX by n
Endcap CAL
Edep(n)~1GeV/BX
155cm
205cm
Support
Tube
W Mask
VTX (rmin=2.4cm)
200 mrad
150 mrad
Compensation Mag.
LUM
50 mrad
QC1
Graphite Mask (rmin=2cm)
Beam Pipe (rmin=1.8cm)
200cm


3T Detector
3T detector with reduced W mask
CDC
~2 hits/BX by γ
~2 hits/BX by n
155cm
205cm
Endcap CAL
223 mrad
LUM
W Mask
Compensation Mag.
100 mrad
150 mrad
70 mrad
45 mrad
100cm
CH2 Mask
200cm
QC1

3T *l**=4.3m Detector



Impact of the new optics (*l**=4.3m) on the detector

- Huge W-mask NOT needed
- Background hit much smaller (CDC, CAL)
- No need for Compensation magnet (?)
  if the B field @4.3m is weak enough
  or Super conducting QC1 is adopted
- Better forward coverage for calorimetry
- Smaller R_{min} of CDC and CAL possible

Detector Model	CDC hits / BX (γ)	(n)	CAL Edep (GeV / BX) (γ)	(n)	θ_{min} (mrad)
2T	2	30	~0	0.6	50
3T (*l**=2 m)	1	2	~0	0.9	50
3T (*l**=4.3 m)	1	0.1	0.01	0.03	22

Summary

- Steady progress in R&D for JLC detector -> “ACFA Report”

- But still “holes” in the study : Particle ID, Forward Tracker, etc.

- Other options (e.g. TPC for central tracker) should also be studied

- And still many things to do for TDR

- Pantaleo’s new F.F. optics is very atractive from the viewpoint of detector design

- Study on the new optics including the QC1 design is in progress