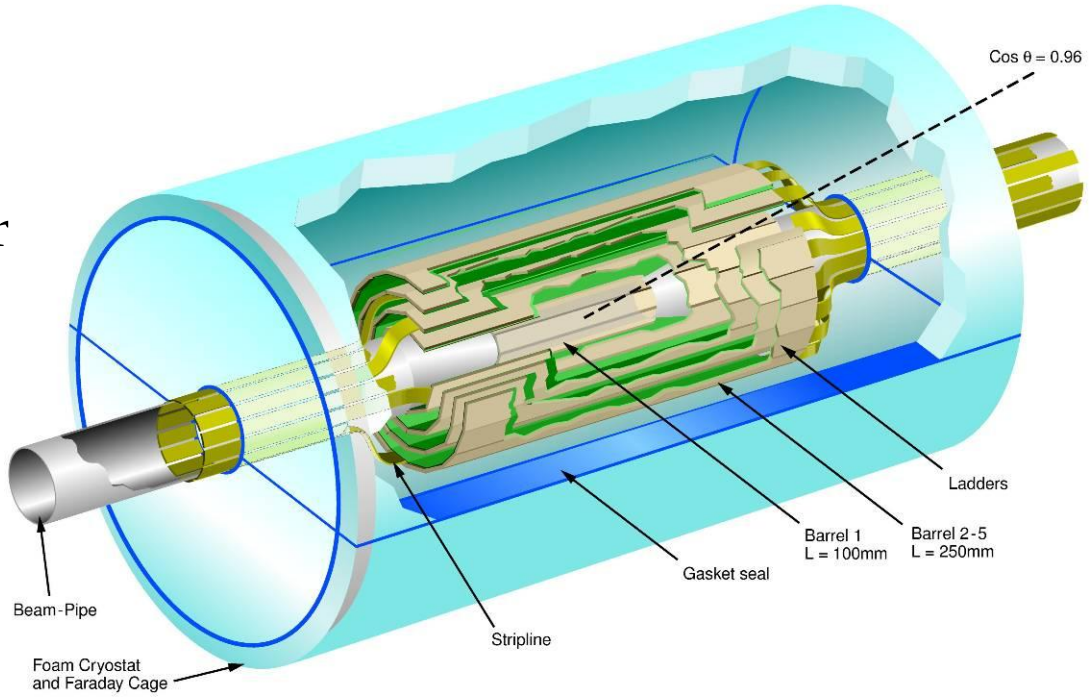
LCFI in April 2008

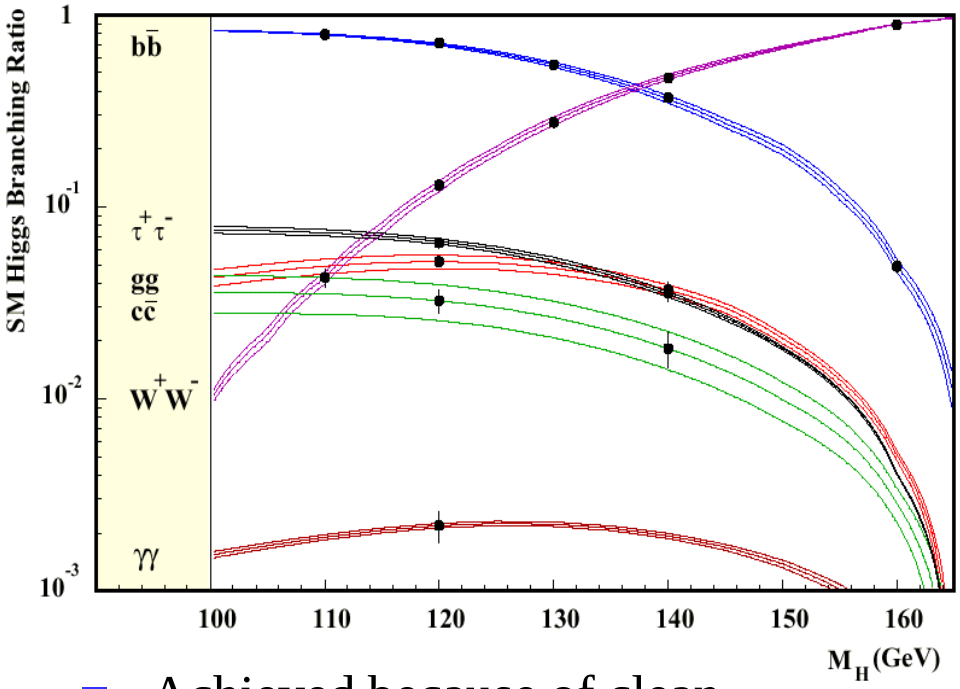
- Introduction
- Physics studies
- Sensor design and testing
- Mechanical design of ladder and vertex detector
- Plans for the future
- Summary



Introduction

- The case for the (I)LC remains as strong as ever.
- Two examples (SLHC kick-off meeting 9th April):
  - The LHC will allow measurement of ratios of many Higgs BRs to about 20%, the SLHC to 10%.
  - The SLHC will allow measurement of the Higgs self-coupling to about 20%.
- Is this enough?
- May well soon become clear that answer is no...and the way forward is a LC/the ILC

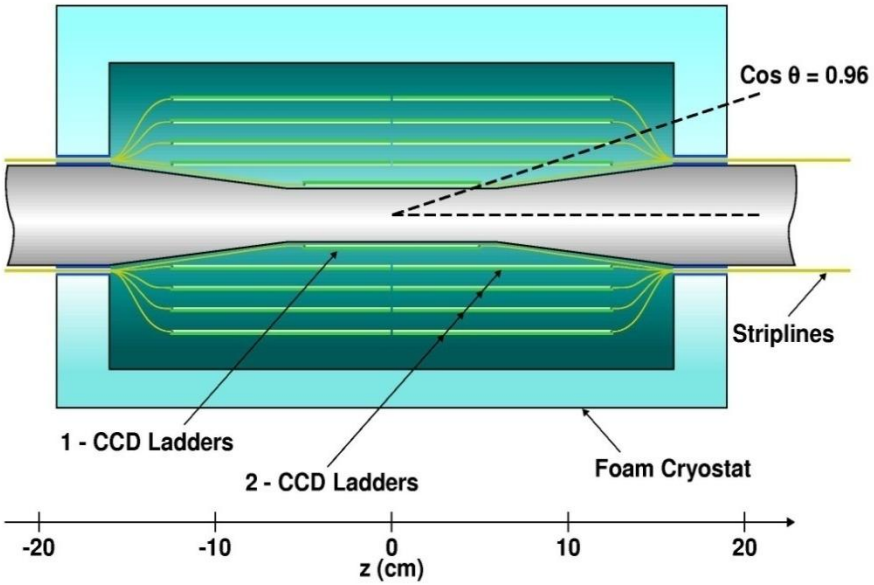
- C.f. Higgs BR measurements at ILC.



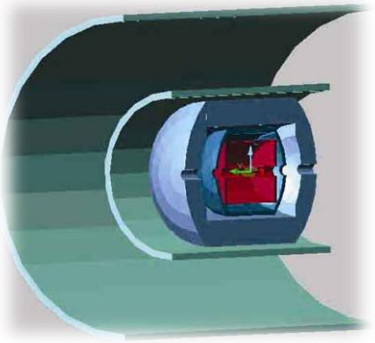
- Achieved because of clean interactions, understood initial state...
- ...and first class flavour ID.

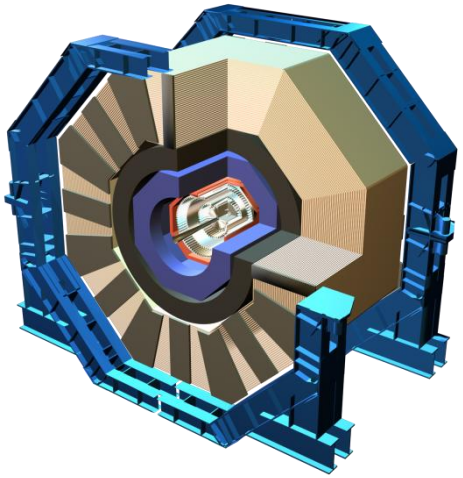
Introduction

- LCFI studying physics and designing sensors (CPCCD and ISIS), support structures, ancillary electronics for the vertex detector....

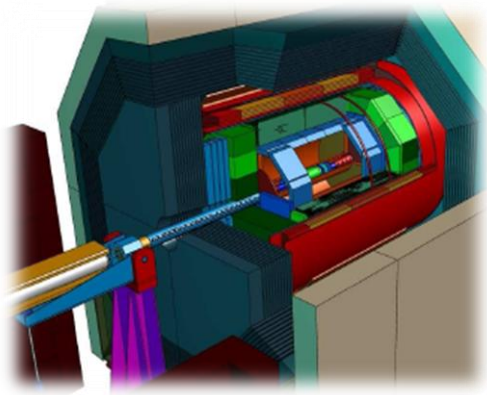


- ...of the fourth, SiD...



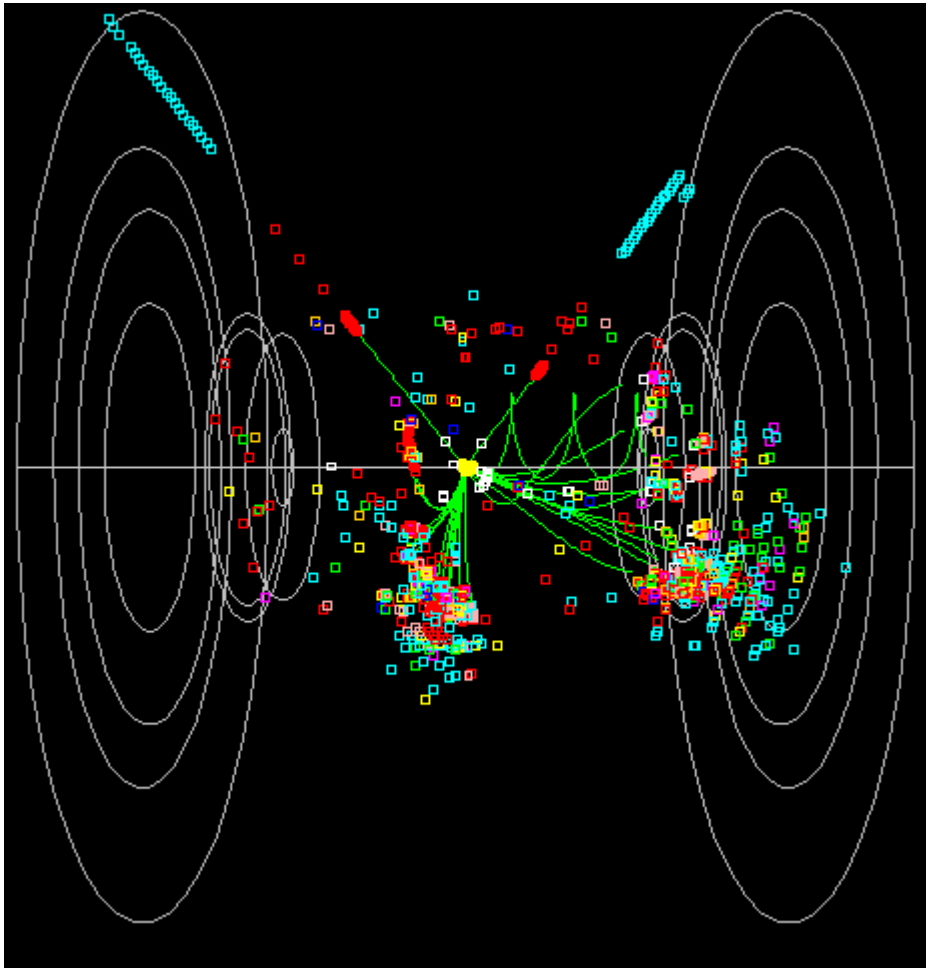


- ...and ILD.

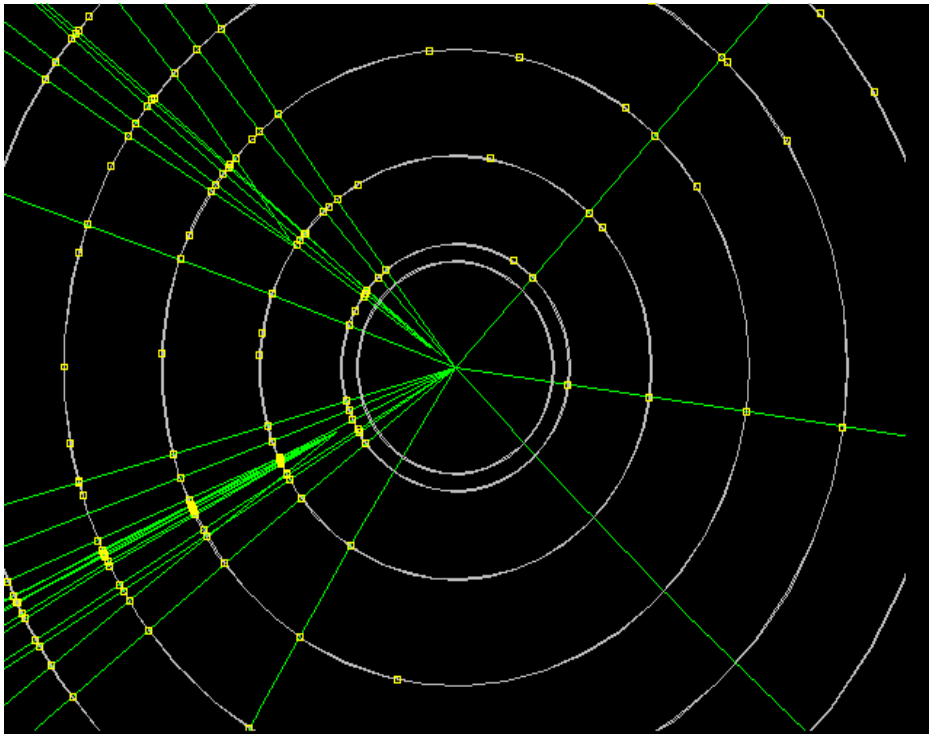


Physics studies – the LCFI Vertex Package

- E.g. $e^+e^- \rightarrow ZH \rightarrow \mu^+\mu^-$ jet jet.



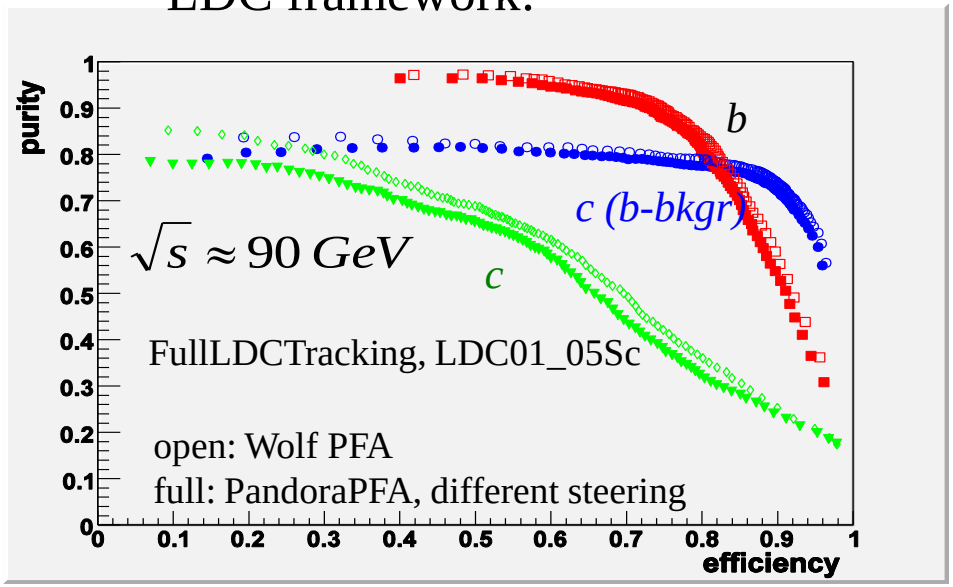
- Vertex region:



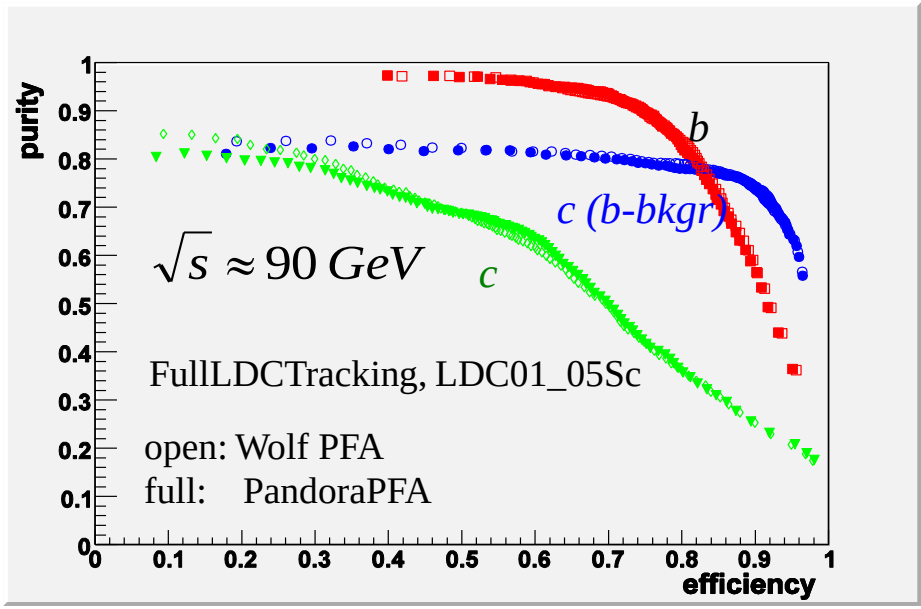
- Challenge is to associate all charged tracks with correct vertex in high track density environment.

LCFI Vertex Package – recent work

- Understand package in context of complete detector software environments.
- E.g. apparent poorer performance with Pandora PFA than Wolf in LDC framework:



- This was traced to differences in the tracking settings used for the PFAs and “fixed”...

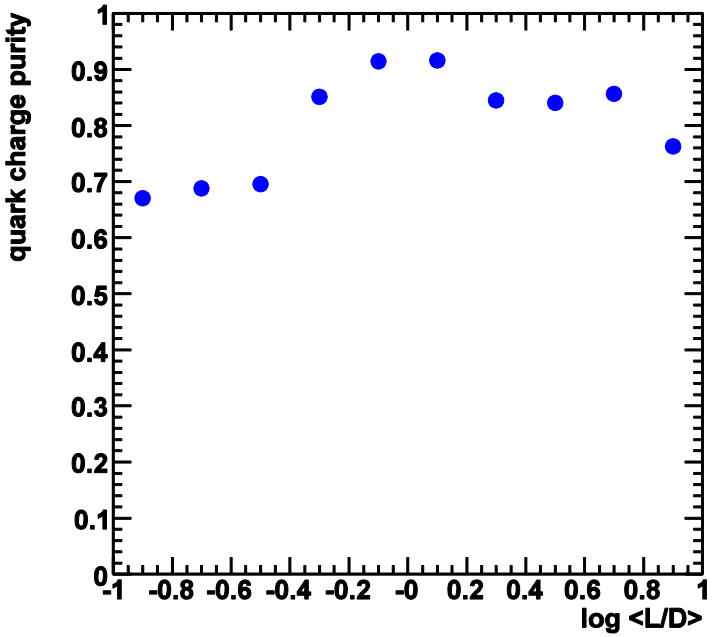


- ...without spoiling the excellent performance of Pandora.

LCFI Vertex Package

- Improvements to and tuning of the package are ongoing.
- Developed (semi)automatic tuning of flavour/charge ID parameters.
- Adding routines to determine quality of charge tag.
- Allows e.g. choice of best charge in $e^+e^- \to b\bar{b}$ events in which both jets have same measured charge.
- Quality estimator based on product of charge purity obtained for variables used in flavour/charge determination.

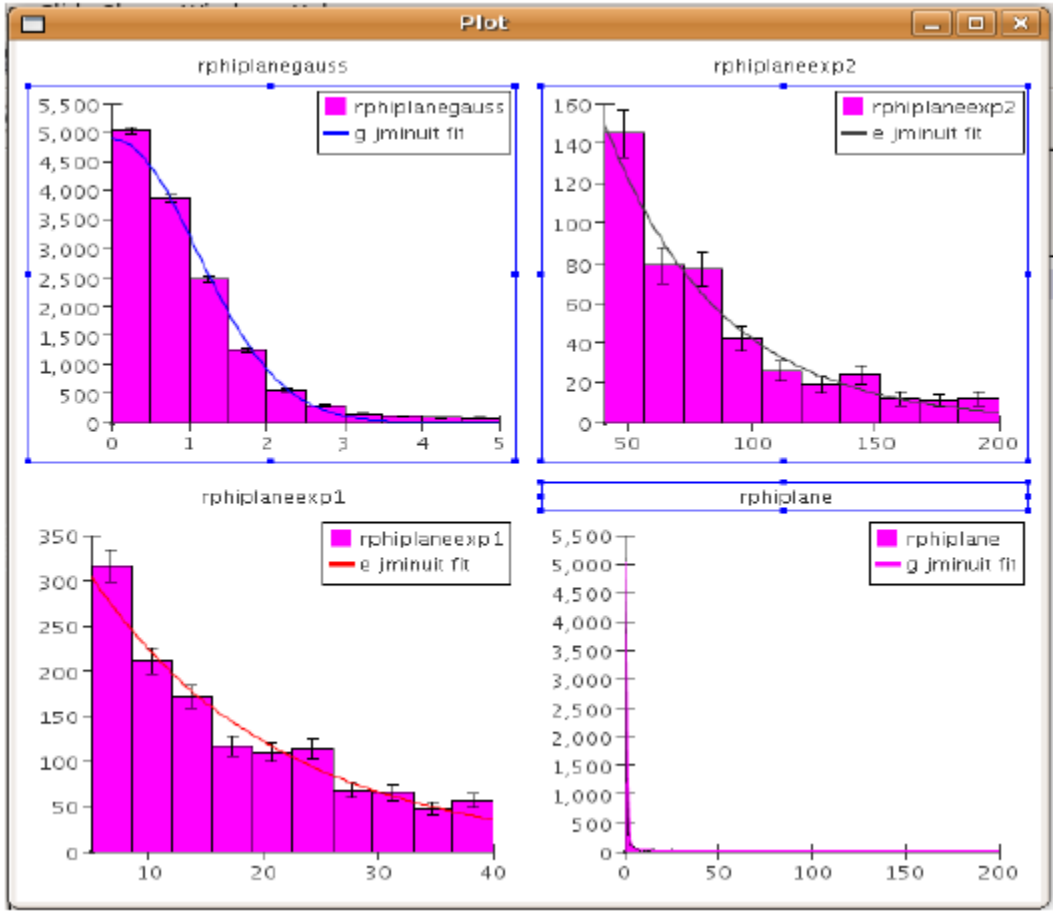
- E.g. dependence of quark charge purity at Z peak on L/D value for jets in which 2 vertices found:



- Can improve measurements of b, c asymmetries...

LCFI Vertex Package

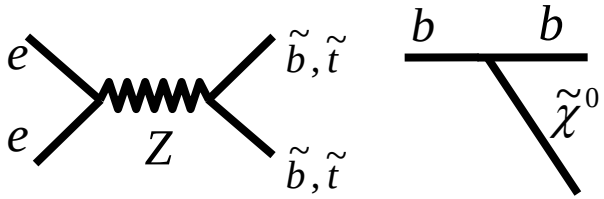
- Important input to flavour tag is “joint probability”, probability that all tracks originate at the IP.
- Need to know impact parameter distribution of tracks truly from the IP.
- Results so far have used distributions from fast MC
- New routines now added to derive parameters from fit.



LCFI Vertex Package

- So far K^0 and L decays have been removed in flavour ID process using MC "truth" information.
- Routines now being developed to identify these using track information.
- Work also ongoing on removing tracks resulting from interactions in the material of the detector.
- First results using Marlin with input from Jupiter and org.lcsim obtained.

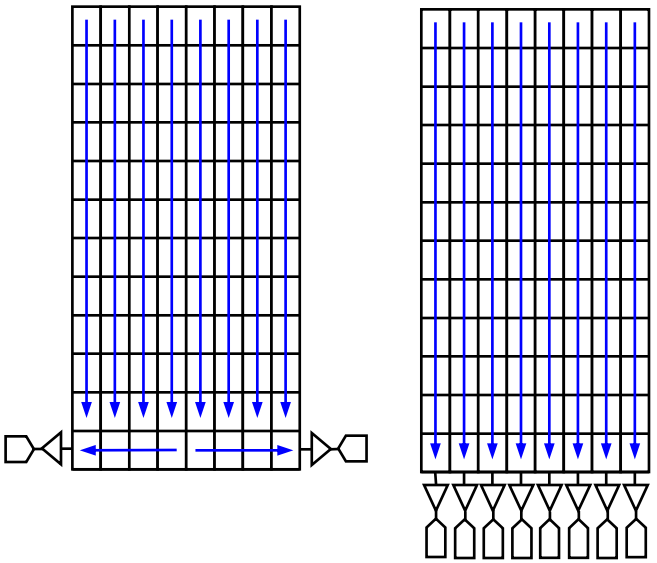
- Investigations of Benchmark reactions underway, including studies of:
  - $e^+e^- \rightarrow t\,\bar{t}$.
  - $e^+e^- \rightarrow ZHH$.
  - Production of soft $\tilde{b}$.



  - Higgs ranching ratios: expected precision ~ 1% for b, ~ 10% for c and g...

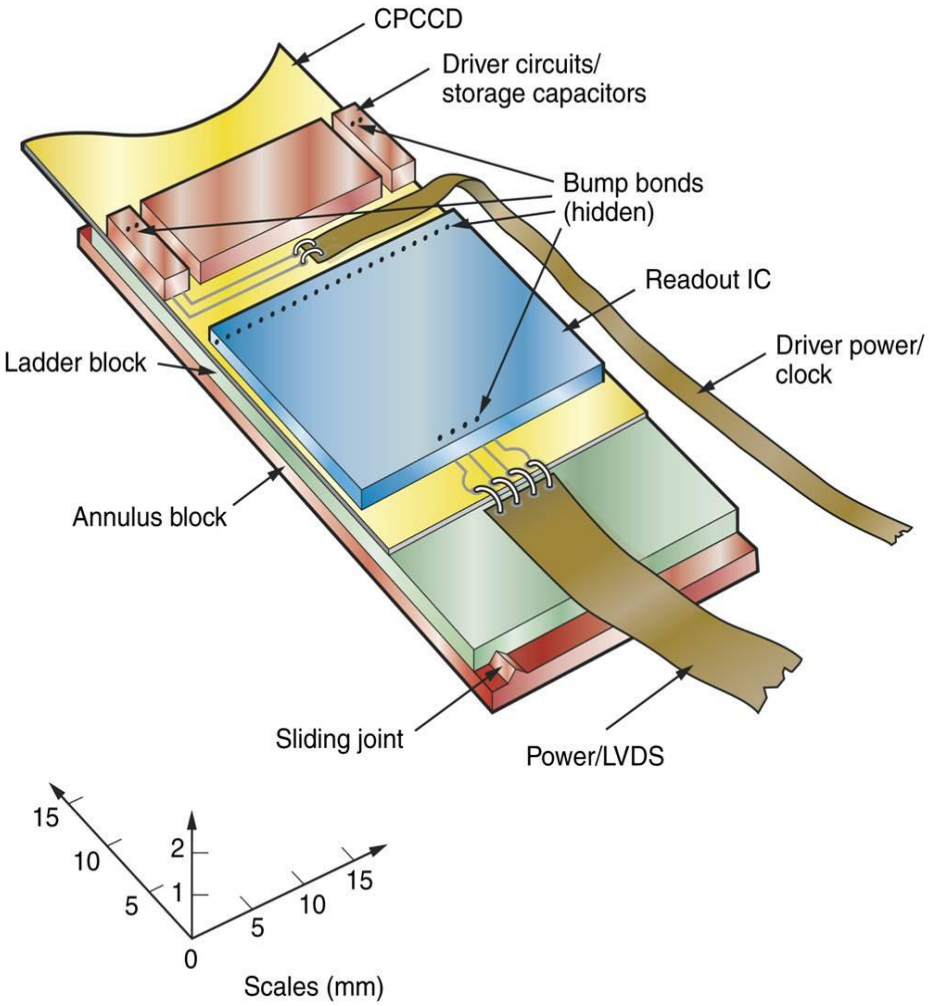
Sensors for the VXD – Column Parallel CCDs

- Achieve necessary readout speed with CCDs using column parallel architecture:



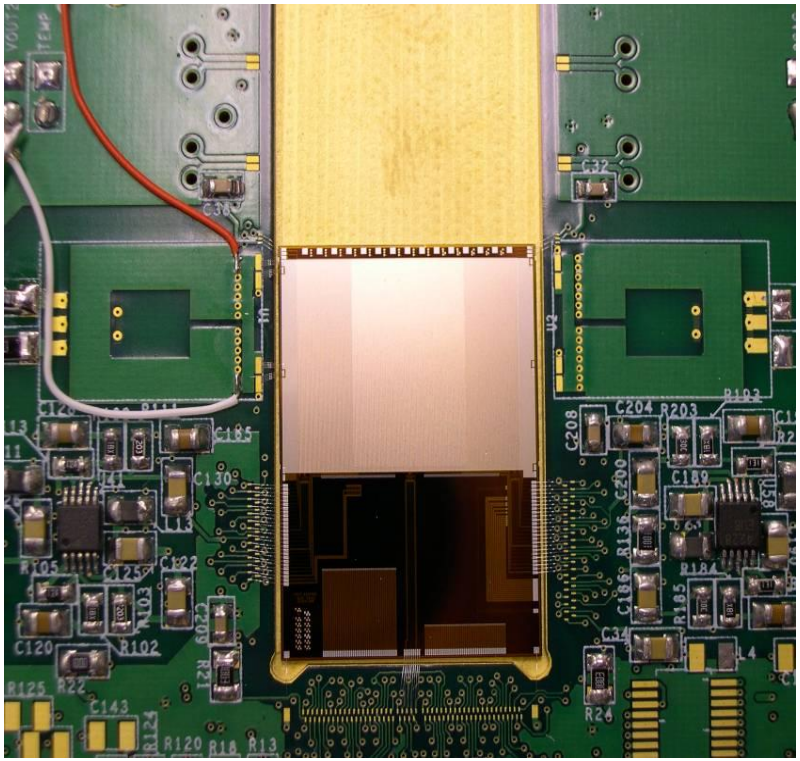
- Must drive image register at 50 MHz to readout in 50 μs.

- Conceptual "ladder" design:

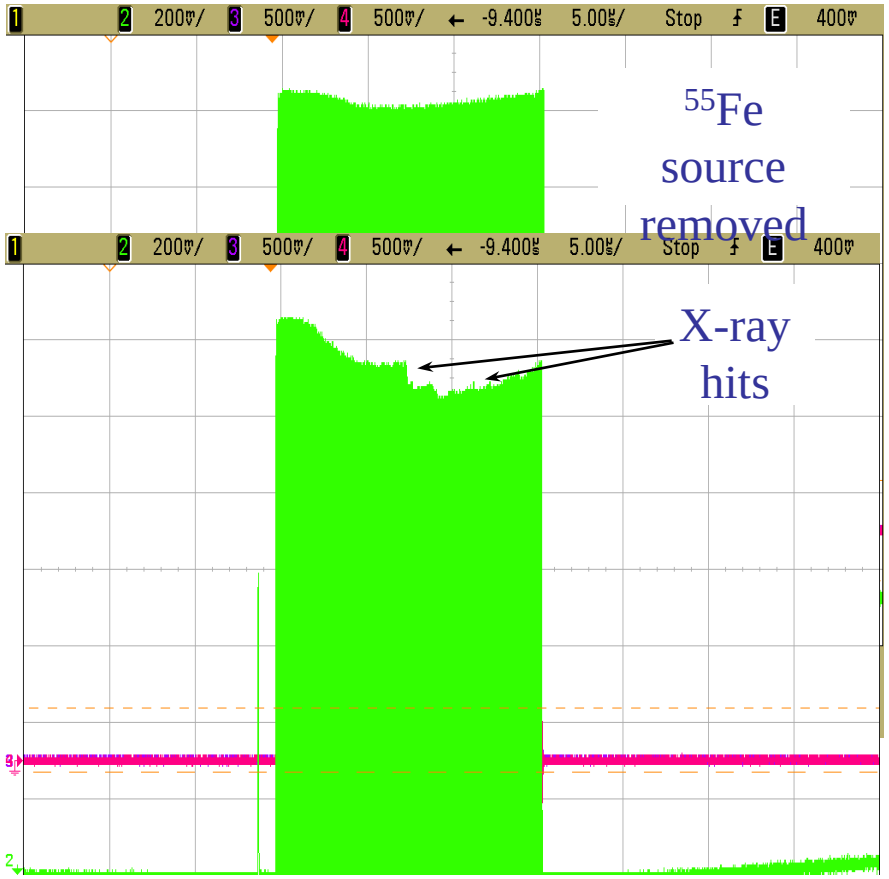


Testing the CPCCD at high speed

- CPC2-10 wire bonded to mother-board with transformer drive.

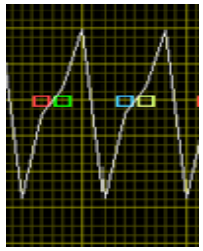
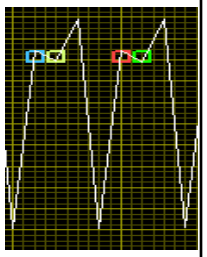


- ^{55}Fe X-ray signals observed at up to 45 MHz.



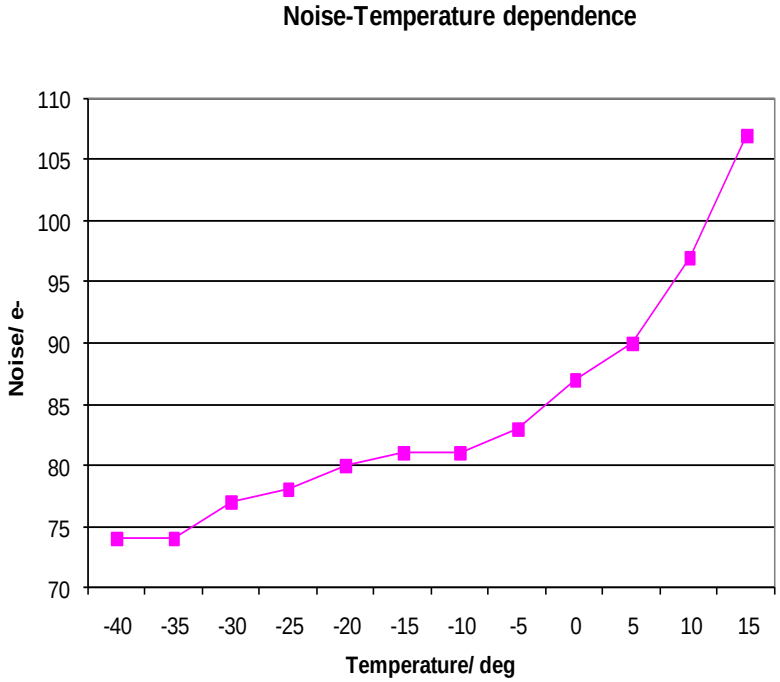
High speed ladder operation with CPD1

- Careful tuning of clock delays improves signal sampling:

Delay (ns)	15	18.5
Sampling points		
Noise (e^-)	83	73

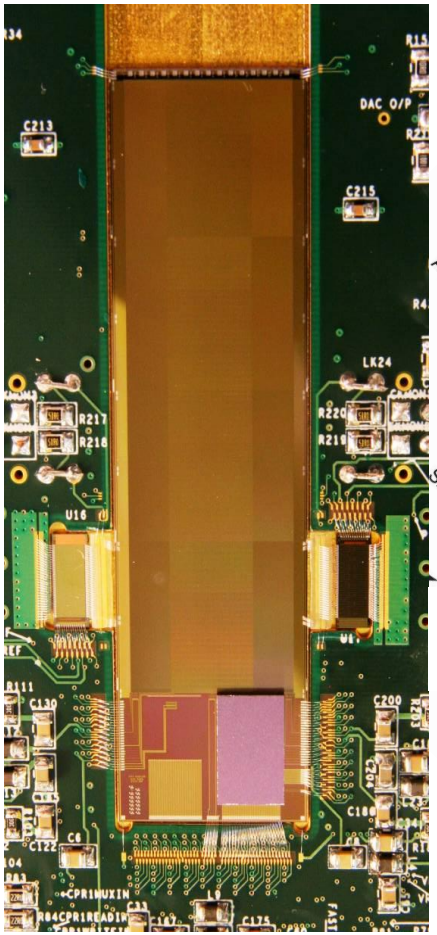
- Here using 2 sections of CPD1.

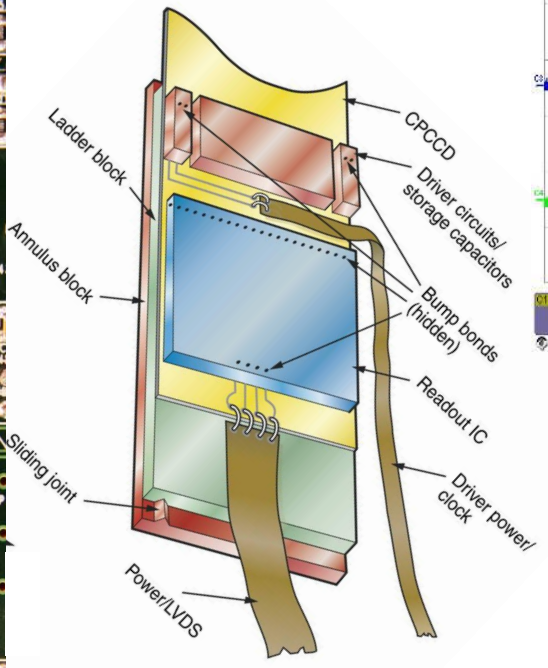
- Can now operate at 20 MHz with significantly reduced noise.

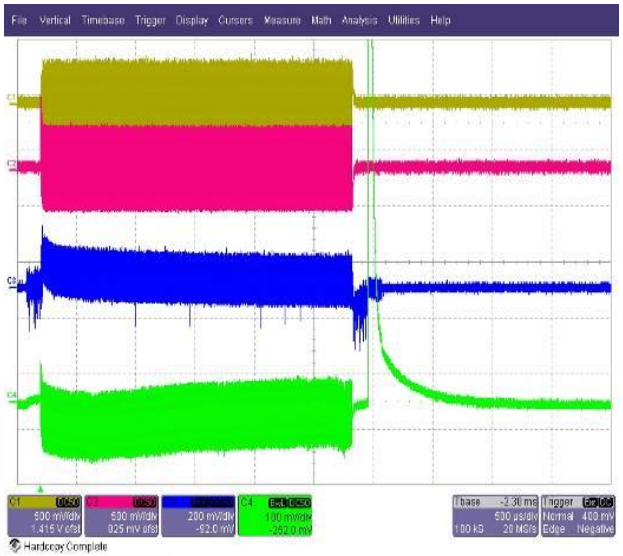


Towards a prototype ladder

- CPC2 with CPD1 driver chip and CPR2 readout chip:



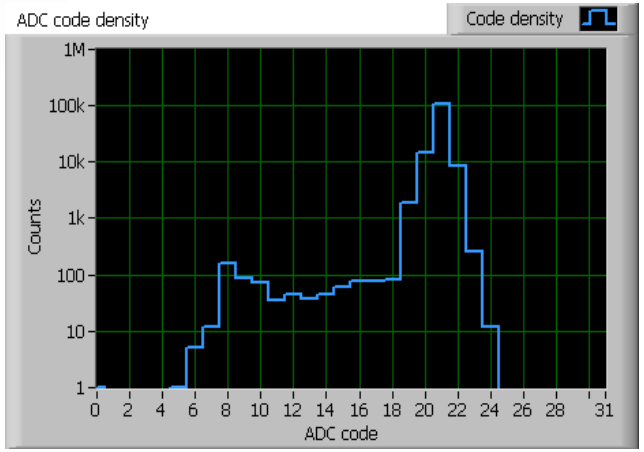




$1.5V_{pp}$ Clocks

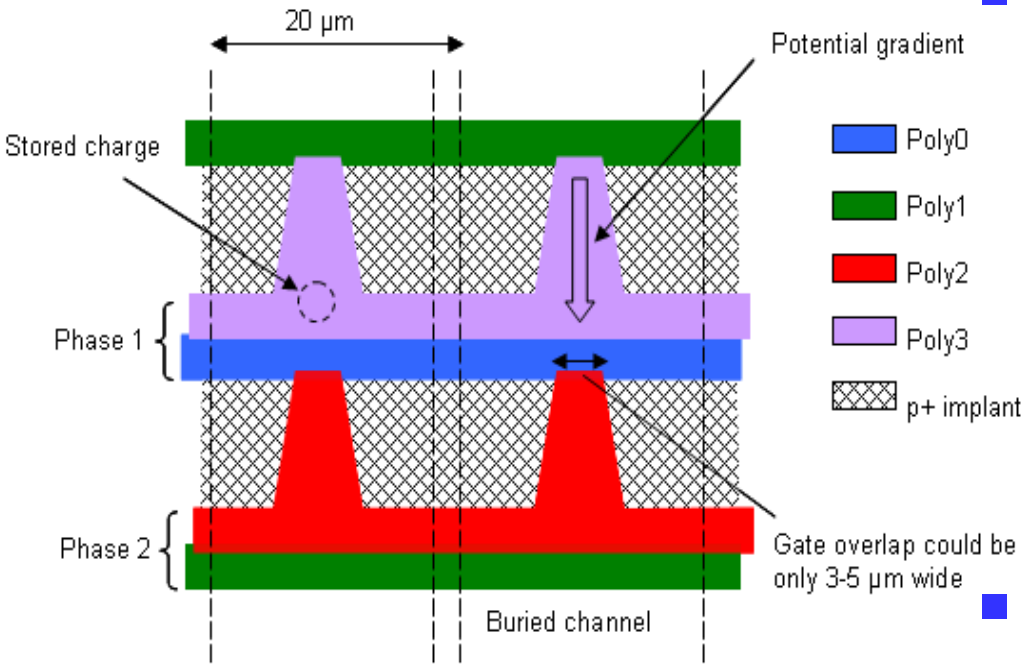
CPR2 Voltage Amplifier output

CPC Source follower output

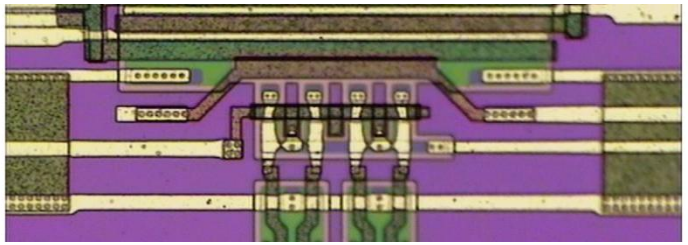


Future CPCCDs – reducing demands on clock

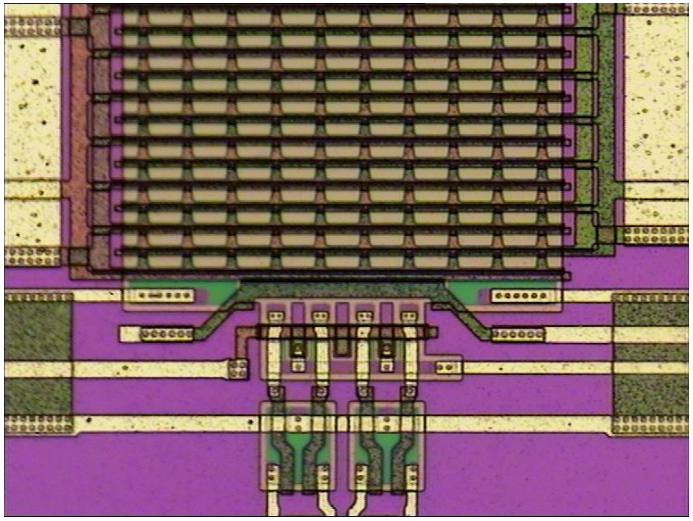
- Many ideas to reduce necessary clock voltage and inter-gate capacitance, developed by LCFI/e2v – CPC-T structures.
- E.g. open phase CCD:



- Initial concerns...



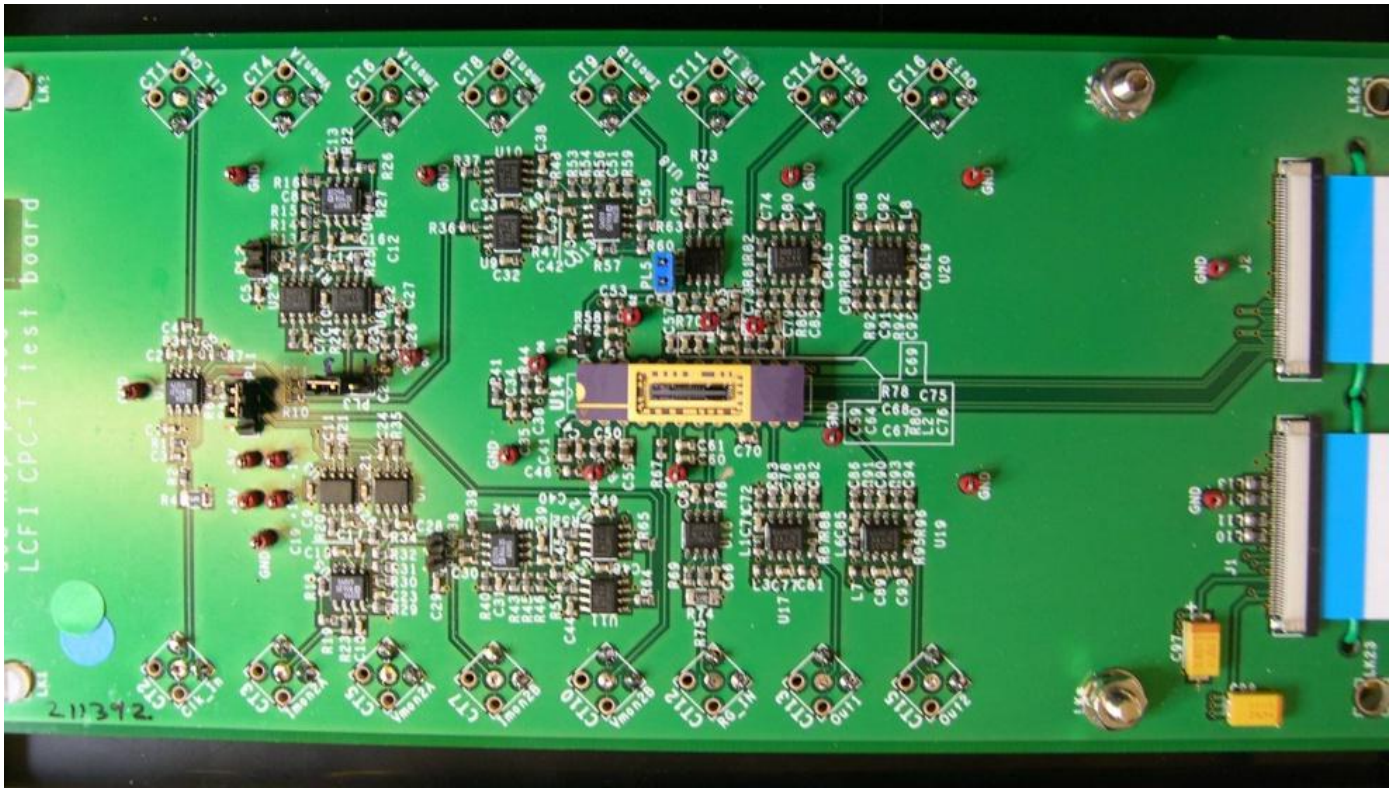
- ...proved unfounded:



- All but the “stepped nitride” structures have passed first tests!

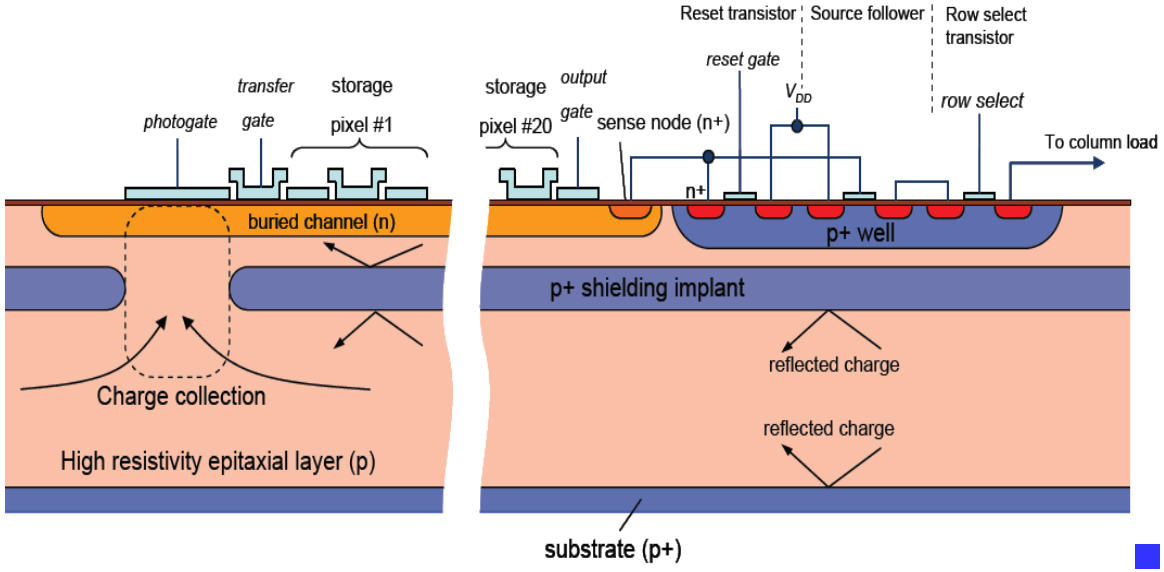
CPC-T

- All 29 variants now need study.
- Six month programme.



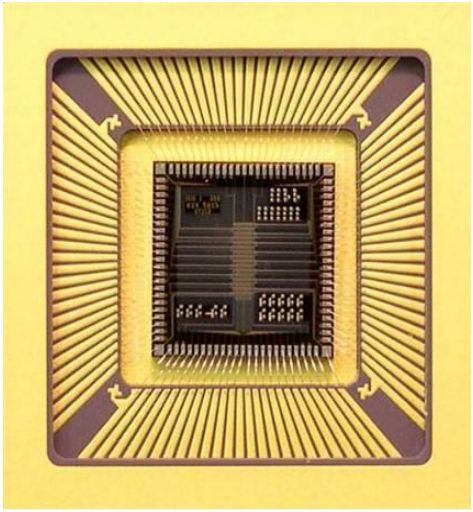
Sensors for the VXD – In-Situ Storage Image Sensor

- Alternative to fast readout: store signal in pixel during bunch train.



- Drive at 20 kHz during bunch train.
- 1 MHz column parallel readout between bunch trains.
- Charge to voltage conversion when least affected by EMI.

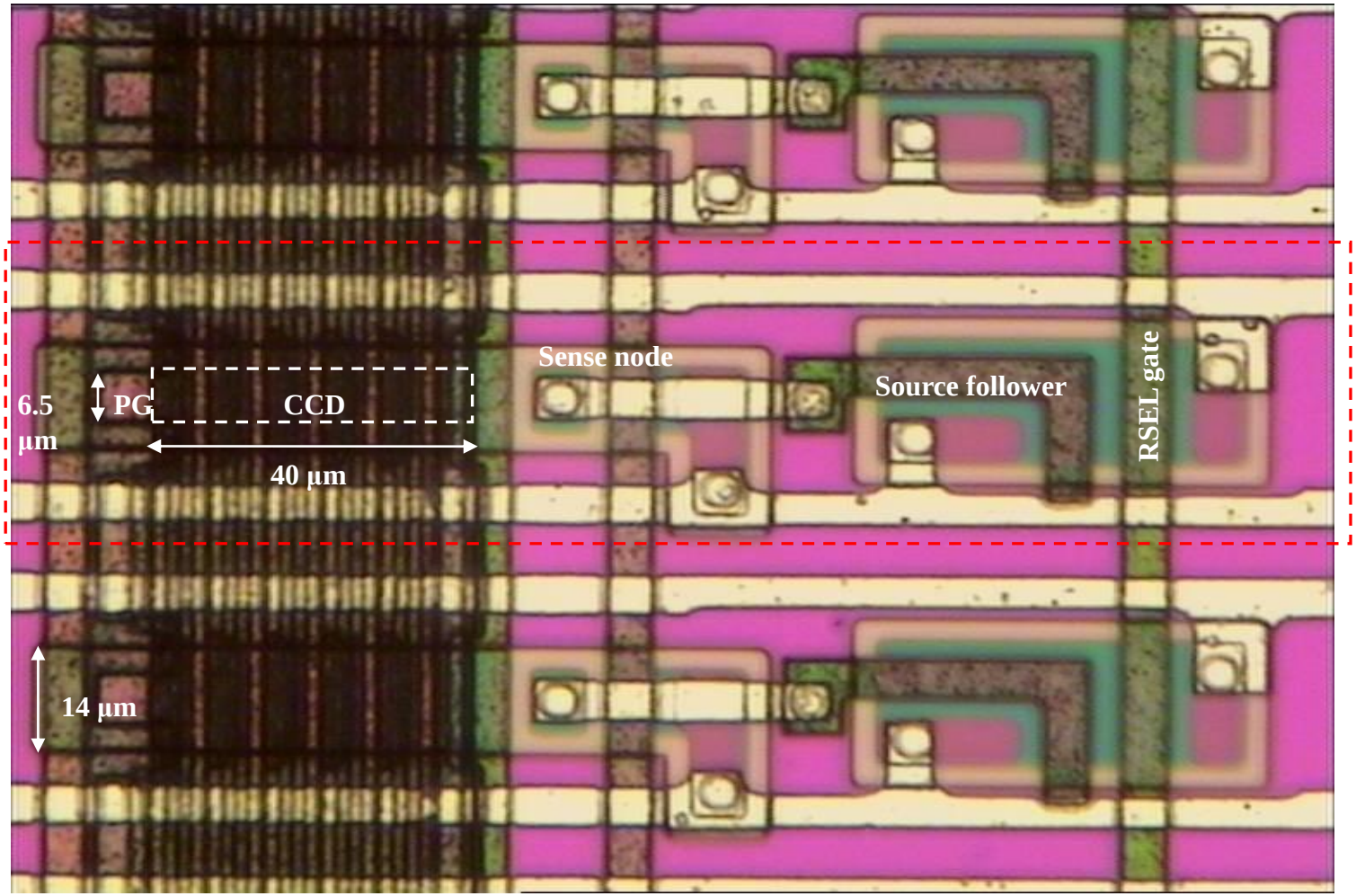
- ISIS1, "proof of principle" device built by e2v.



- 6 × 16 array of ISIS cells, each with 5-pixel buried channel CCD storage register.
- Cell pitch 40 × 160 μm^2, no edge logic.
- Chip size 6.5 × 6.5 mm^2.

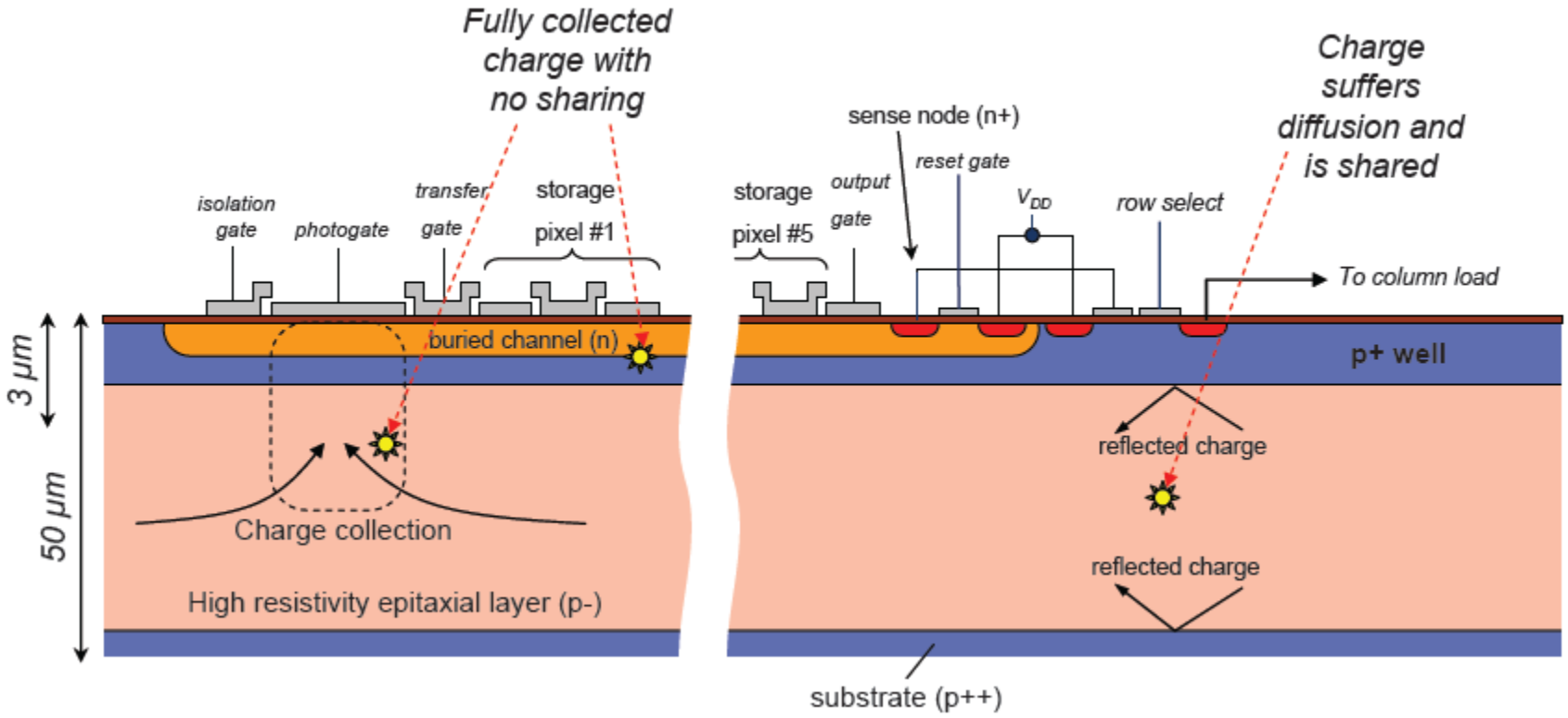
Tests of ISIS1 with p-well

- The ISIS1:



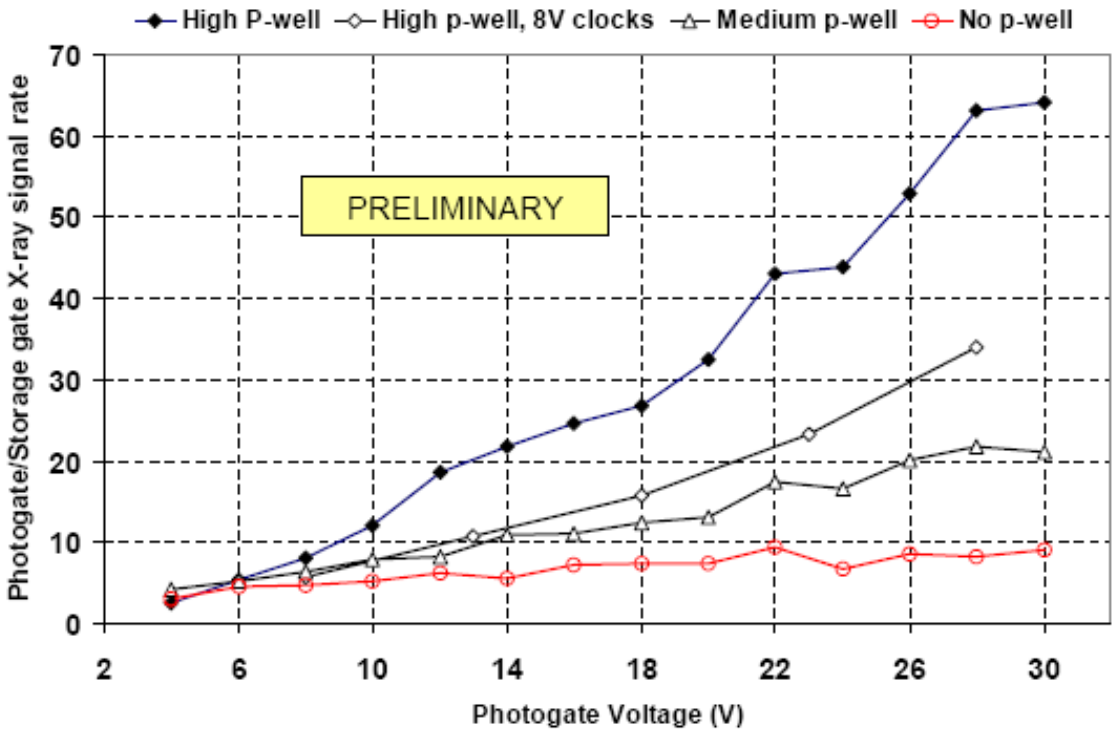
Tests of ISIS1 with p-well

- Does p-well reflect charge?
- Study using ^{55}Fe X-rays (5.9 keV, attenuation length 30 μm, charge released in 1 μm sphere).
- Look at ratio of charge collected on photogate to charge collected on storage pixels.

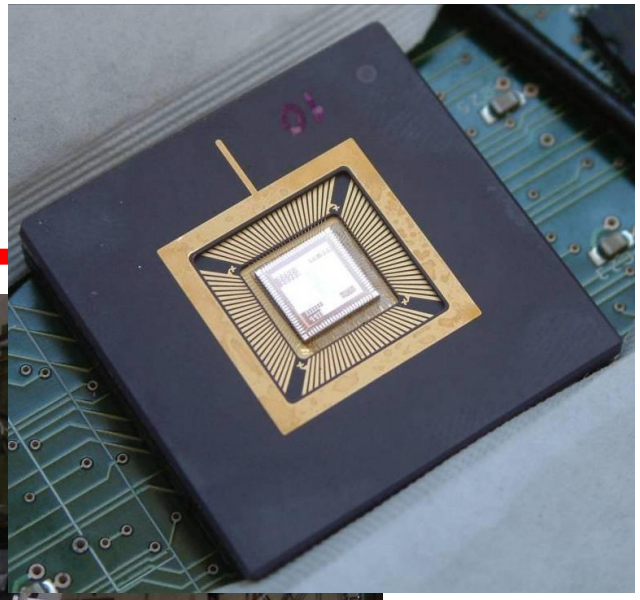


Tests of ISIS1 with p-well

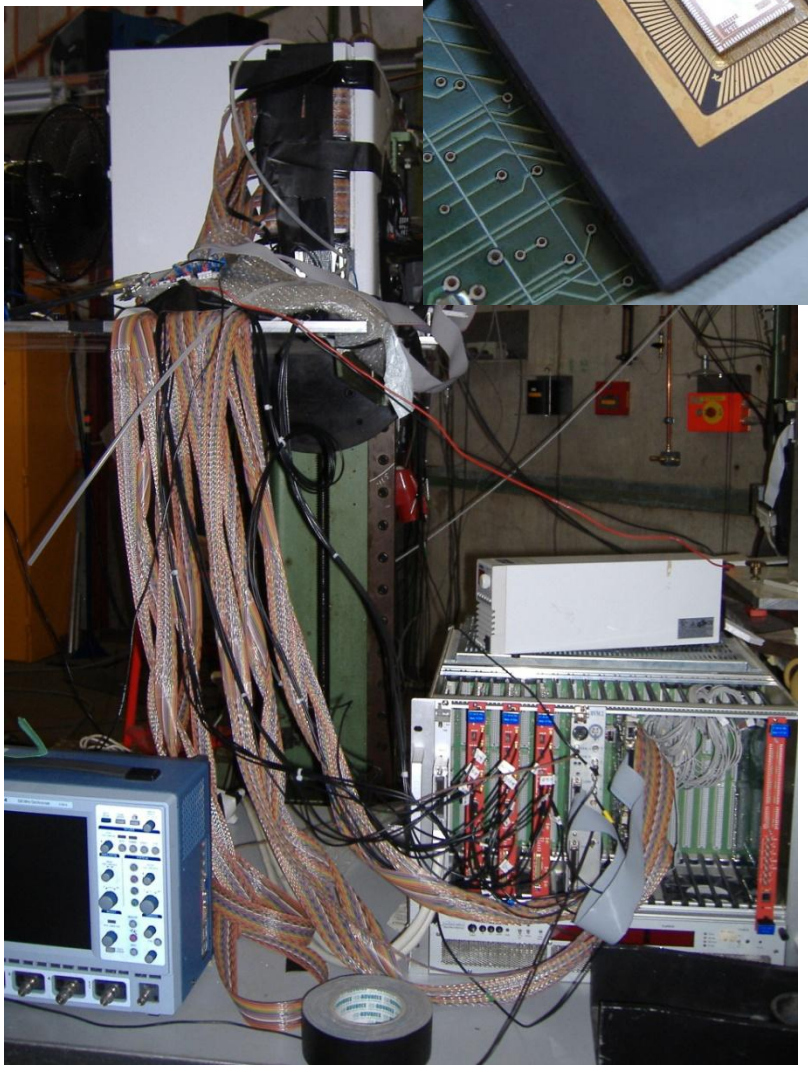
- High p-well doping, storage register protected, p-well works!
- If increase clock voltage, get punch through under in-pixel CCD, R drops.
- Lower p-well doping, charge reflection decreases.
- No p-well, R dependent on gate geometry and voltages.
- Publication being prepared.



Tests of ISIS1 in Beam

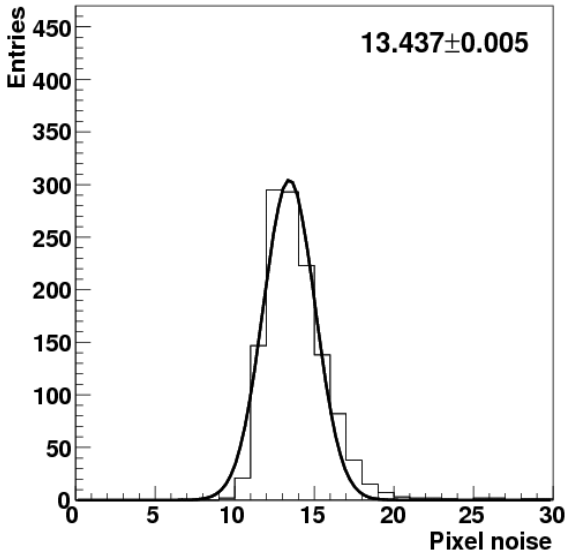


- ISIS1 telescope constructed with five ISIS1 chips.
- Sensors have:
- 16 × 16 pixels, each of $40 \times 160\ \mu m^2$.
- Five storage cells per pixel.
- Active area $0.56 \times 2.24\ mm^2$.
- Accurate alignment required!
- Tests performed in DESY 1...6 GeV e^- beam.
- Readout speed 2.5 MHz, (ILC needs 1 MHz).



Tests of ISIS1 in Beam

- Calculate pedestal for each pixel.
- Noise from standard deviation after pedestal subtraction.

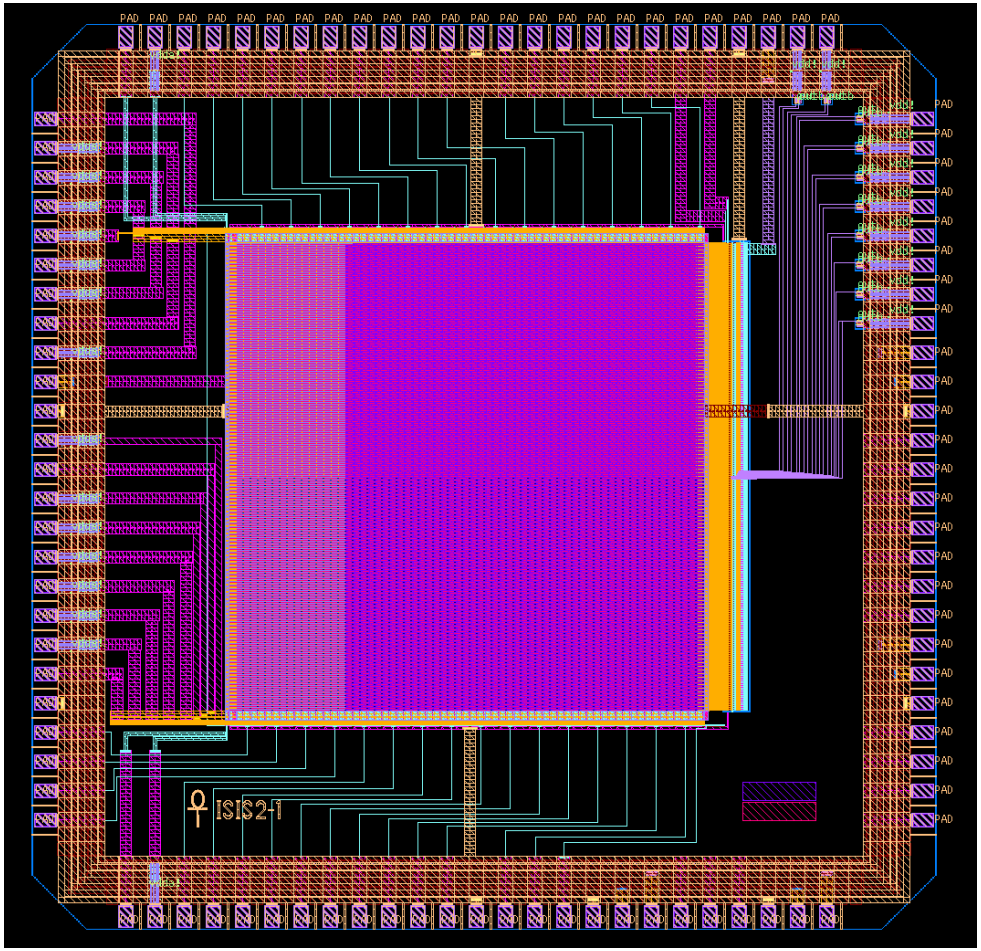


- Clusters 5σ seed, 2σ neighbours.
- Clusters small: little charge sharing in x ("long") direction.
- S/N ~ 37, σ_y = 11.6 μm.

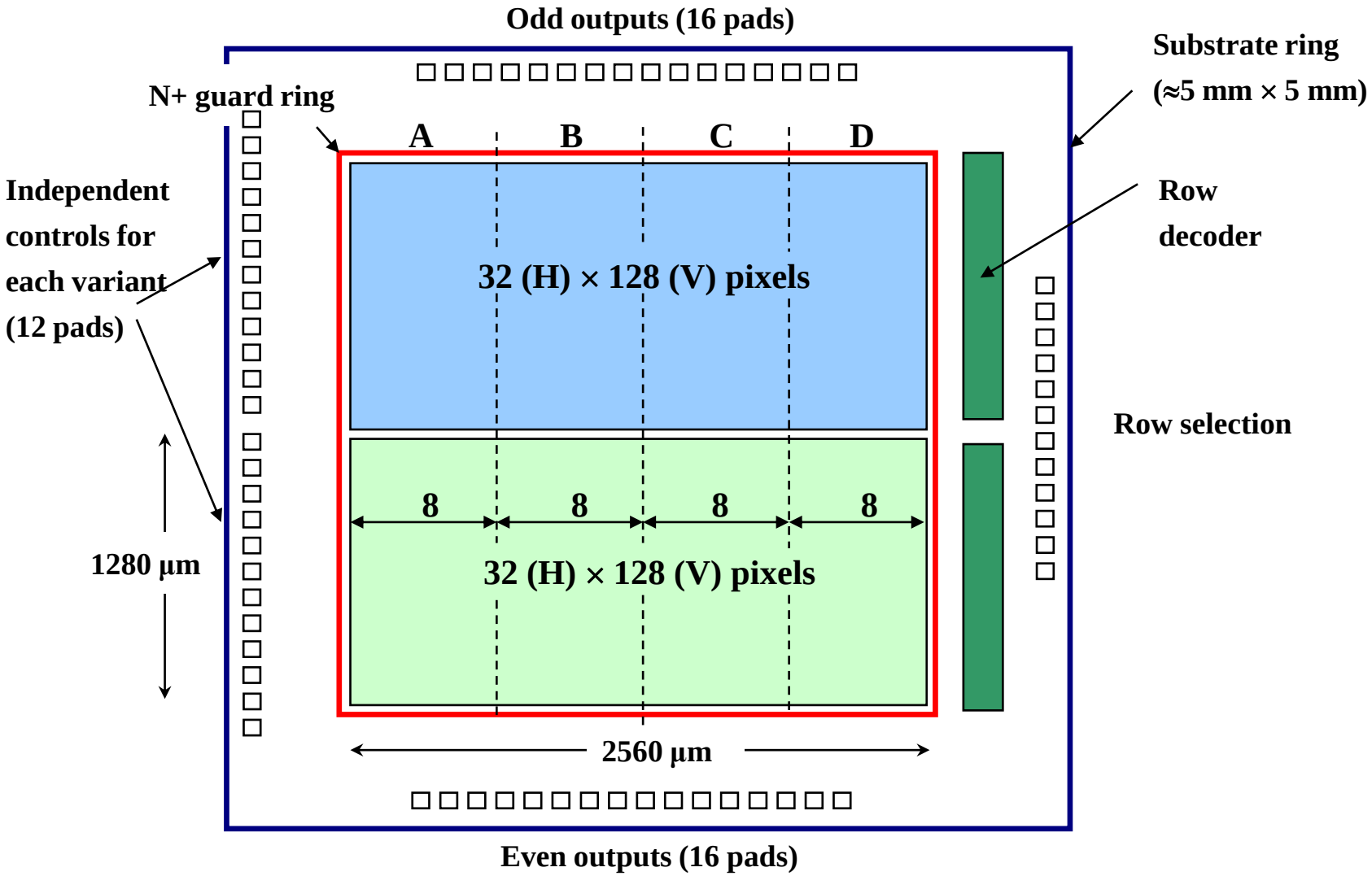
- Attempt made to map performance of ISIS1 pixels.
- Resolution achievable with DESY test set-up inadequate.
- High energy beam test planned last week August at CERN
  - 3 standard ISIS1
  - 3 ISIS1 with p-well
  - Use EUDET telescope for tracking (~ 3 μm predicted position precision).
- Supplement with laser studies.

ISIS2 Status

- Impressive progress made with design of ISIS2.
- Pixels 80 × 10 μm^2, buried channel ~ 5 μm wide.
- Top level design (logic, source followers...) now complete
- Some test structures will also be included (transistors, short CCD).
- Design discussed with e2v and now with Jazz engineers.
- Target completion date 30th April.
- Three months ago the LCFI team knew nothing about the tools needed to design this sensor...

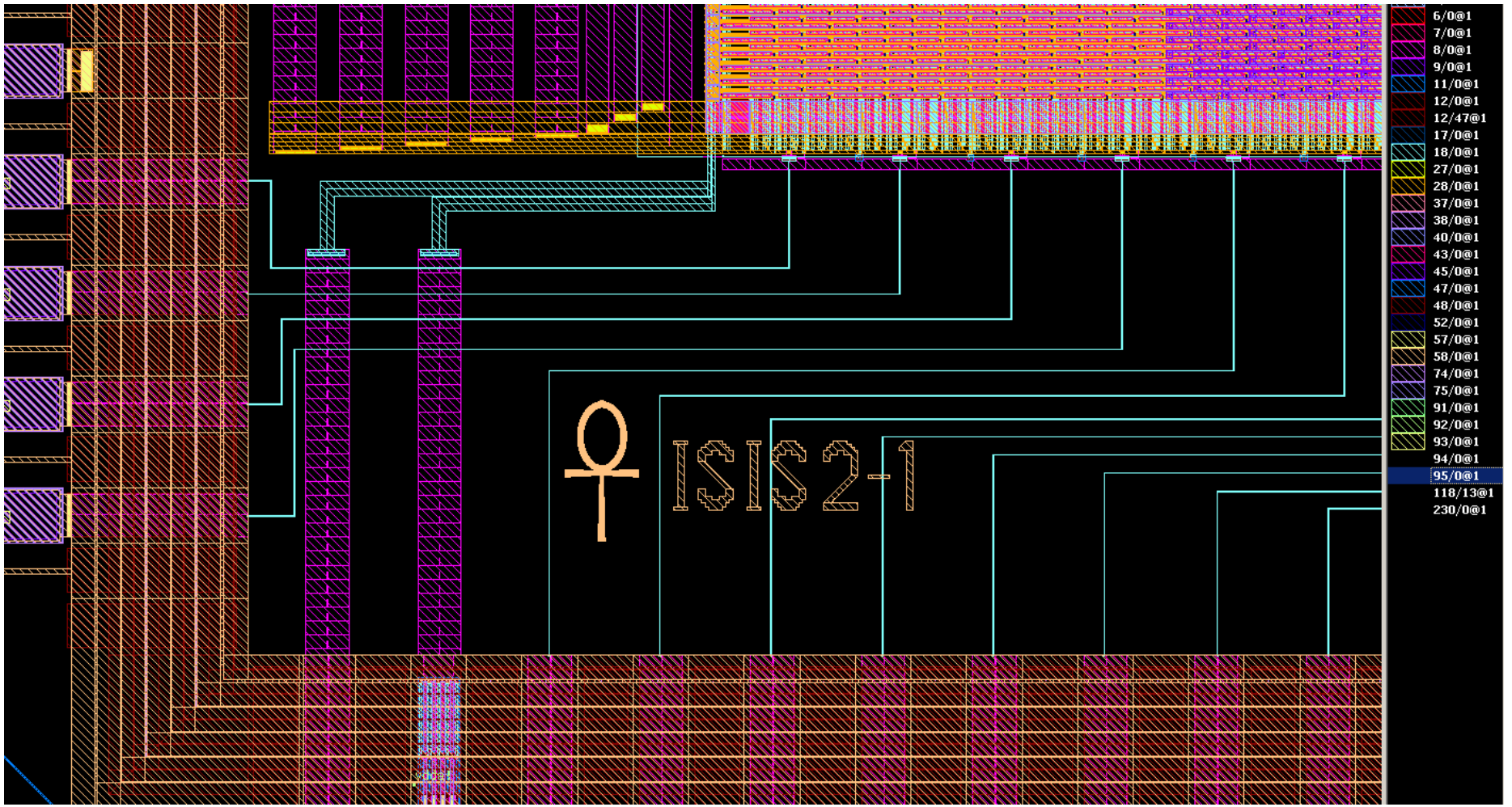


ISIS2 chip layout



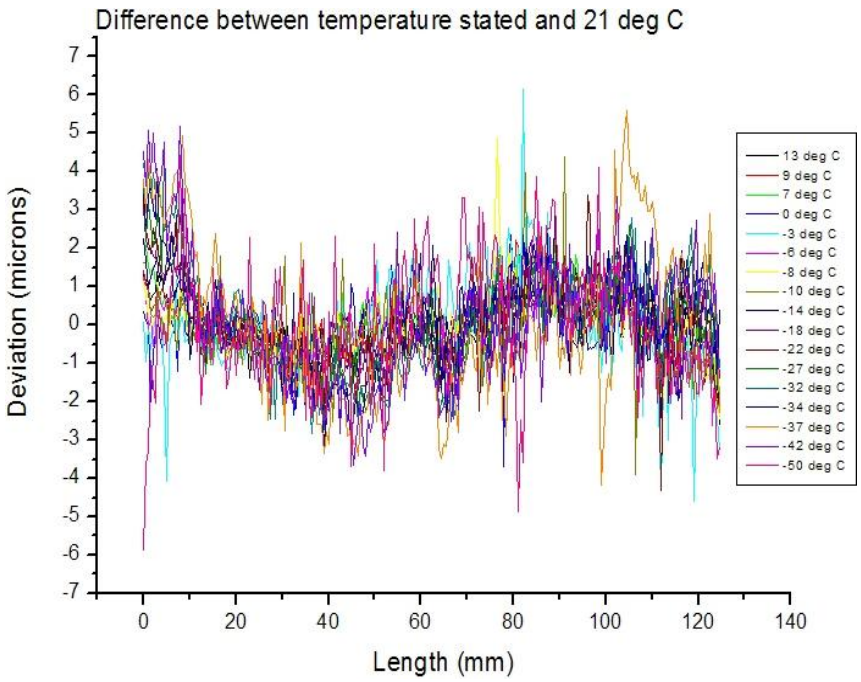
ISIS2

- Due homage paid to the Egyptian gods...

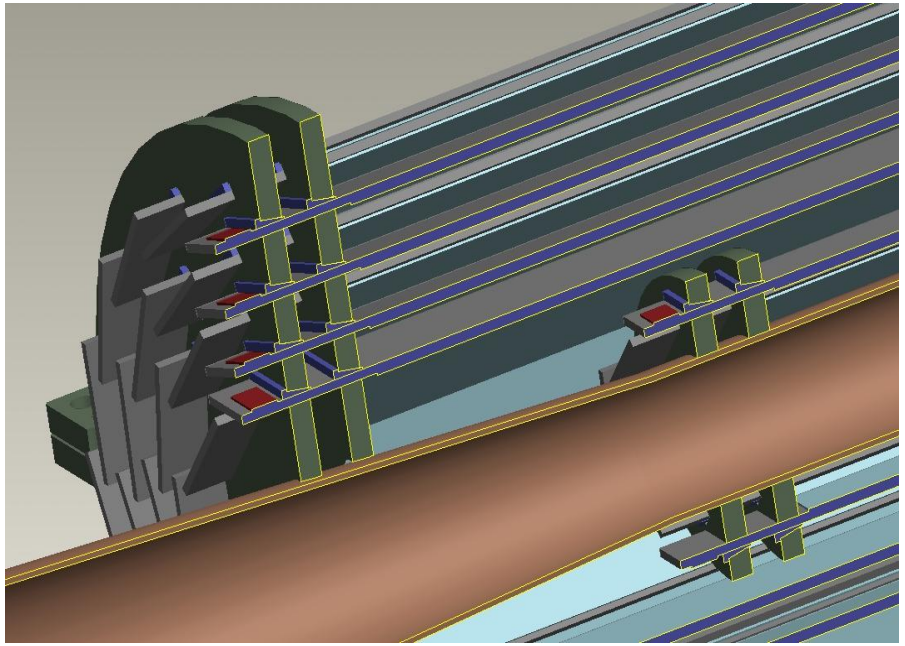


Mechanical studies

- SiC foam promises to provide extremely stable VXD structures.
- Very good CTE match ensures excellent temperature stability.



- Investigating possibility of constructing entire VXD using SiC:



- Issues of, machining SiC, choice of adhesive still to be solved.

Future programme

- Will seek funding within current grant for:
  - Completion of aspects of physics/Vertex Package work.
  - Studies of CPC-T and completion of some CPCCD work.
  - First tests of ISIS2.
  - Studies of CPR2A/B/C.
  - Testbeam measurements on ISIS1 with p-well.
  - Completion of current work on RVC foam, carbon fibre.
- Considering bidding for new funding for:
  - Continuation of work on and with the Vertex Package.
  - Further studies of ISIS2.
  - CPC2/CPR2A bump-bonding and testing.
  - Further investigation of SiC foams.
  - System design aspects of VXD.
- Considering how best to get these bids into and through the system...advice would be welcomed!

Summary

- Improvement and tuning of Vertex Package continues.
- User base broadening.
- Continuing to improve performance of CPC2.
- CPC-T tests starting.
- New readout chips CPR2A/B now available for testing.
- ISIS2 design nearly complete.
- Functioning of p-well in ISIS1 demonstrated.
- Further ISIS test beam planned at CERN for end August.
- Negotiating with Janet Seed to complete as much of current programme as possible.
- Developing ideas for proposal(s) for continued funding of aspects of the LCFI programme.