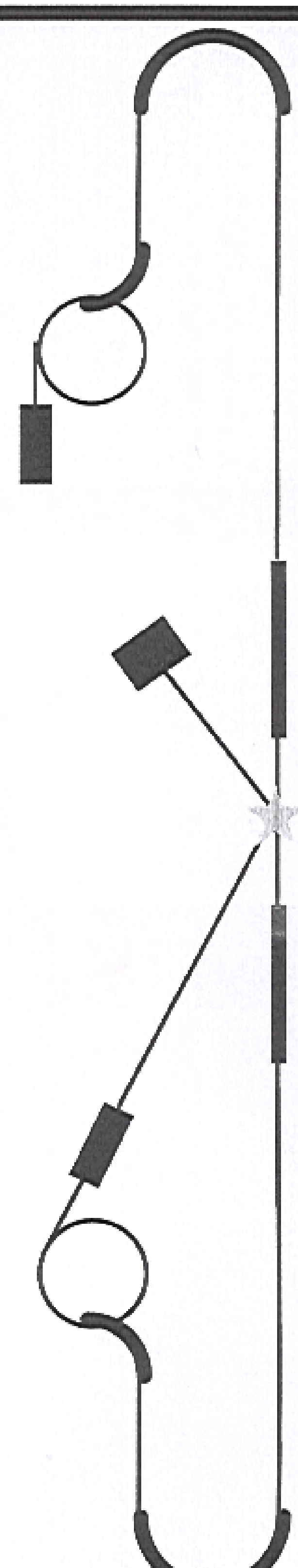
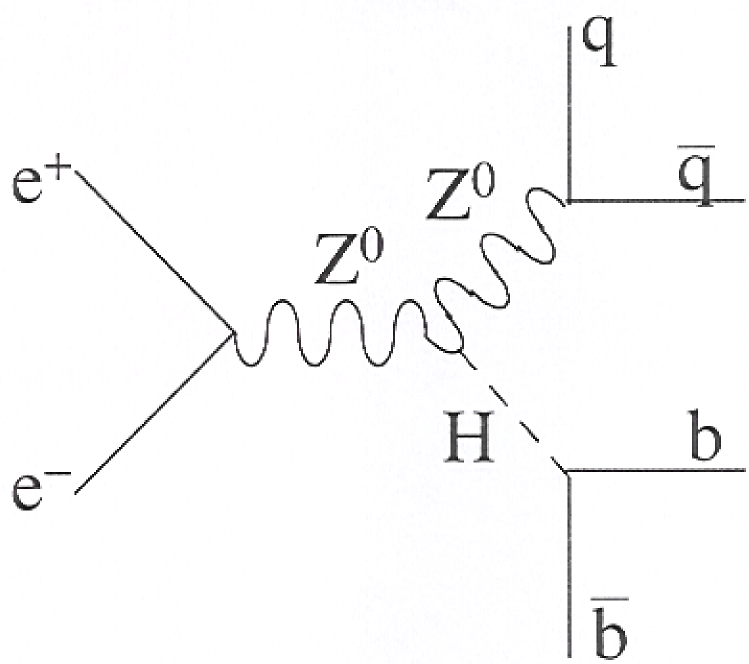
A TESLA compatible vertex detector design

- Introduction
- Detector design
- Progress with realization
- Performance
- Problems at TESLA...
- ...and their solution
- Summary



Introduction

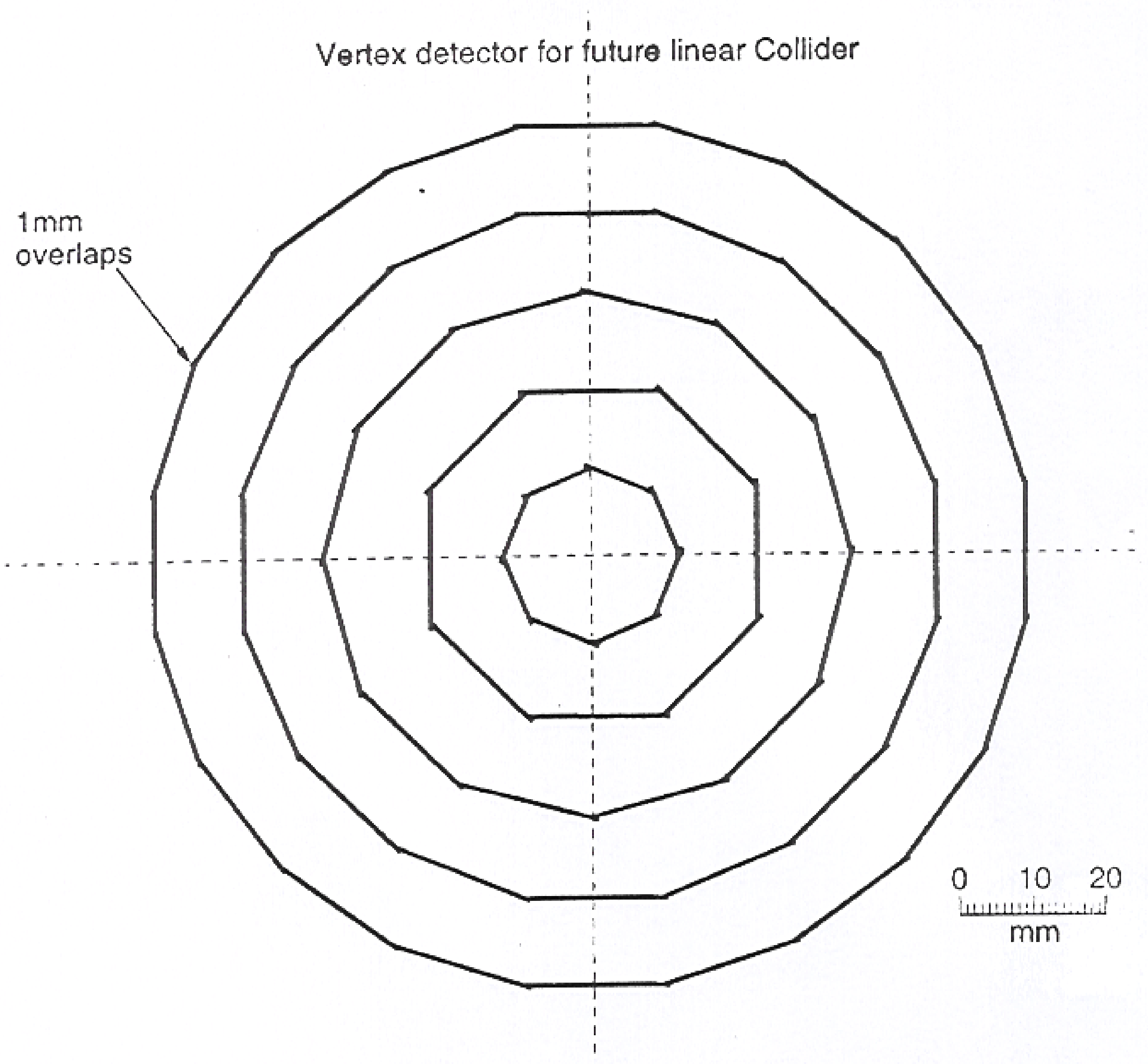
- Develop vertex detector and associated analysis techniques which allow high purity and efficiency beauty and <u>charm</u> identification.
- Physics motivation:
  –


  – $$\frac{BR(H^0 \to c\bar{c})}{BR(H^0 \to b\bar{b})}.$$

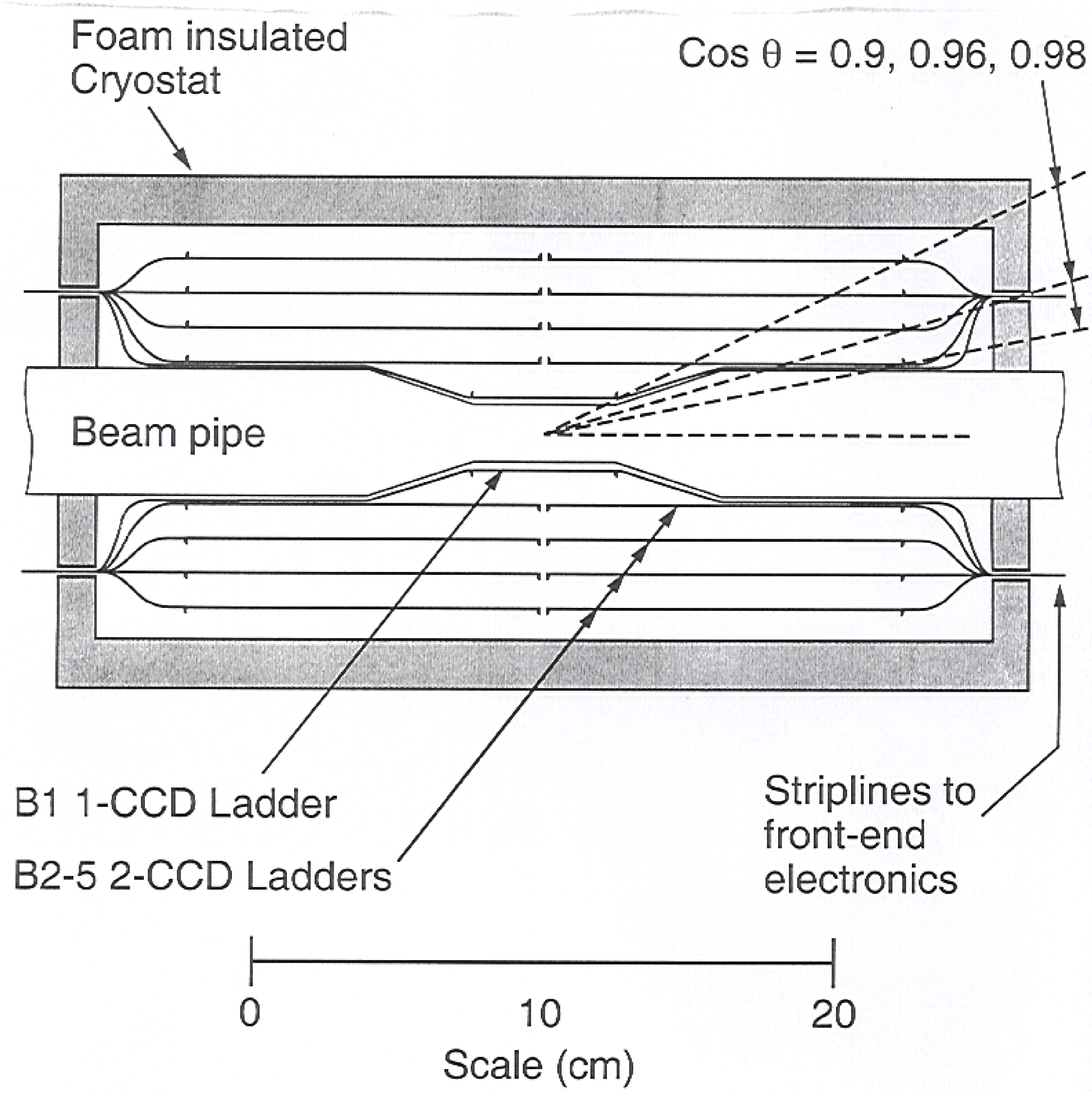
Flavour tagging, goals for detector

- Layer 1 thickness ~ $0.12\% X_0$.
- Layer 1 radius ~ 12 mm.
- σ_{pnt} ~ 3.5 μm.
- These all appear feasible with a CCD based vertex detector.
- Proposed design...

CCD based vertex detector end view

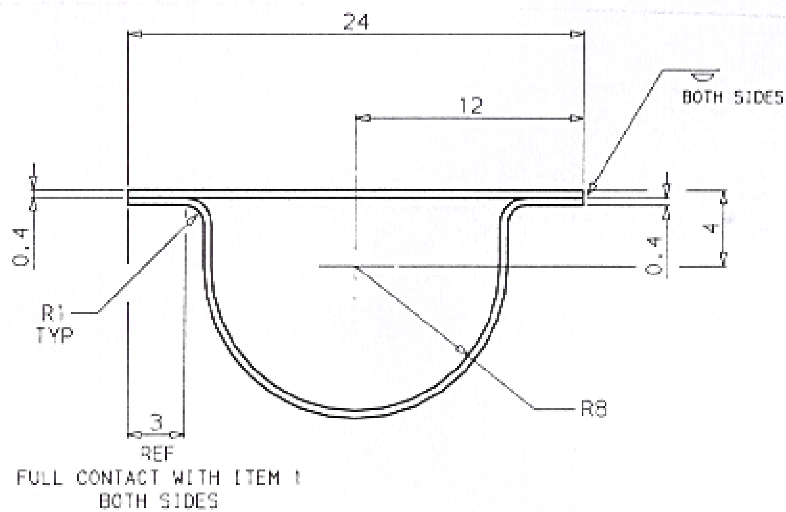


CCD based vertex detector side view

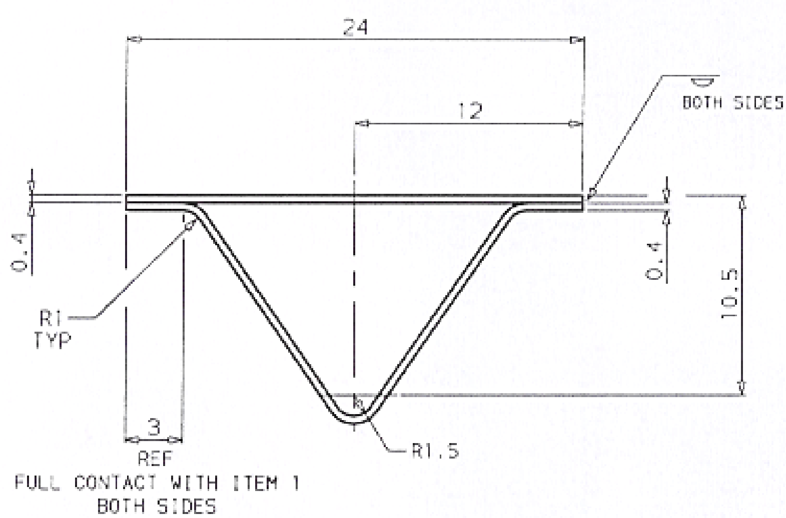


Material budget and mechanical support

- Beryllium Ω beam...

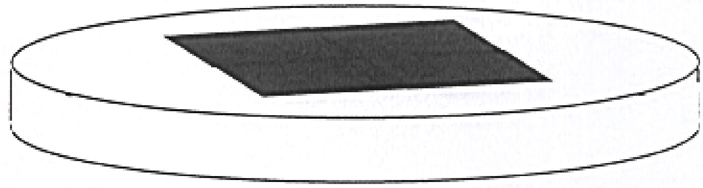


- ...or V beam.

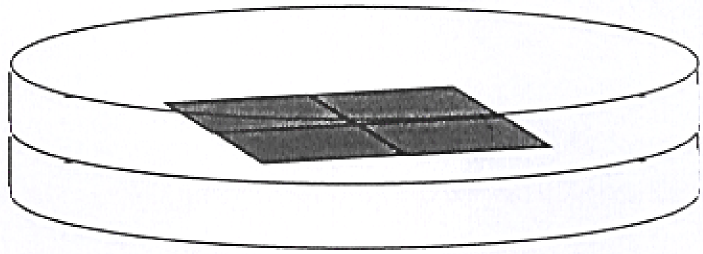


Thin CCDs

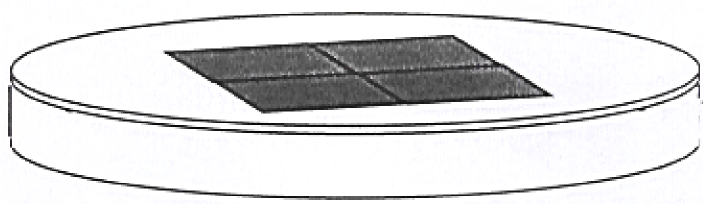
- Processed wafer.



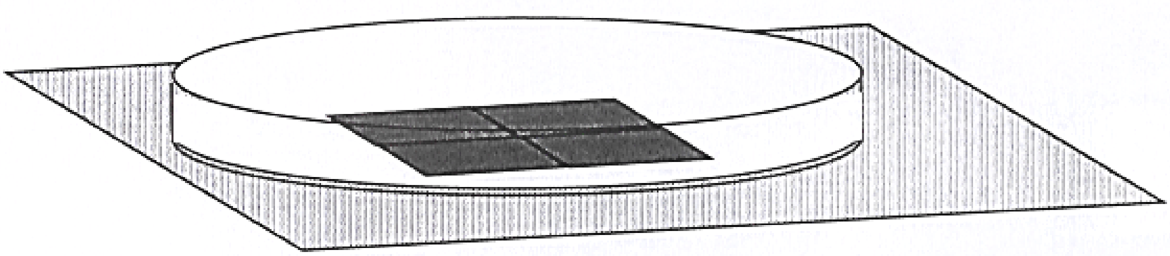
- Face to face with dummy wafer.



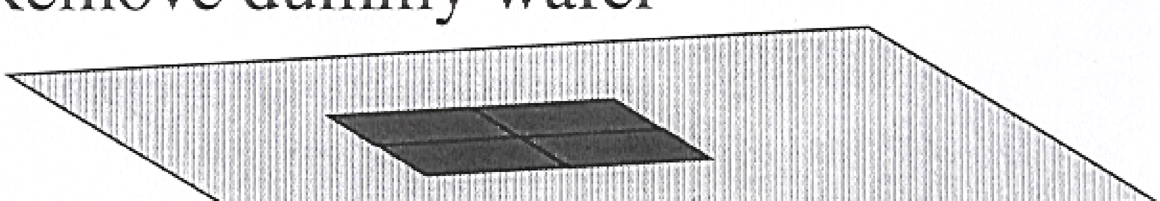
- Lap and etch sandwich.

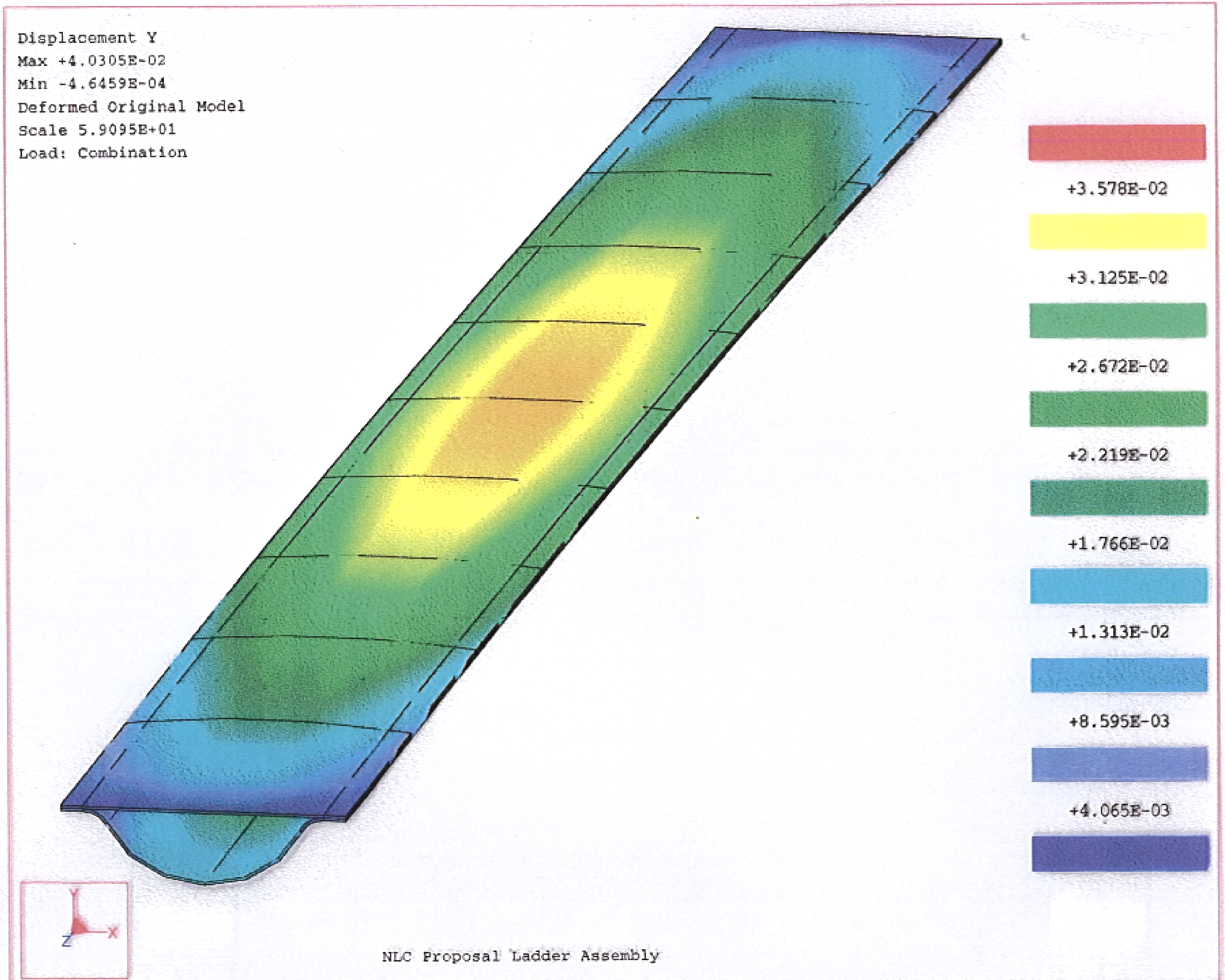


- Attach to ladder.



- Remove dummy wafer




Displacement Y
Max +4.0305E-02
Min -4.6459E-04
Deformed Original Model
Scale 5.9095E+01
Load: Combination
+3.578E-02
+3.125E-02
+2.672E-02
+2.219E-02
+1.766E-02
+1.313E-02
+8.595E-03
+4.065E-03
Y
Z
X
NLC Proposal Ladder Assembly

Material budget

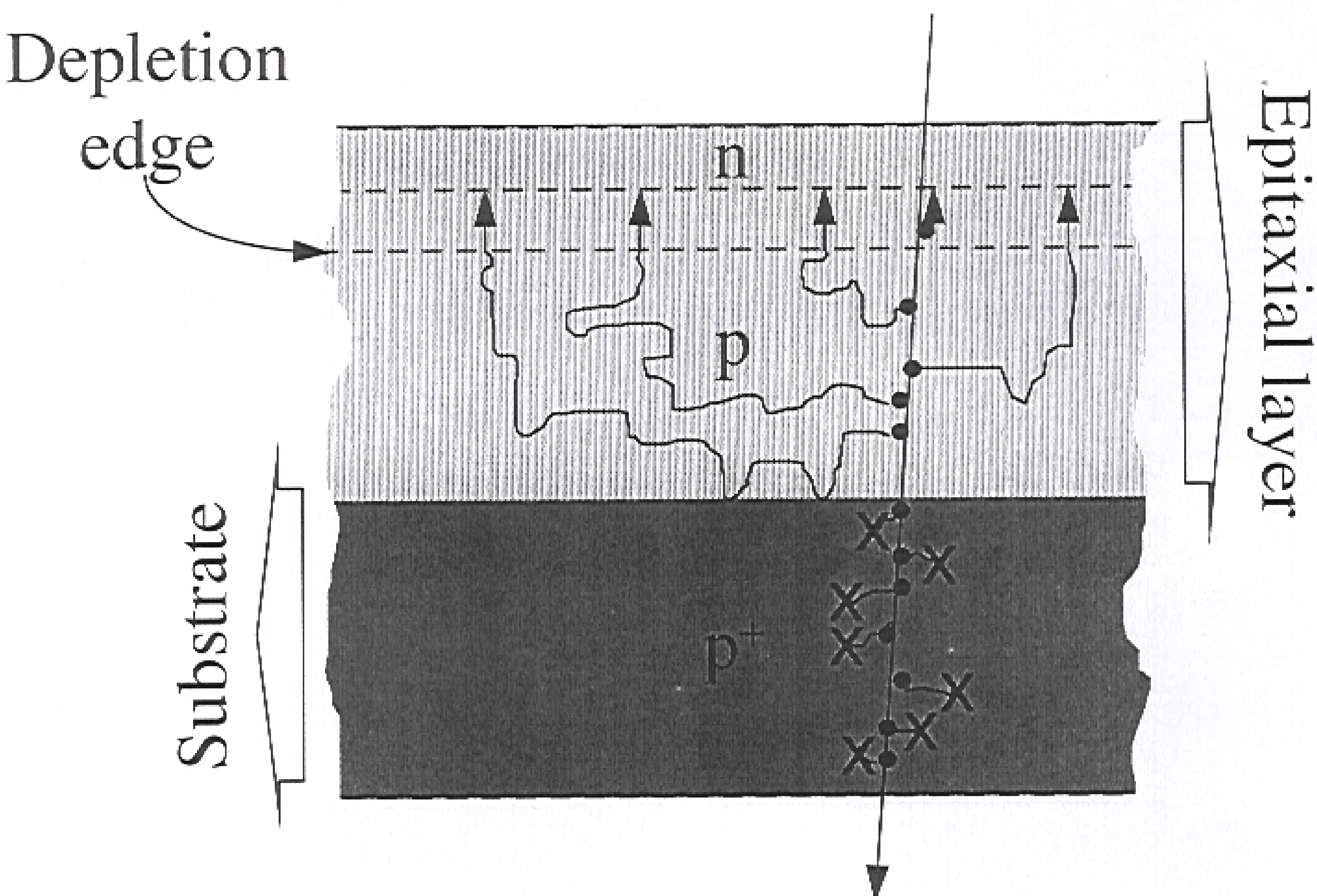
- Currently foreseen:

Item	Thickness ($\%X_0$)
250 µm Be beampipe	0.07
Adhesive	0.02
20 µm silicon	0.02
Total layer 1	0.11

- Reduction of beampipe thickness possible?
- Consider putting first layer CCD in vacuum?

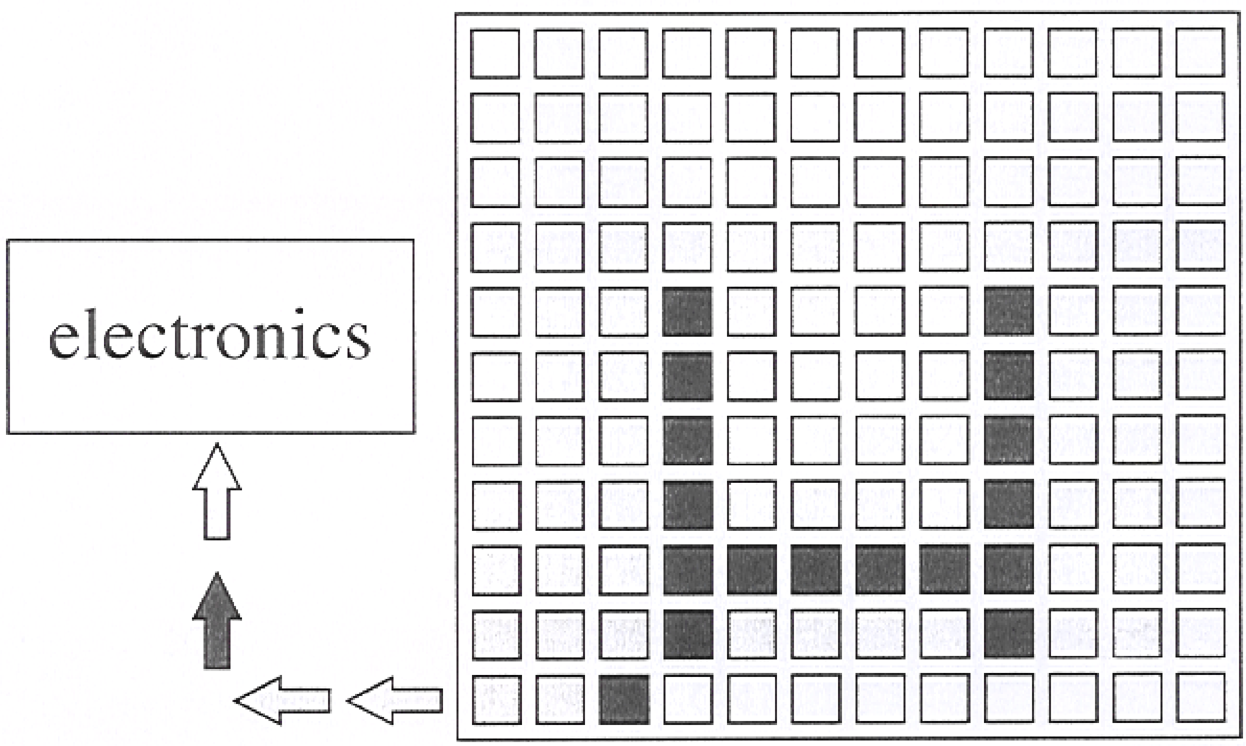
Point resolution

- σ_{pnt} ~ 3.5 μm achievable with 20 x 20 μm^2 pixels with modest improvements to S:N for CCDs.
  - Thicken epitaxial layer.
  - Improve readout circuit.



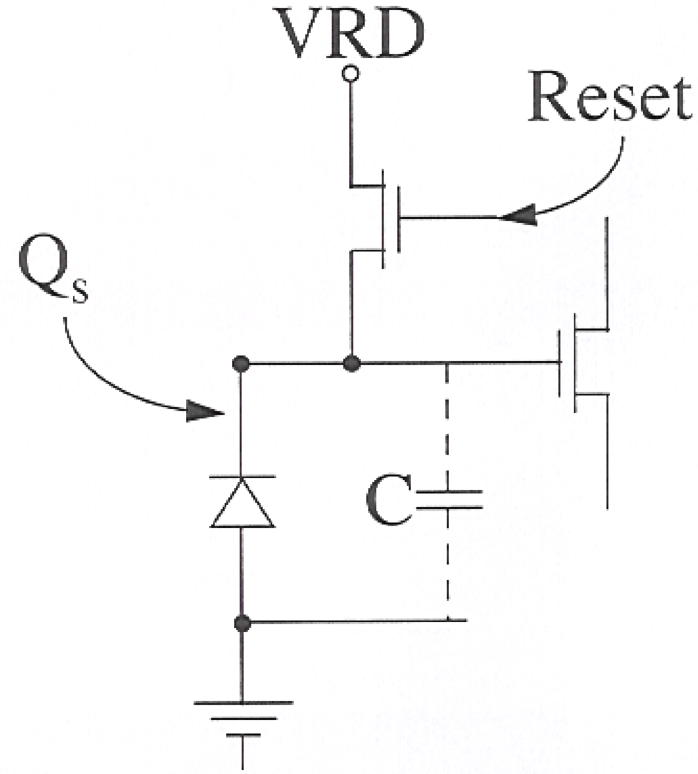
CCD readout

- Schematic diagram of CCD readout scheme:

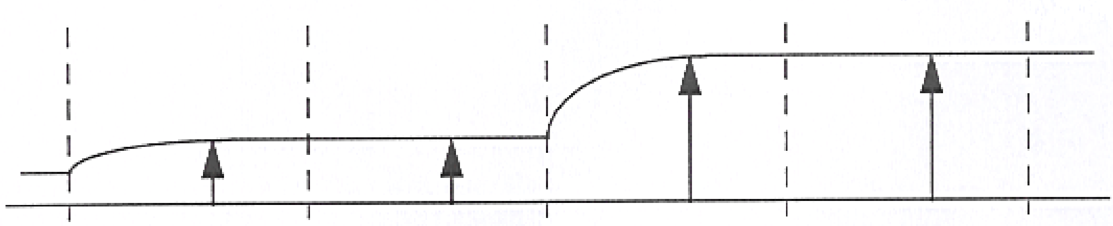


Improving S:N

- Current readout circuit:

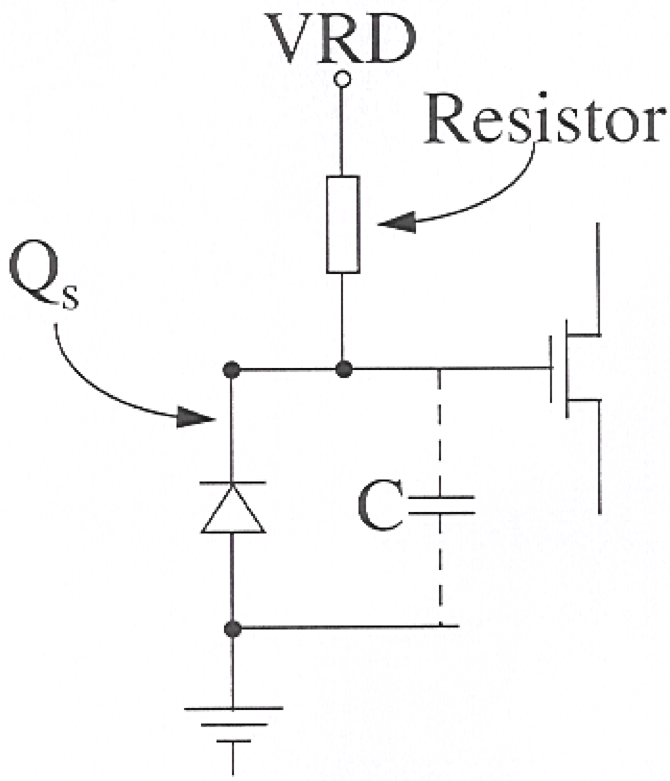


- Reset once per row, so readout of row looks like:

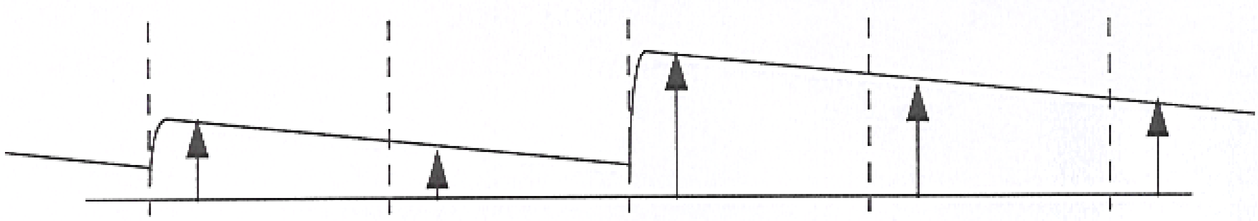


Improving S:N

- Replace reset transistor with resistor

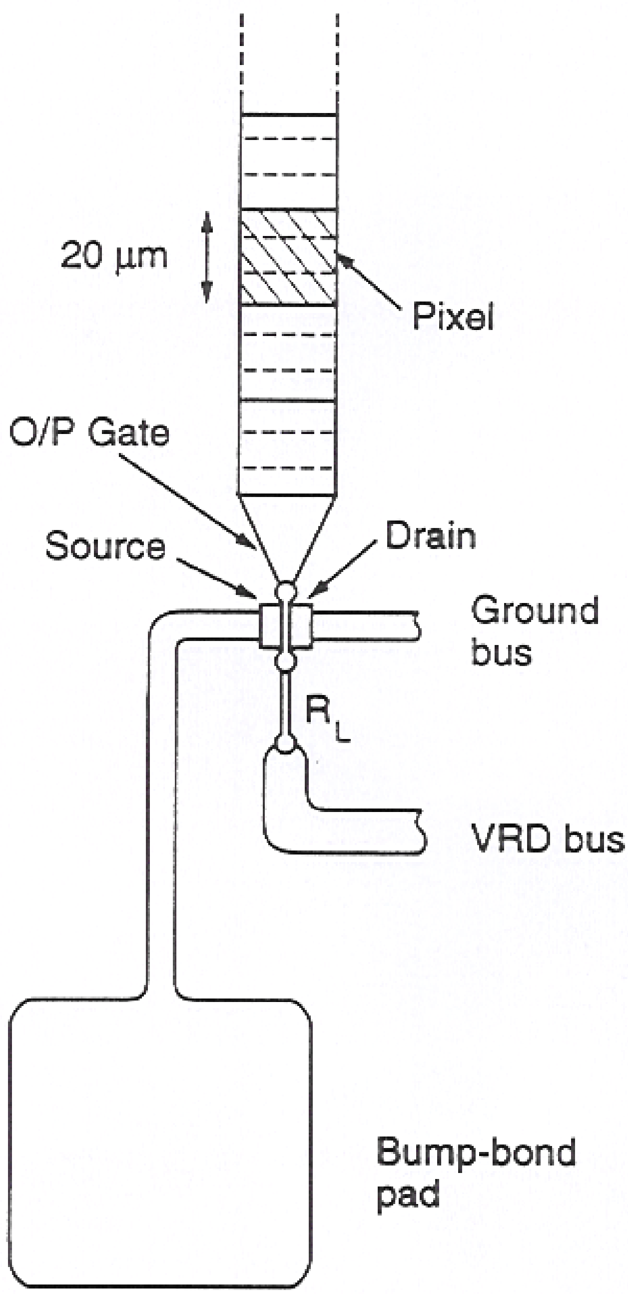


- Readout then looks like:



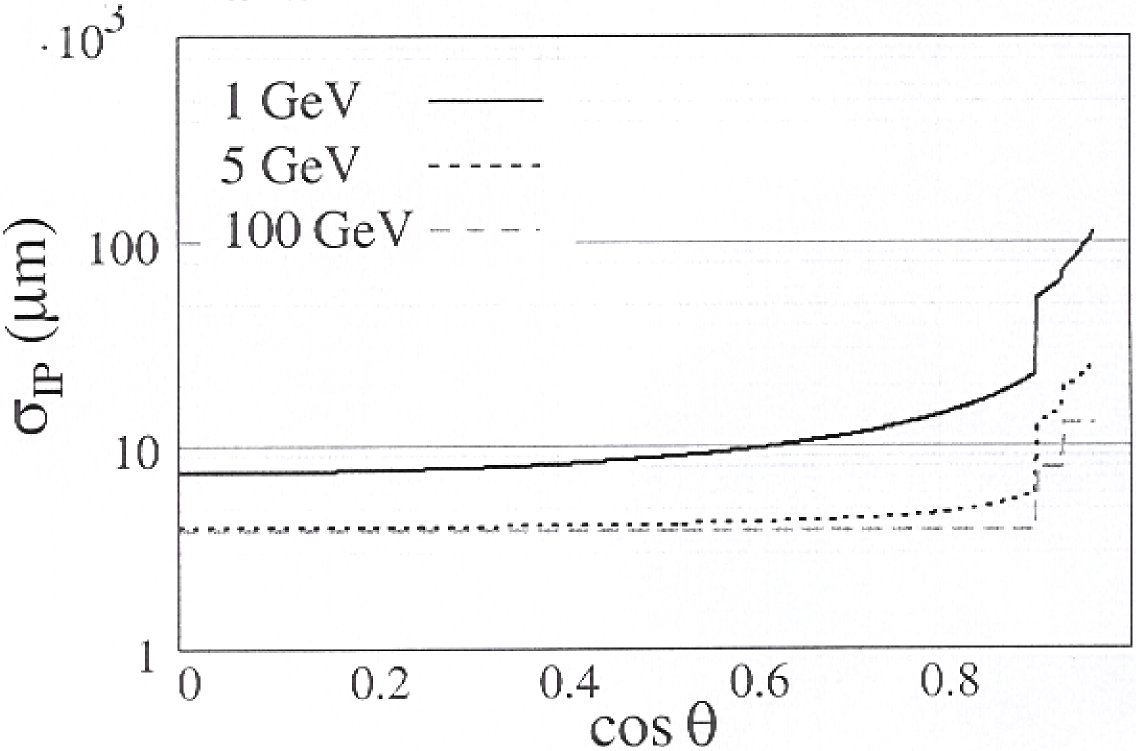
- Issues:
  - How to construct resistor?
  - Achievable noise?

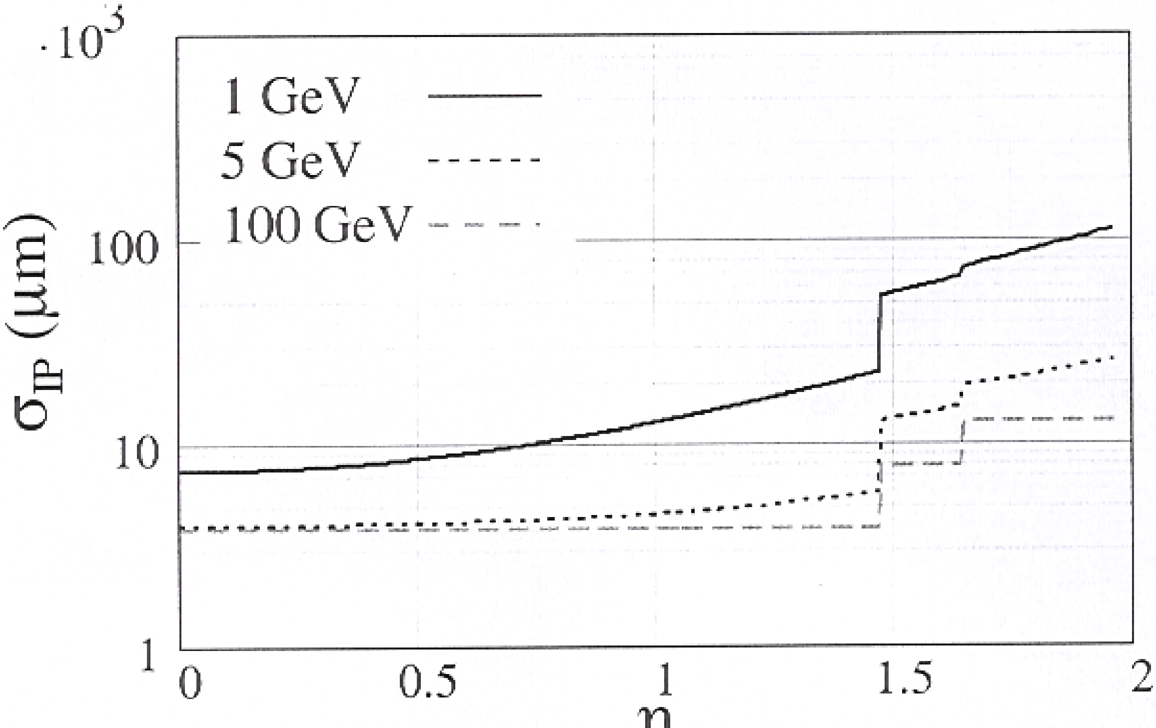
Possible output circuit design



Impact parameter resolution

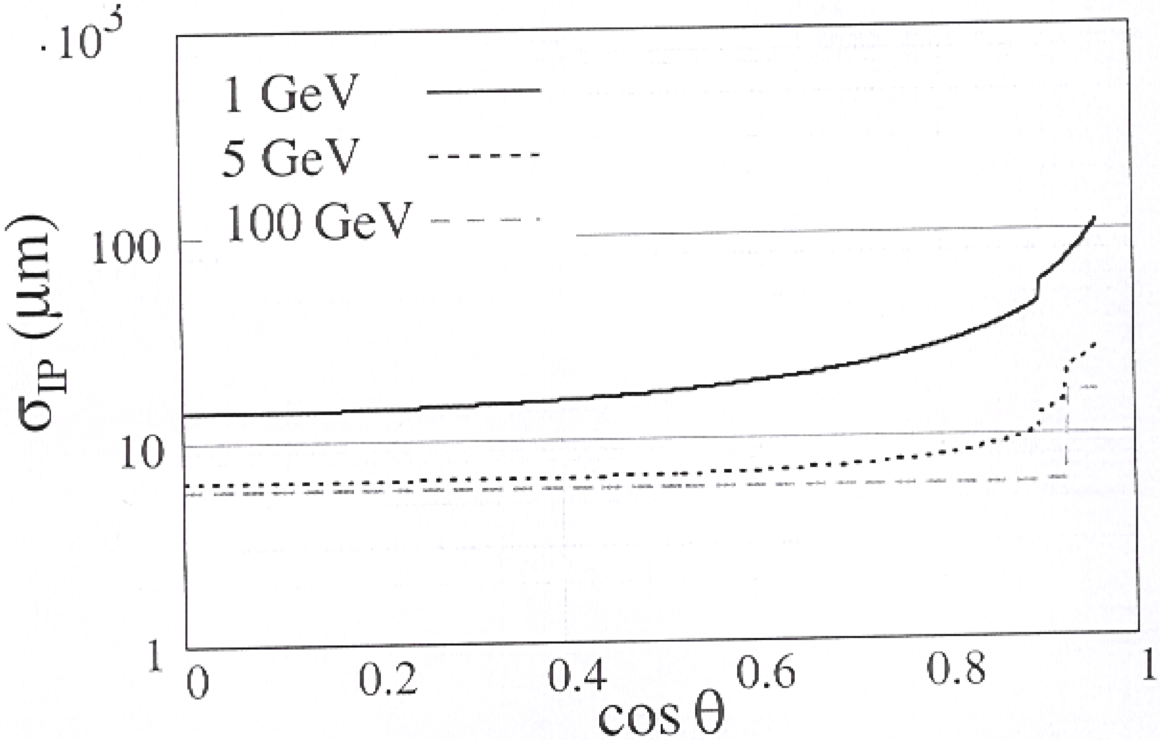
- Beam pipe radius 10 mm

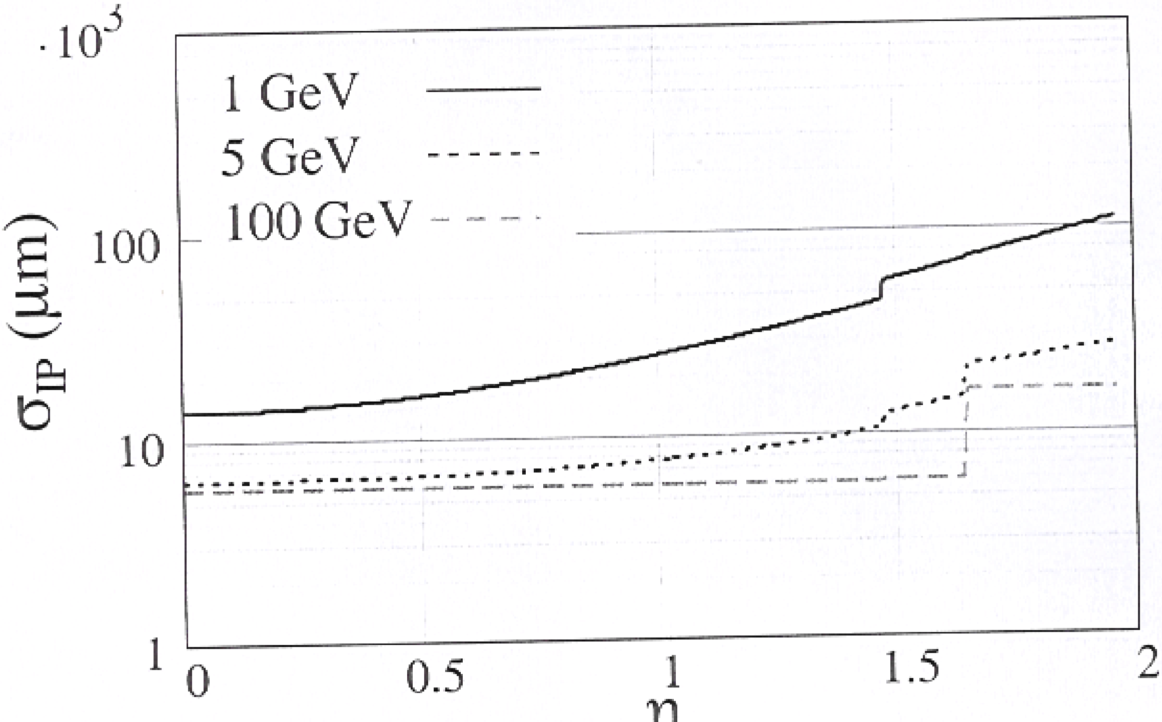




Impact parameter resolution

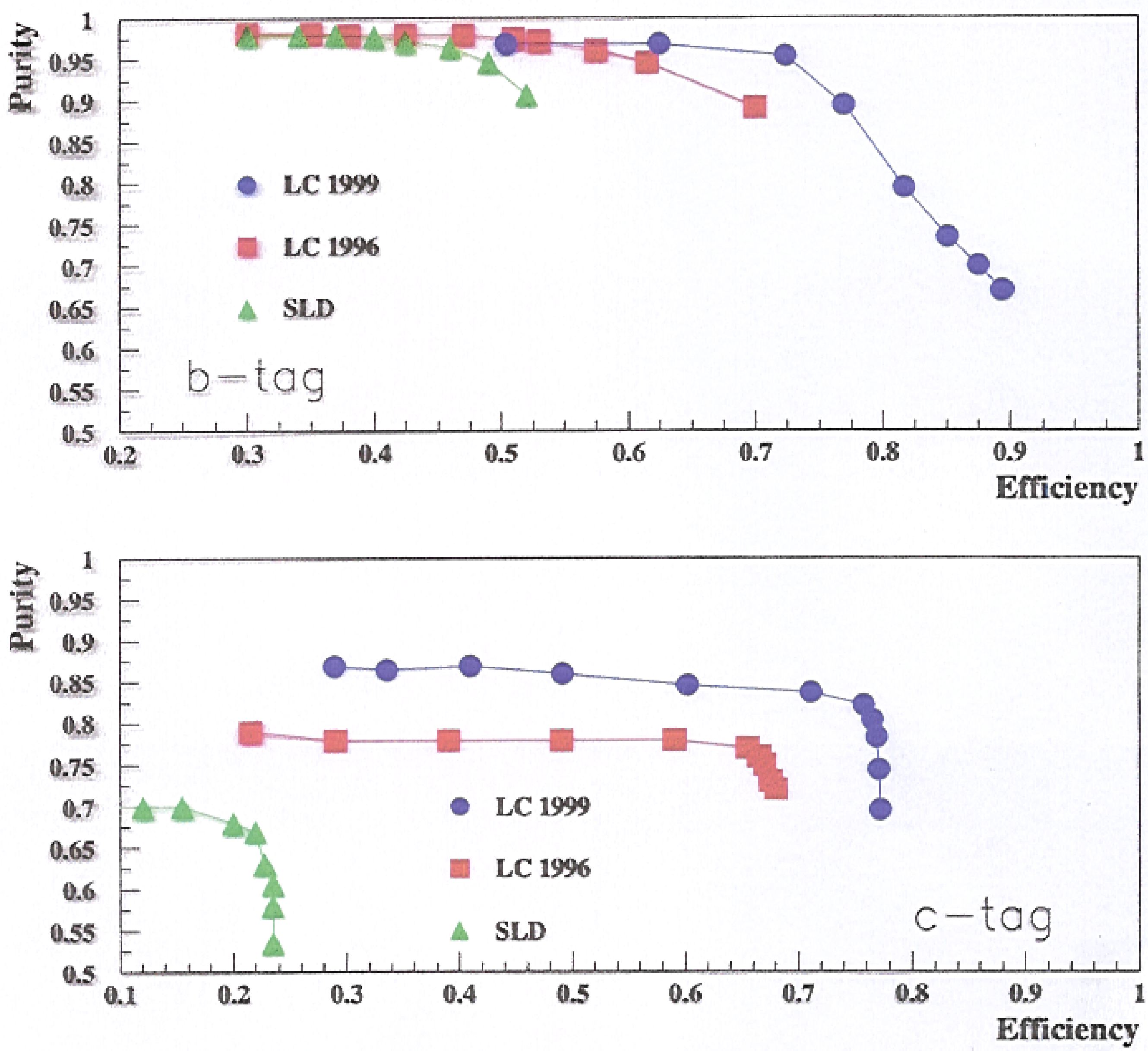
- Beam pipe radius 20 mm



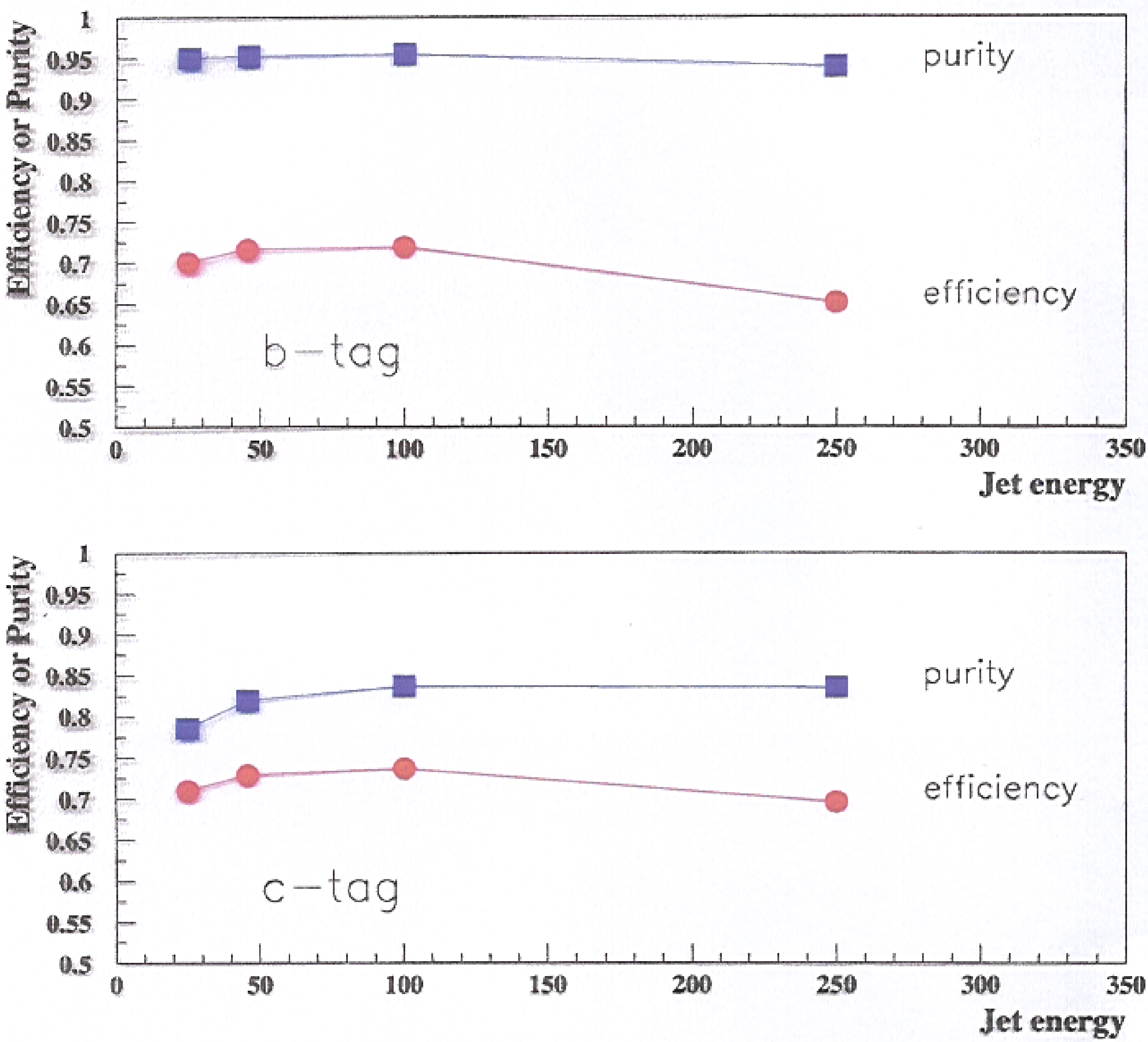


Using ZVTOP, $\cos\theta_{jet} < 0.71$:

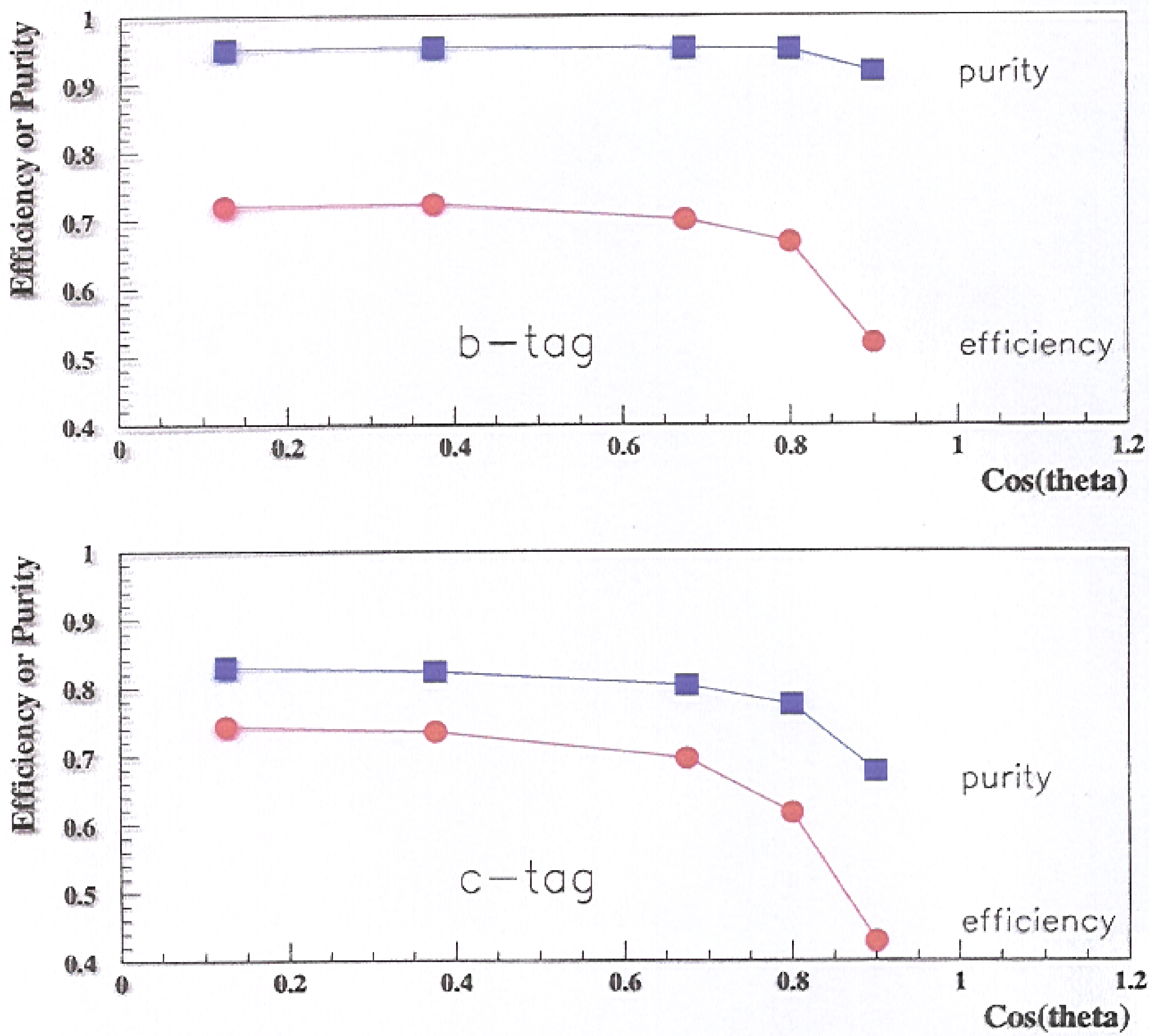
CCD VXD flavour tagging results: Ejet = 46 GeV

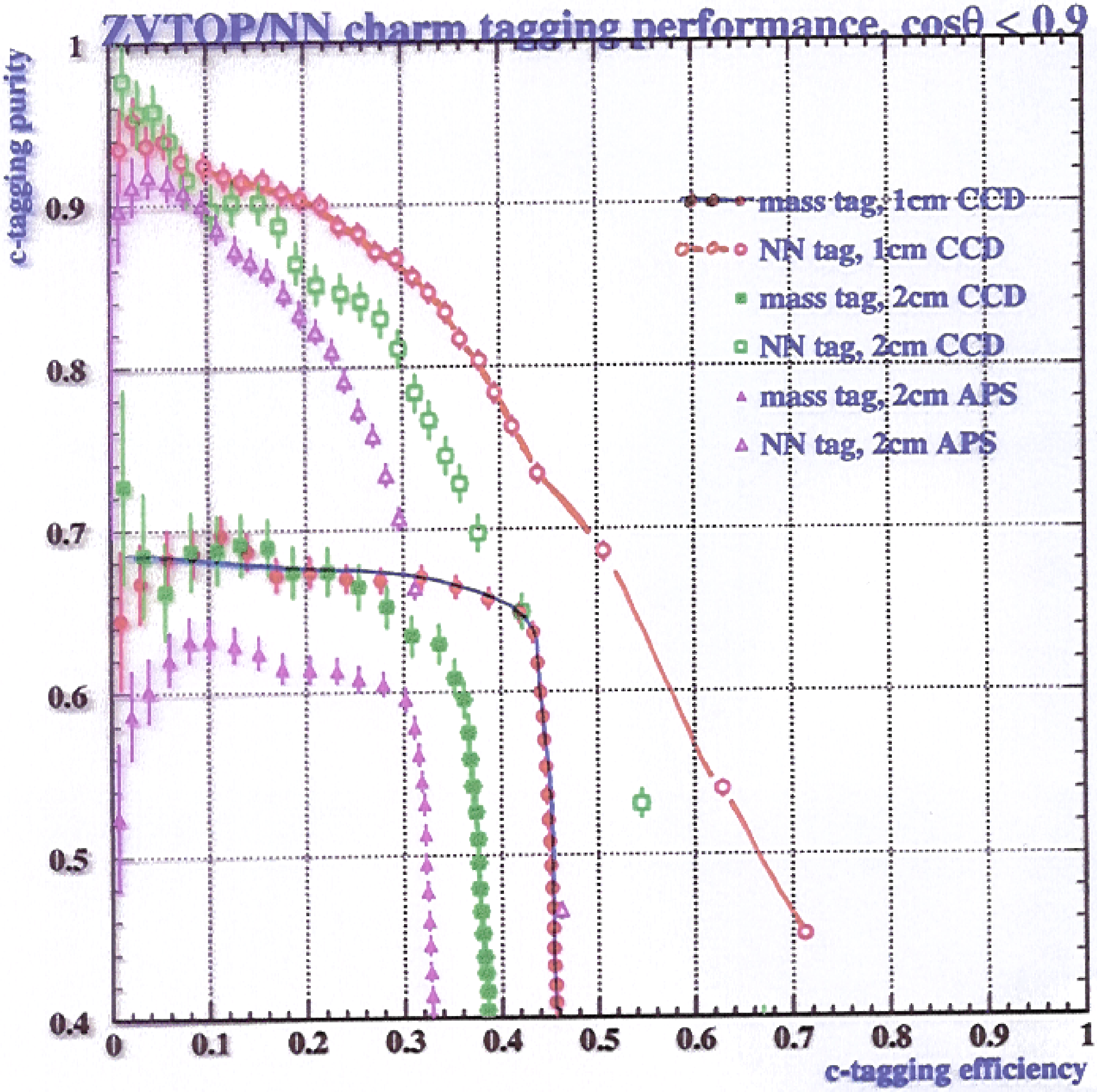


CCD VXD flavour tagging results: jet energy dependence



CCD VXD flavour tagging results: polar-angle dependence

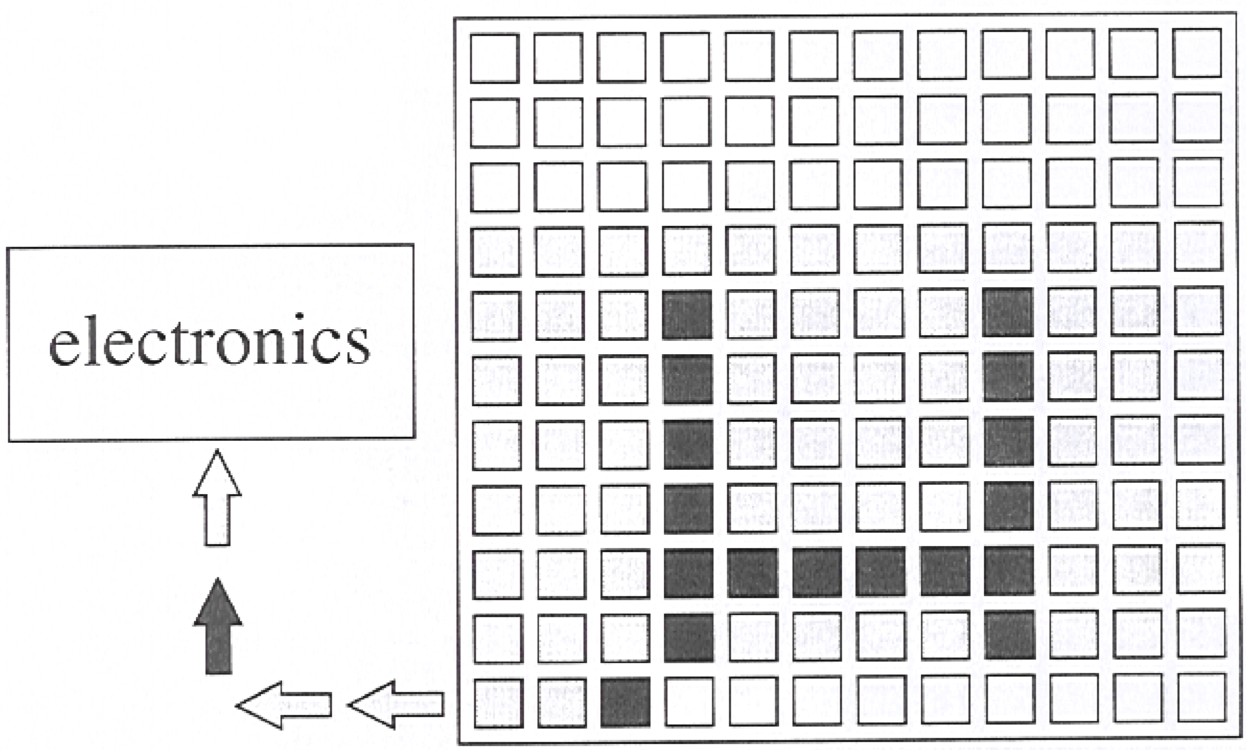




Richard Hawkings

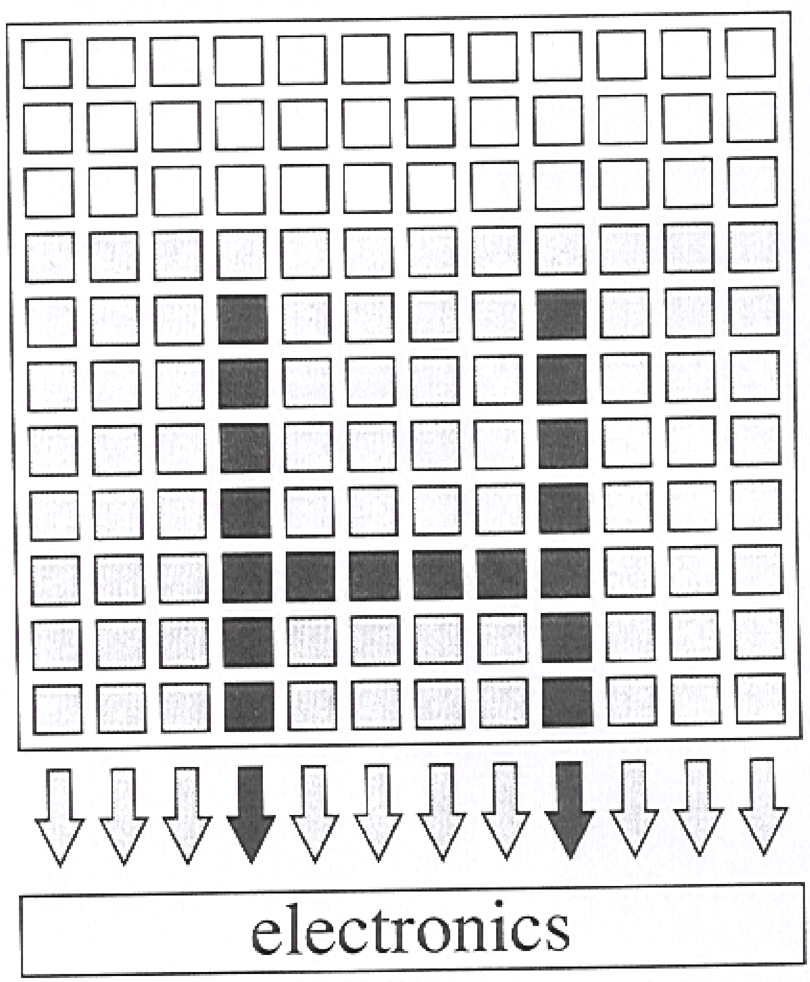
Problems due to TESLA environment

- Electron-positron pair induced hit density:
  - At 1 cm radius ~ 1 hit/mm^2 per B.C.
  - Keep occupancy at ~ few % level.
  - Need readout at ~ 25 GHz if "sequential"!

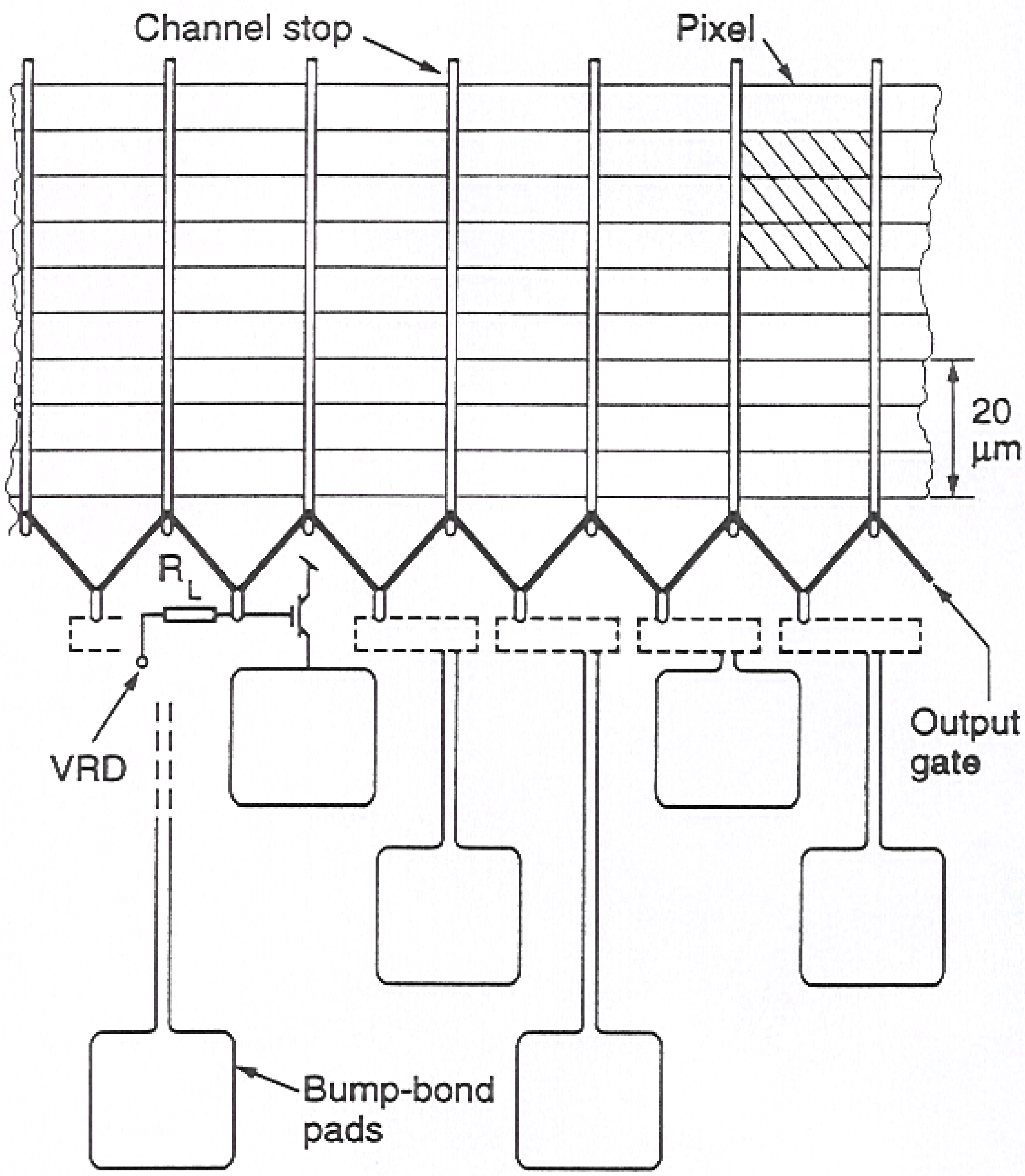


Problems due to TESLA environment cont.

- Solution:
  - Column parallel readout.
  - Necessary I register frequency now 50 MHz.

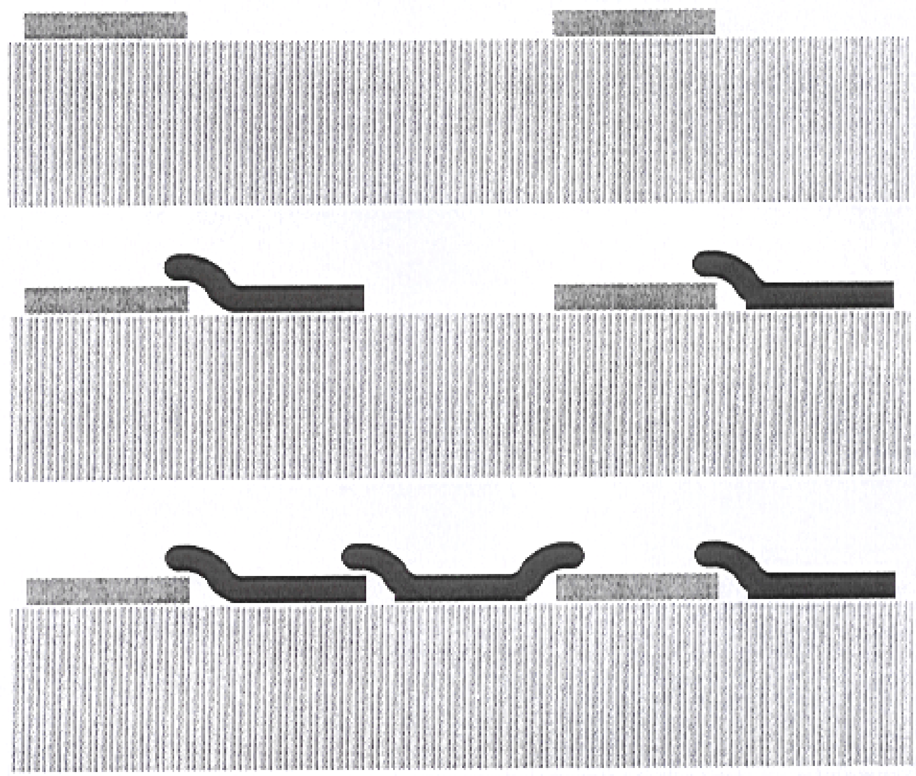


Column parallel readout

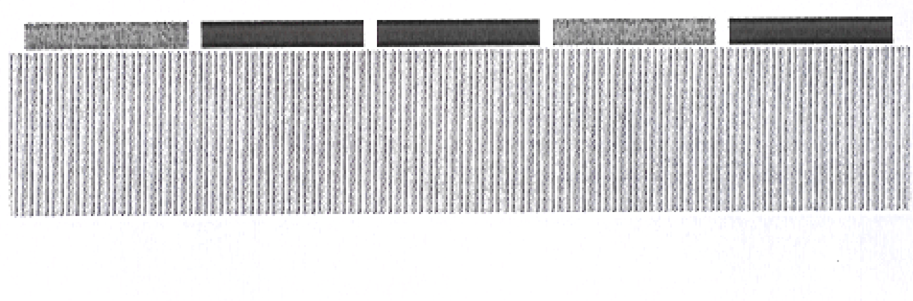


Increased readout frequency

- Work initiated on modifications to I gates. Now have:



- Aim for:



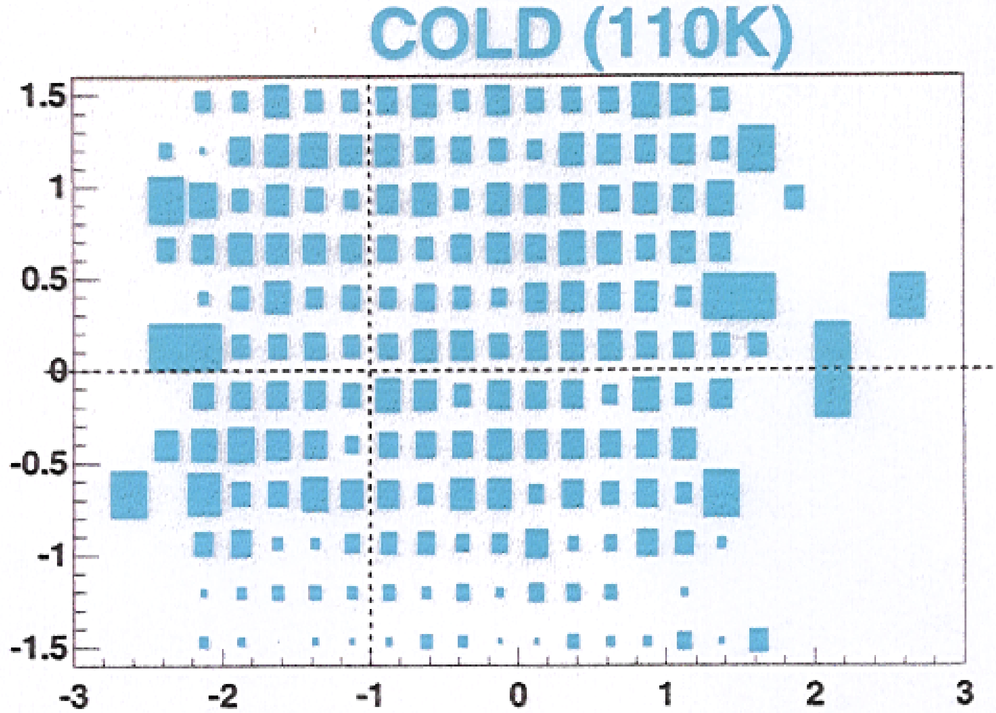
Readout frequency cont.

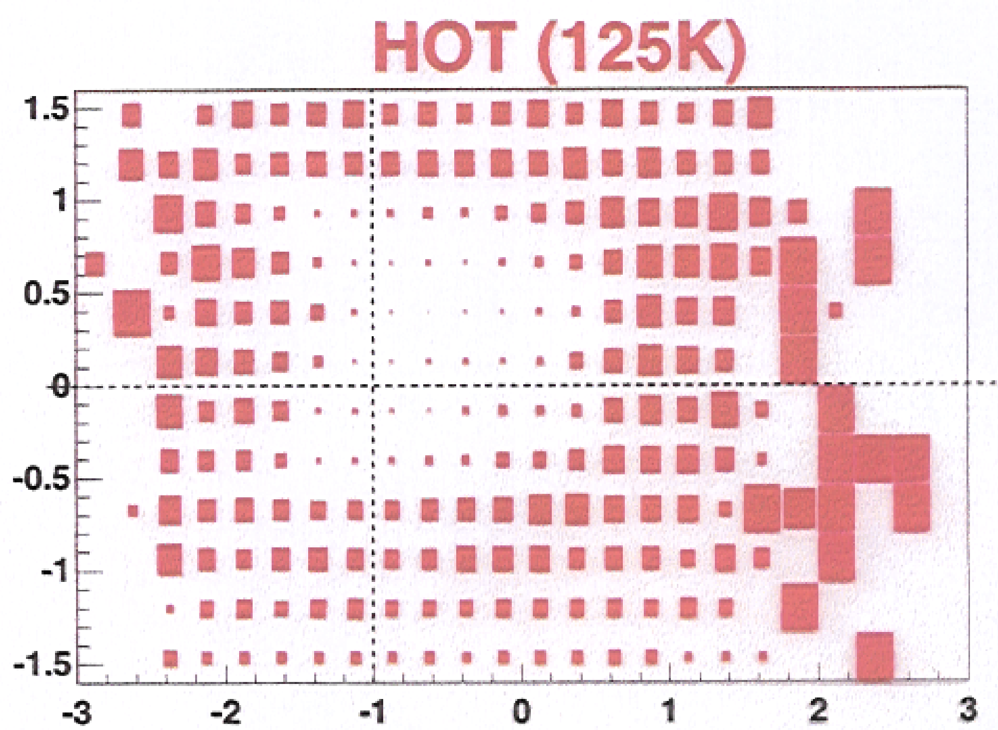
- Programme of simulations initiated.
- Cryostat and readout system under construction at RAL that will allow CCDs to be driven at these frequencies.
- Problems anticipated include additional power dissipation.
- Perhaps solve by combination of:
  - Liquid cooling of local electronics.
  - Reducing drive pulse voltages.
  - Exploiting TESLA duty cycle.

Radiation dose

- Severe radiation damage due to dose of ~ few x 10^9 (?) neutrons per cm^2 per year expected at TESLA?
- From recent proton studies, assuming NIEL conversion applies:
  8×10^9 1 MeV n/cm^2 $\Rightarrow$ CTI = 5×10^{-5}.
- Nick Sinev: "20×10^9 1 MeV n/cm^2 to produce CTI of 5×10^{-5} with no background charge".
- Srour: "1500×10^9 1 MeV n/cm^2 to get CTI of 5×10^{-5} with background charge and at T = 140 K".
- Many ideas to increase radiation hardness:
  - Reduced charge storage volume.
  - Low T operation.

Efficiency for runs at at 90V





Paula Collins. RD39/DELPHI/LHCb/COMPASS.

Radiation dose cont.

- Test system for systematic study of radiation damage in CCDs under construction at Liverpool.
- CCD operation at temperatures down to 40 K to be examined.
- Optical (laser plus optical fibre) charge injection.
- Simultaneous “background” charge injection using radioactive source.

Summary

- Major problems that must be tackled in design and construction of CCD based vertex detector for TESLA:
- Readout speed:
  - Increase by factor 1000 using column parallel readout at 50 MHz.
  - Simulations starting.
  - Test rig under construction.
- Understand and reduce effects of radiation:
  - Study of effects of radiation on CCDs initiated.
  - Many ideas as to how radiation hardness can be improved.

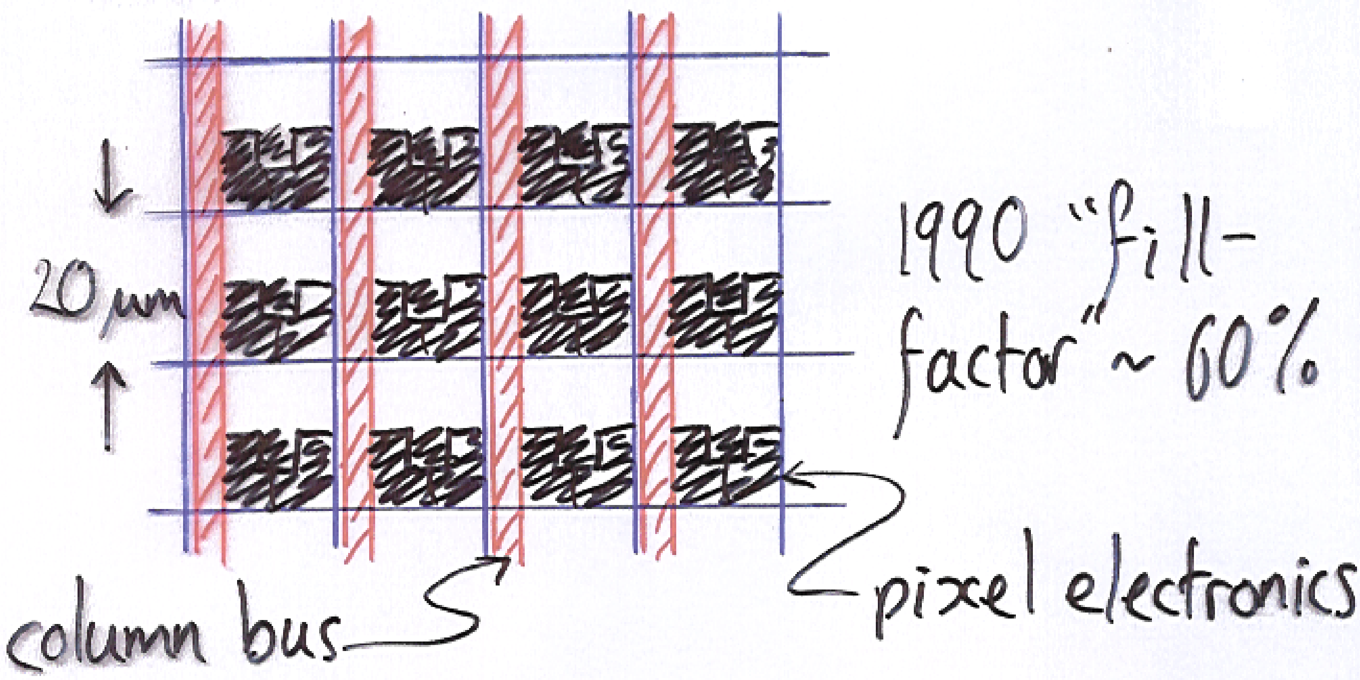
Summary cont.

- Mechanical stability:
  - Beryllium Ω and V beam structures plus gluing procedure being studied.
- Improve signal to noise ratio:
  - New readout circuit to be studied.
- If above can be solved, CCD based vertex detector powerful physics tool at TESLA.
- New directions:
  - Quark charge determination?
  - Vertex trigger?

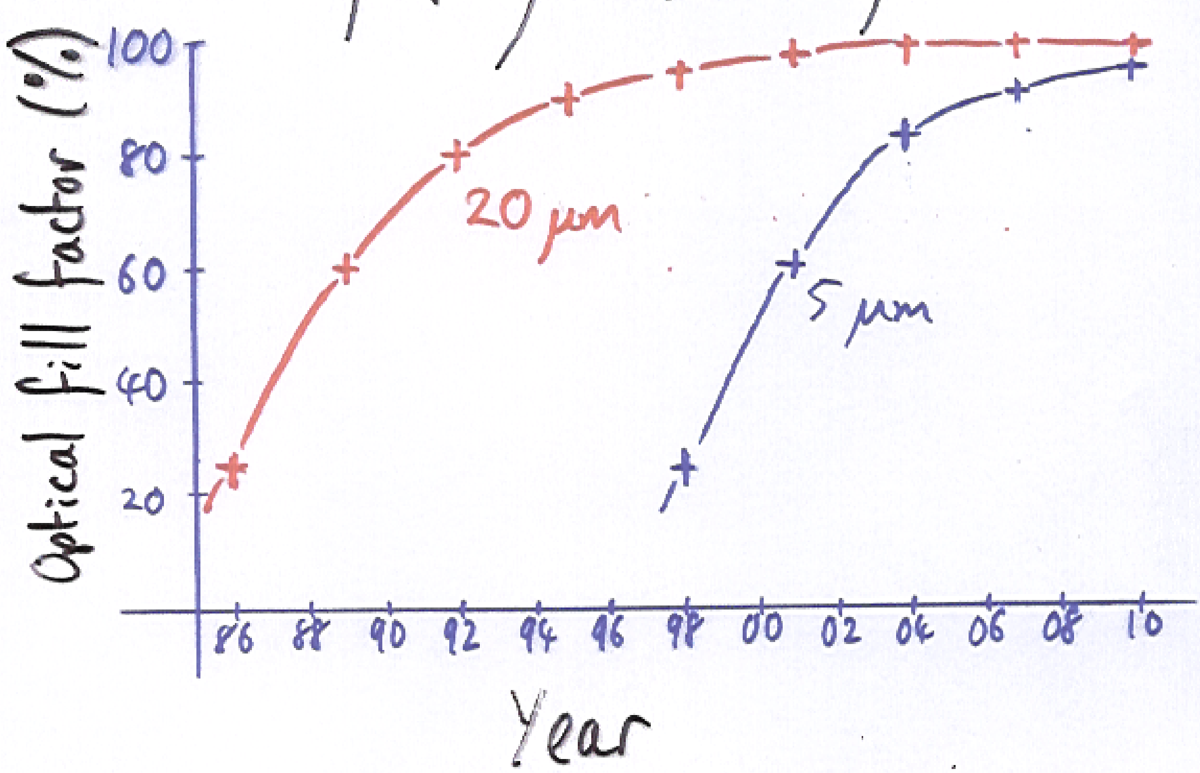
CMOS Vertex Detector

(Marc Winter, Renato Turchetta)

- Problem:



- But lithography improving!



CMOS Vertex Detector cont.

- Satisfactory fill factor for 20×20 μm^2 pixels by ~2000?
- Need "thicker than standard" epitaxial layer, diffusion, centroid finding for required σ_{pnt}.
- Problems with readout remain to be solved, c.f. CCD column parallel scheme.
- Advantage radiation hardness.
- Worth further study!