Heavy Flavour Identification at Linear Colliders

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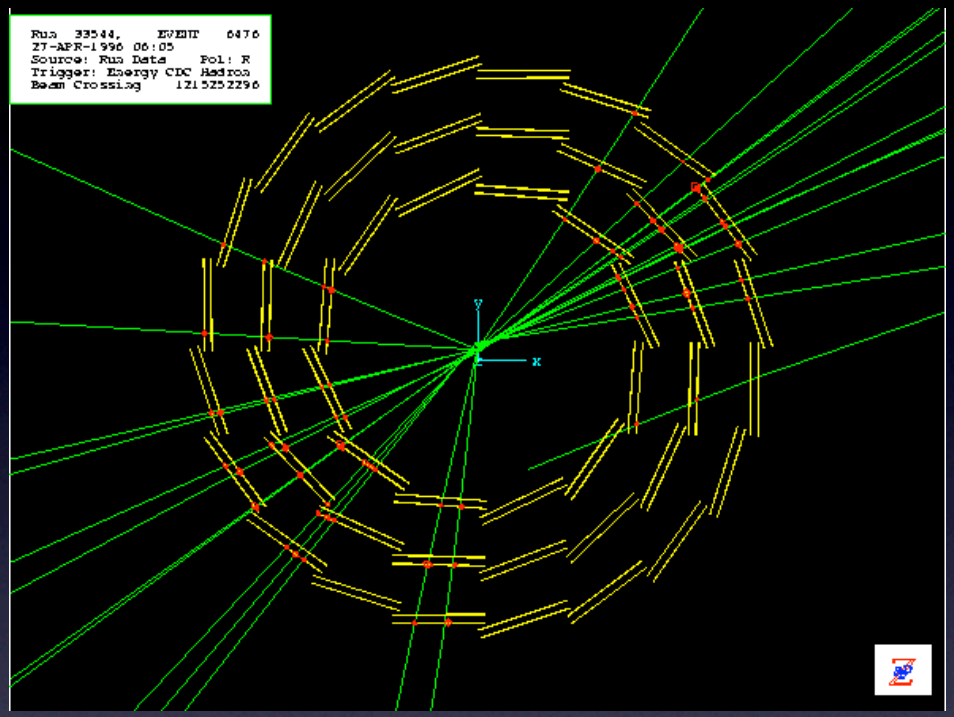
LCFI Collaboration

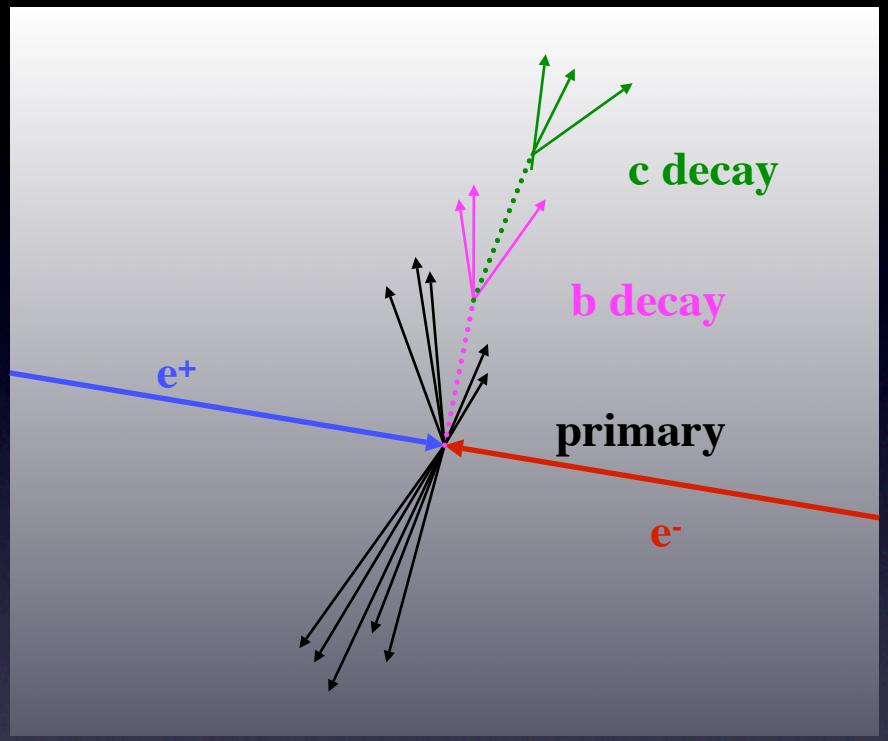
SLAC AIS 9/3/08

LCFI

- Linear Collider Flavour Identification
  - *Has been focusing on ILC*
    - Bristol
    - Edinburgh
    - Glasgow
    - Liverpool
    - Nijmegen
    - Oxford
    - RAL
    - – Sensors
    - – Readout
    - – Mechanics
    - – Software
    - – Physics

Flavour Physics

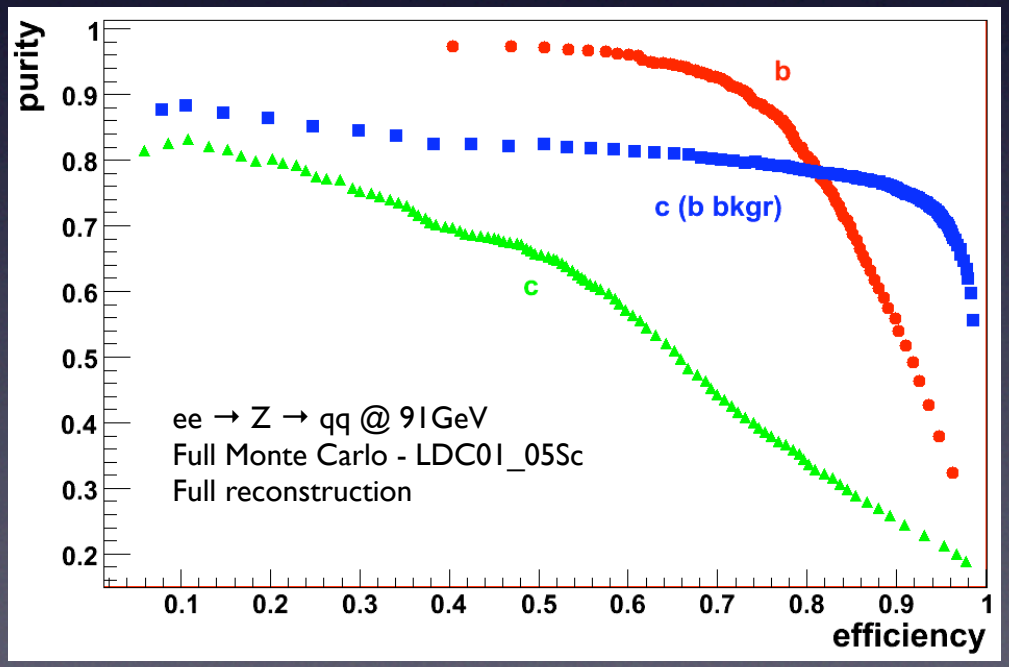


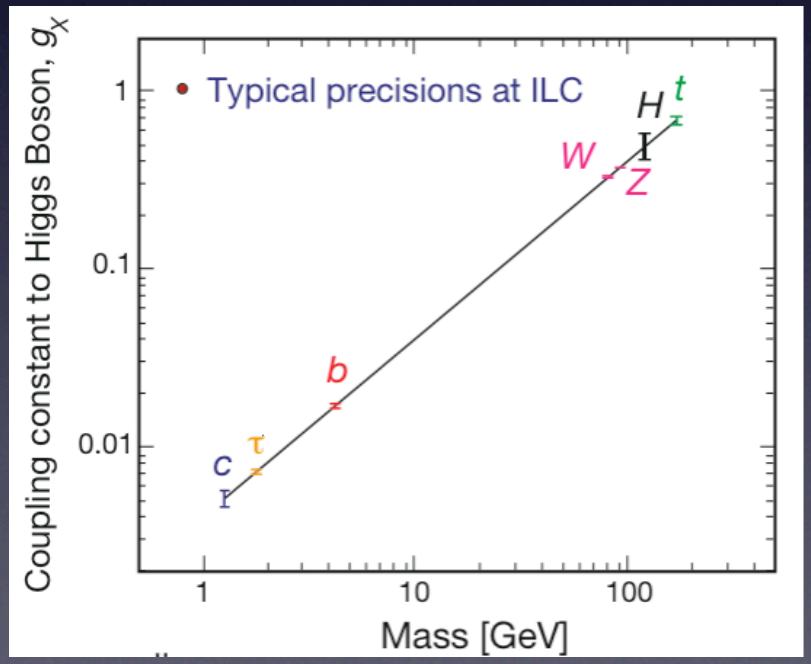


- Precision detectors close to interaction point
- Distinguish tracks from secondary vertices
  - Identify, separate *b*, *c* quarks and τ leptons
  - Measure charge

Flavour Tagging

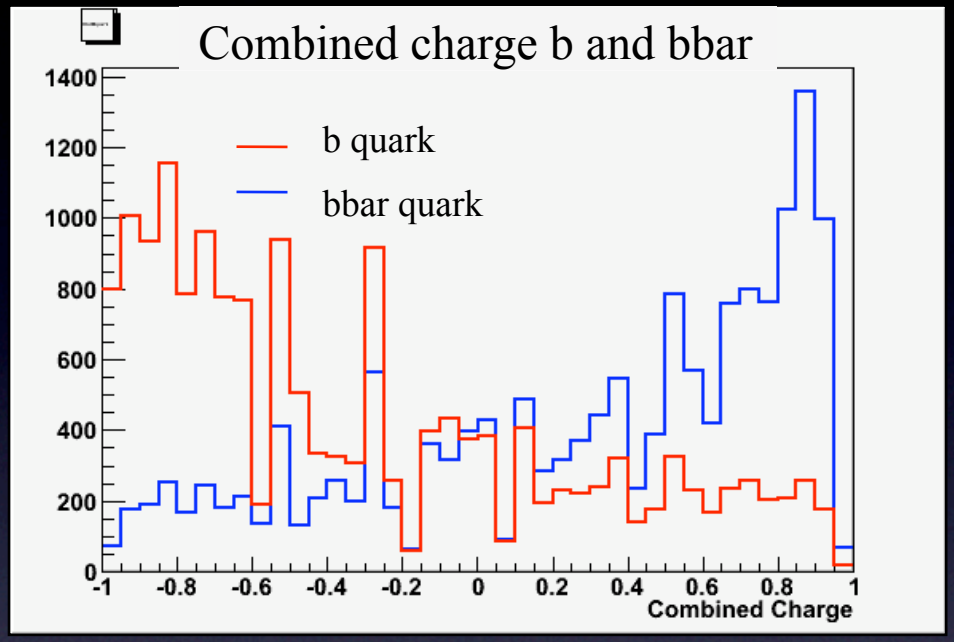
- *b*-tagging fairly robust at the ILC
- c-tagging more detector dependent
  - Measure Higgs branching ratios
  - . . .

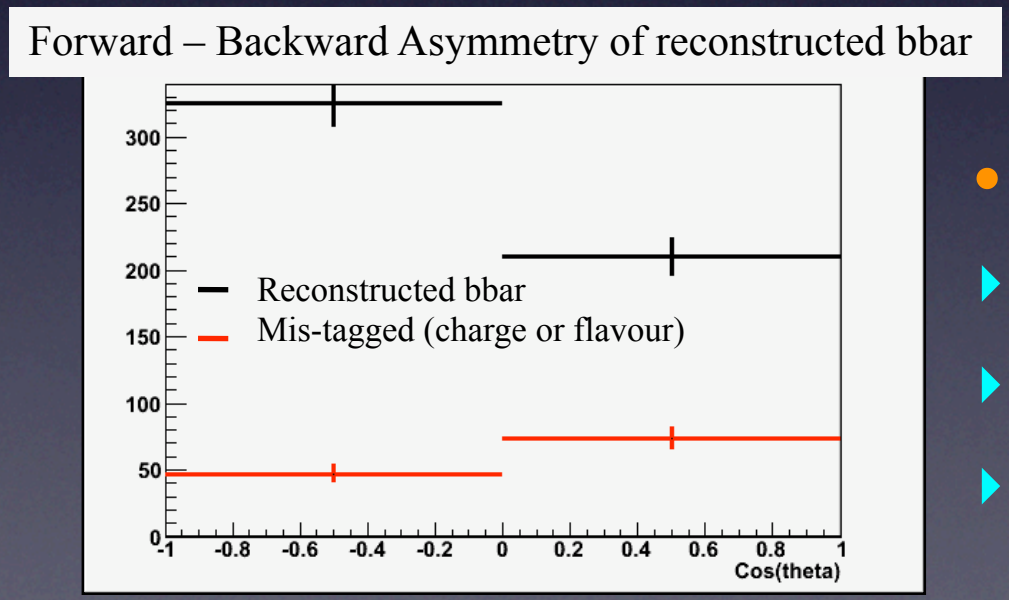




Vertex Charge

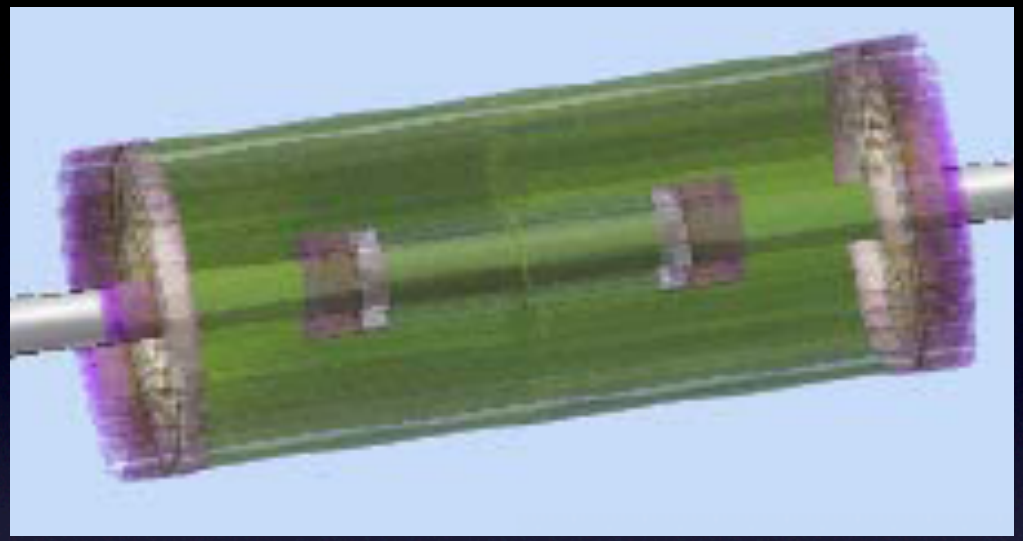
- Add charge of all tracks in vertex
- Identify charge of flavoured hadron
  - Can distinguish quark/antiquark
  - Measure hadronic asymmetries
  - Anomalous couplings, LEDs....





- Sensitive to detector parameters
  - Acceptance
  - Material
  - Geometry...

ILC Vertex Detector

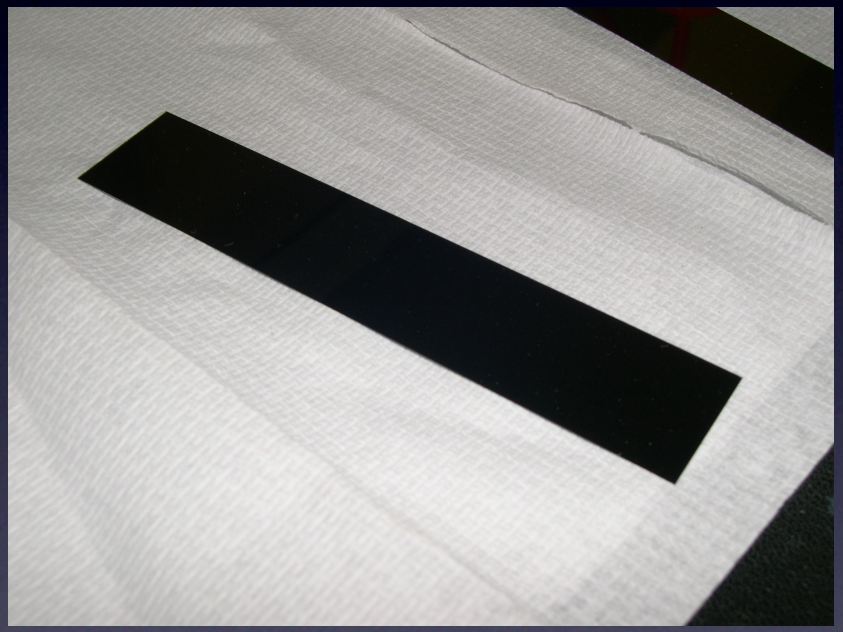


- 800M 20×20μm^2 pixels
- 5 layers, inner radius ~ 1.5 cm
- Gas cooling
  - 0.1% X_0 per layer in active region
  - Uniform material distribution

Mechanics

Material target equivalent to 100 µm silicon

- Thinning silicon to 50-100 µm becoming routine
- Thinning to epitaxial possible

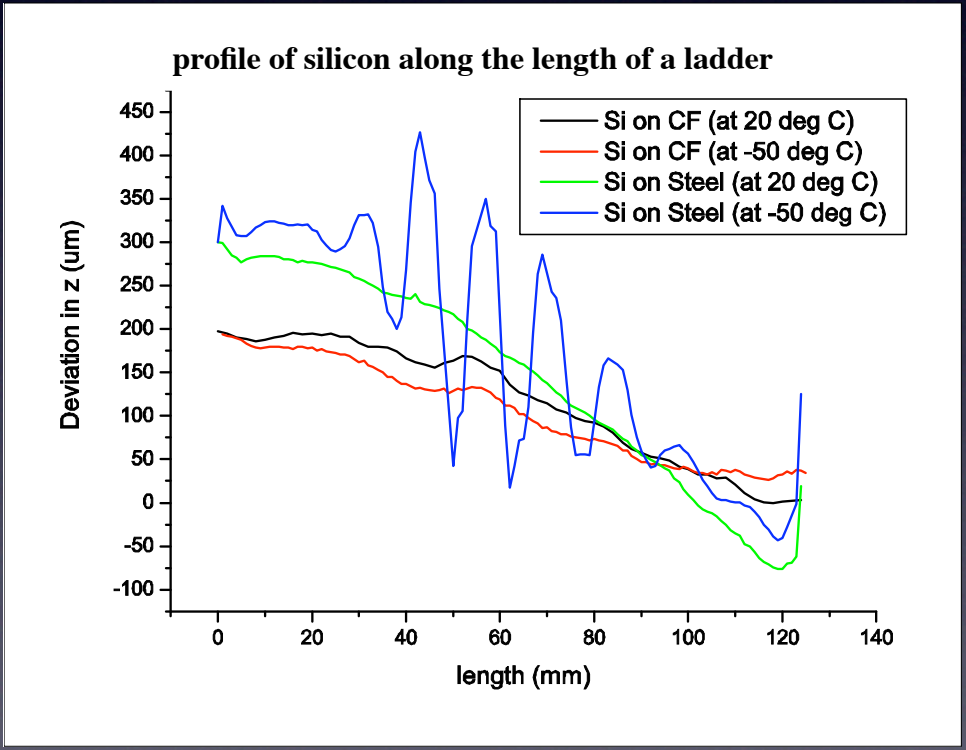


- *Ladders with bulkheads*

1. Unsupported silicon
   - can't control lateral curl
2. Laterally stiffened silicon
3. Rigid structures

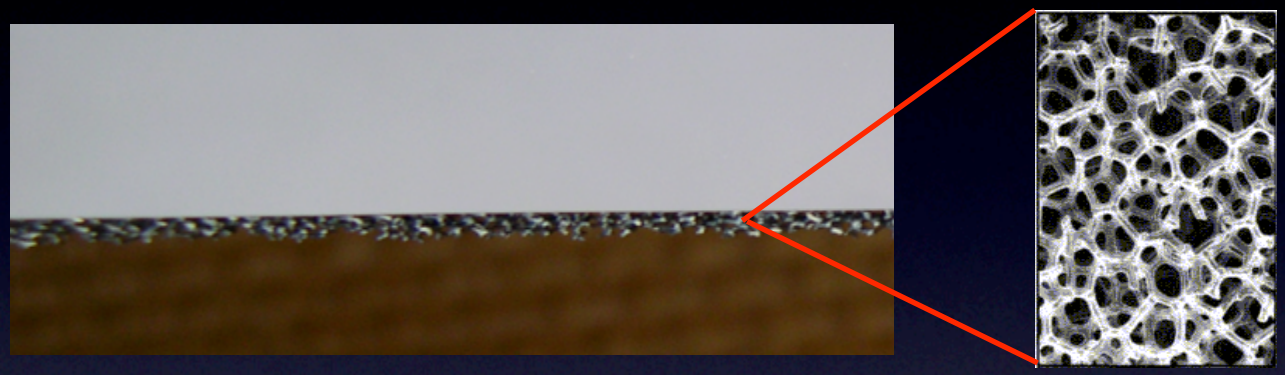
Thin Substrates

- Longitudinal stiffness from tensioning
- Lateral stiffness from thin substrate
  - Beryllium: good specific stiffness but bad CTE
  - Carbon fibre good candidate
    - 0.09% X_0 test model
    - laterally stability insufficient

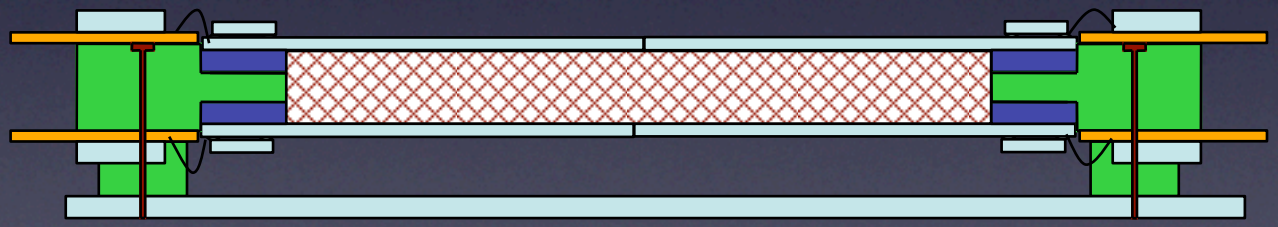


Foam Ladders

- 25 micron silicon on 1.5mm 8% SiC
  - Very rigid
  - Achieved 0.14% X_0

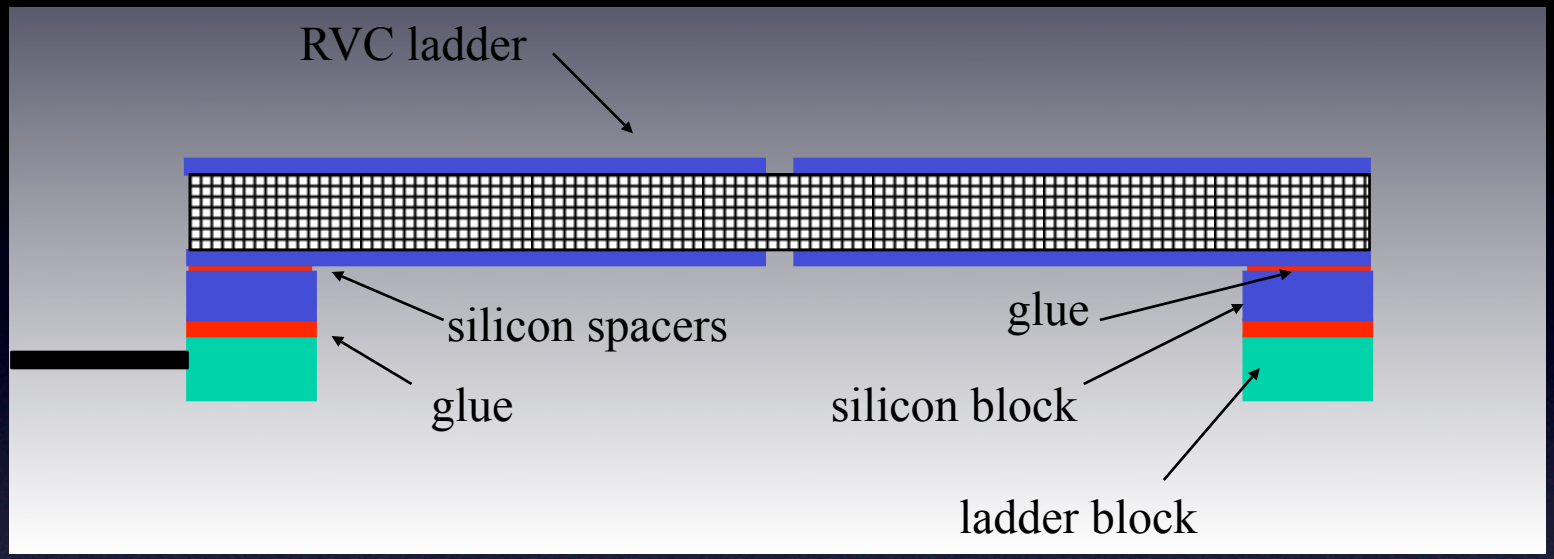


- 20 micron silicon sandwiching 1.5mm 2% carbon
  - Could be double-sided
  - Achieved 0.07% X_0

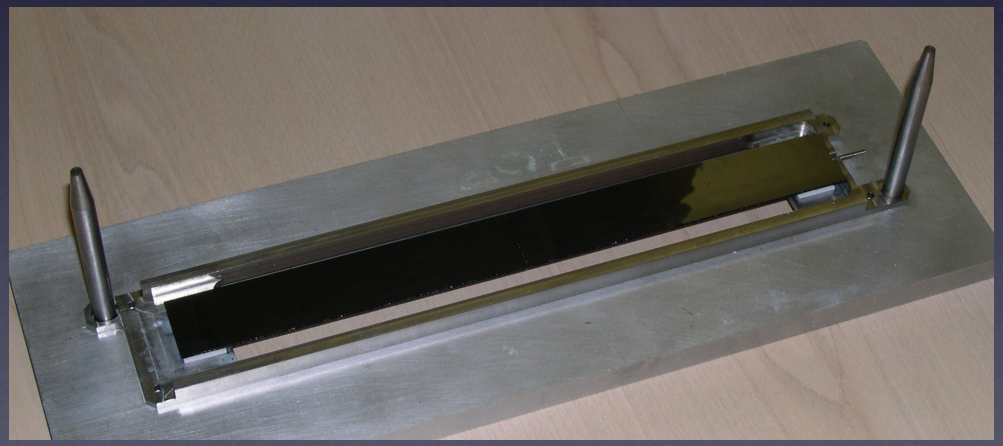


More exotic rigid structures possible

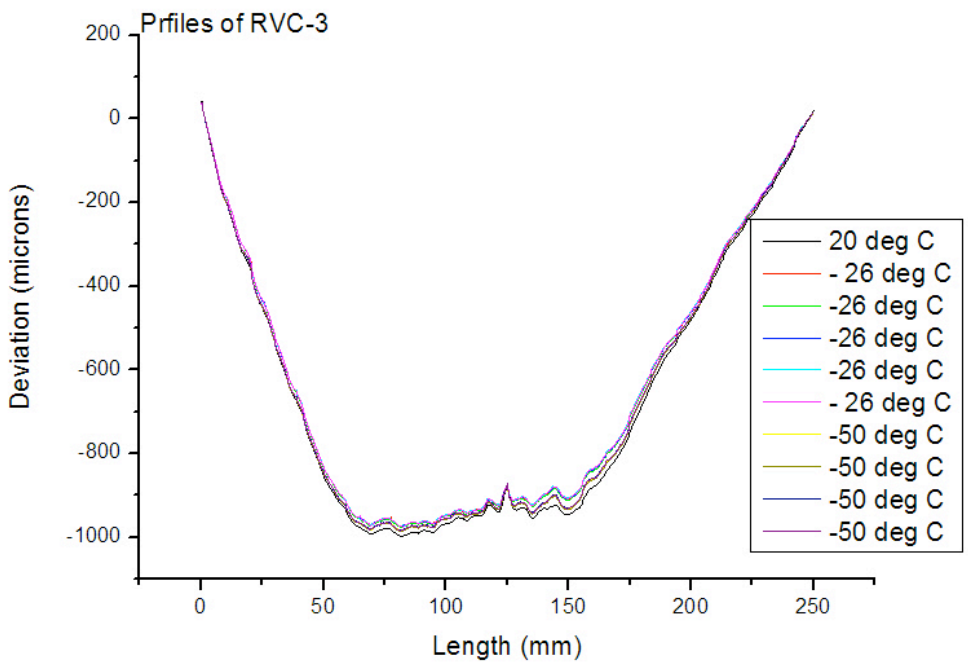
RVC Foam

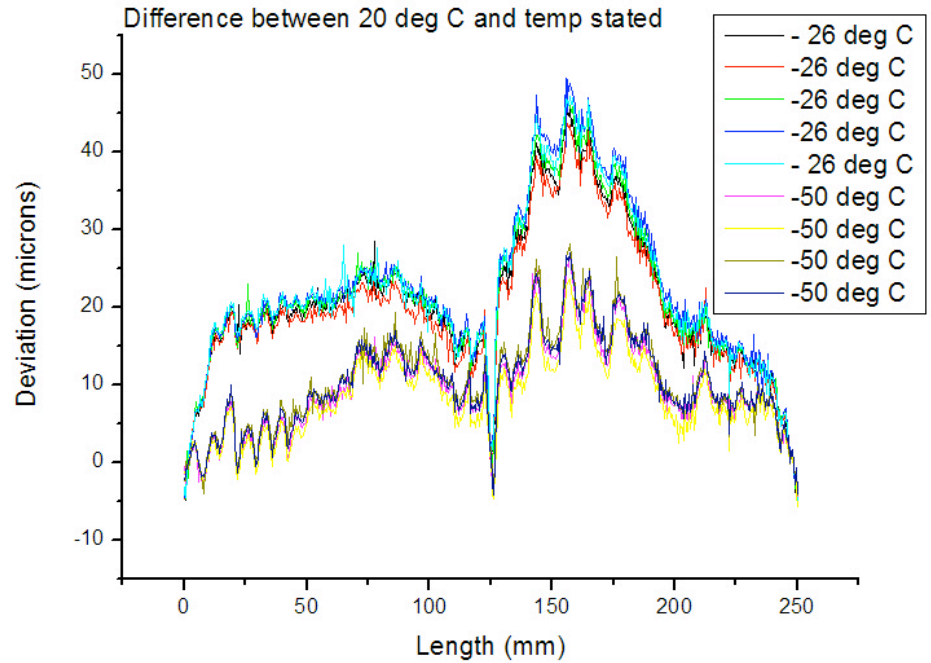


- Reticulated Vitreous Carbon
  - 2-3% relative density
  - Not stiff enough for one-sided



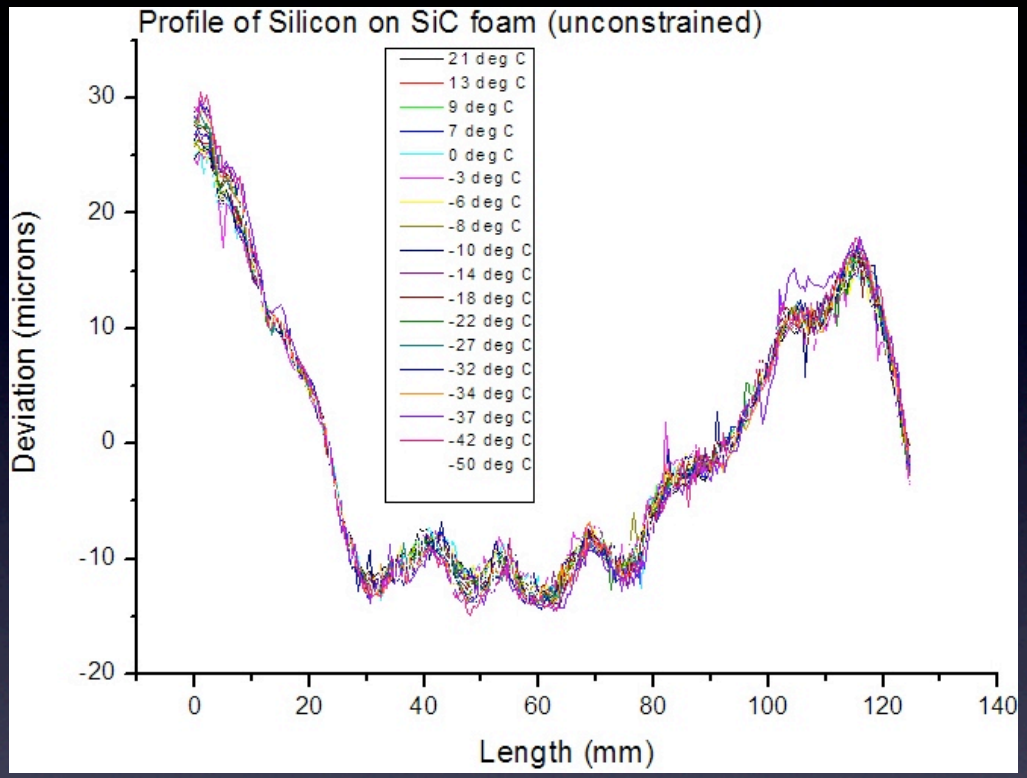
RVC Results





- Shape due to fabrication technique
  - New fixtures look promising
  - Difficult to control behaviour

SiC Foam Ladder



- Processed 8% SiC Foam
  - A fraction of initial shape left
  - 30% over material budget
  - Now have 3-4% foams
- Minimally constrained
  - Eliminate stiction in mountings

Negligible deformation over 70 degrees!

Foam Future

- SiC seems extremely promising
  - Lower density now in hand
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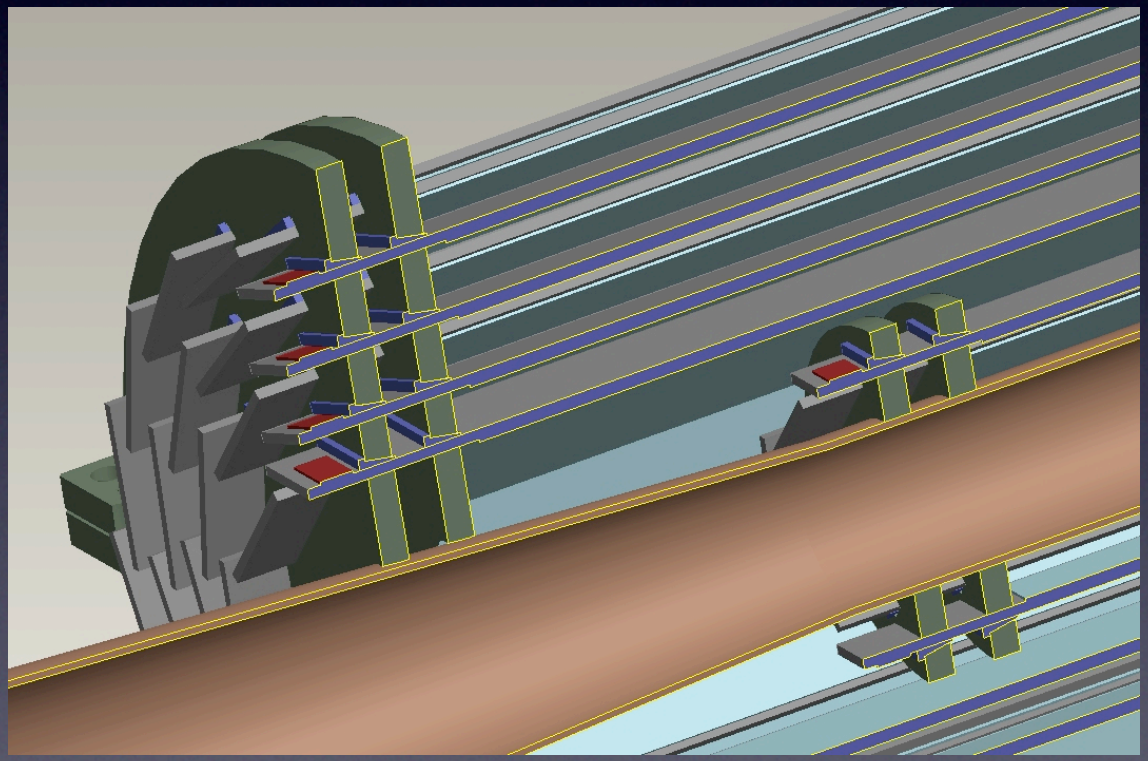
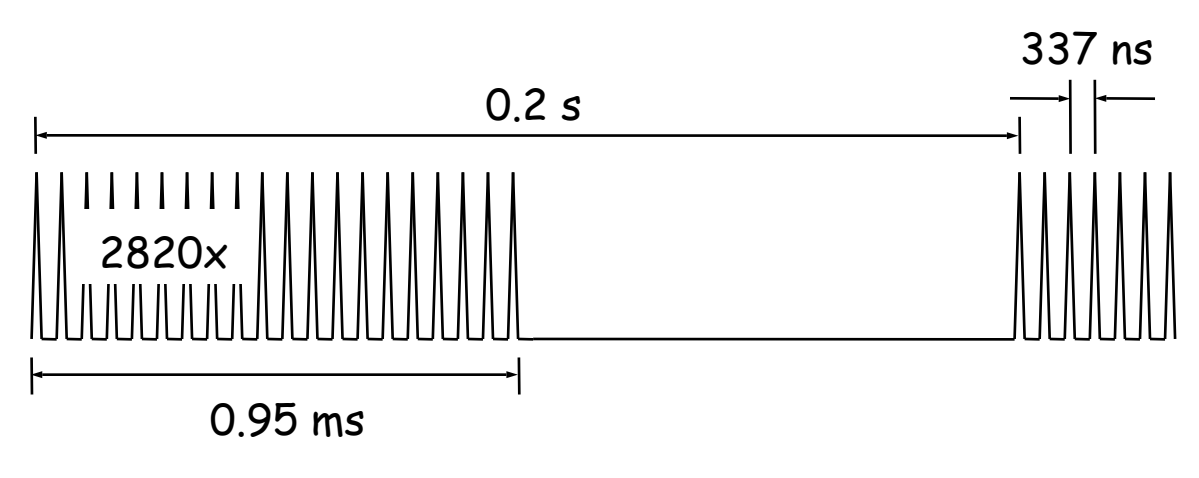


The ILC Challenge

ILC bunch structure:



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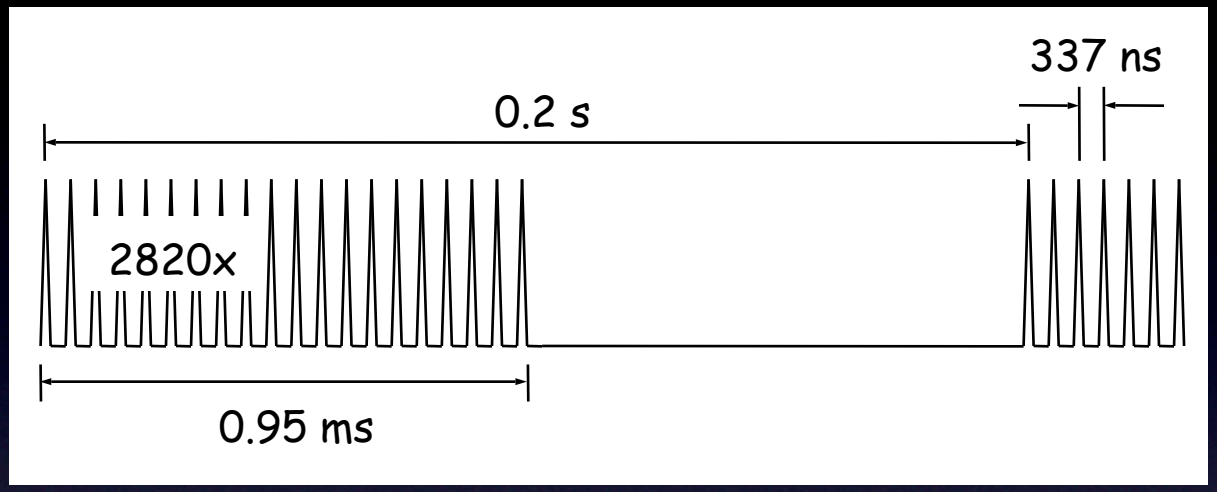

- Once per bunch = 300ns per frame : *too fast*

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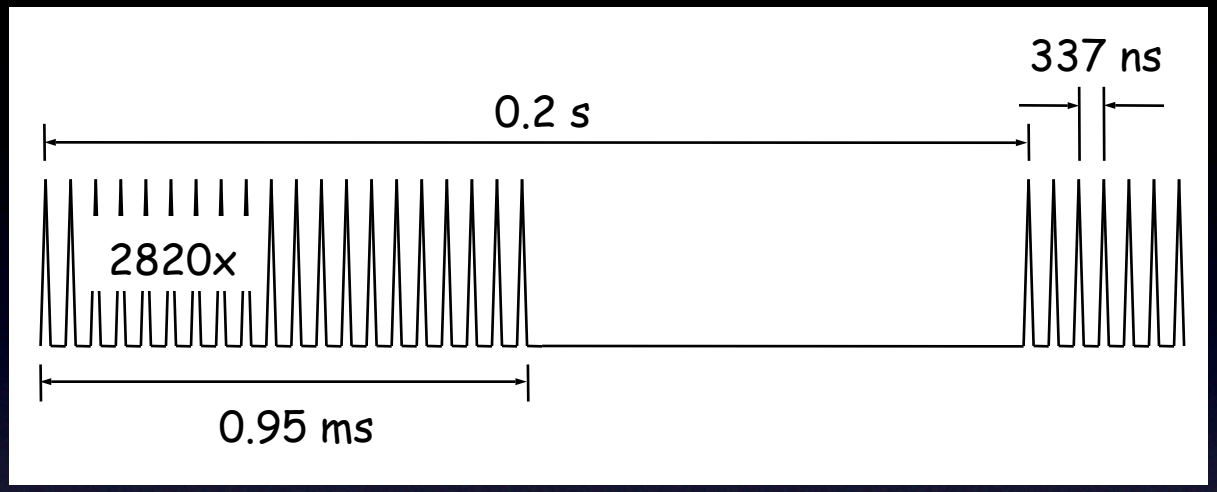

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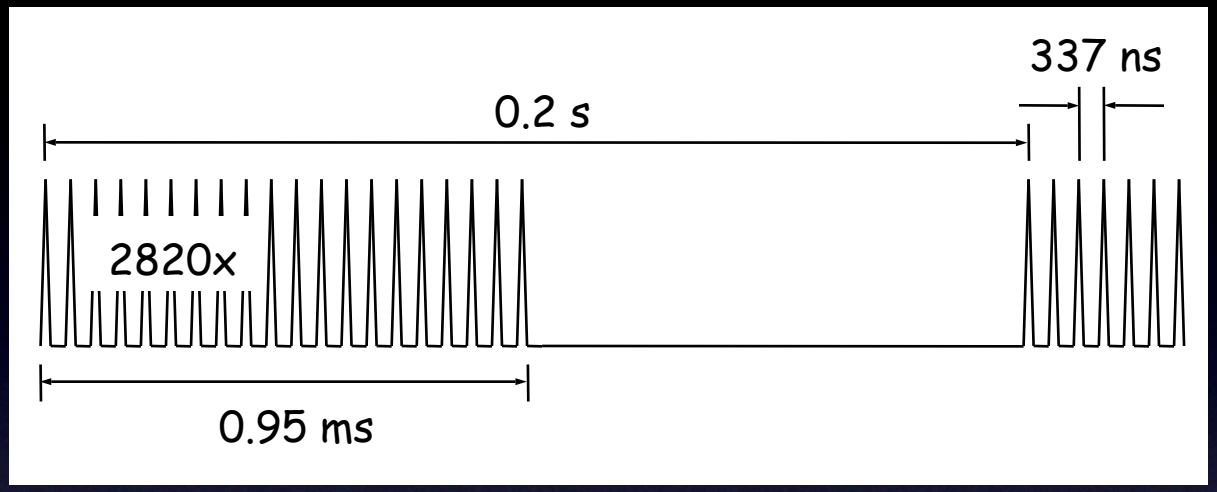

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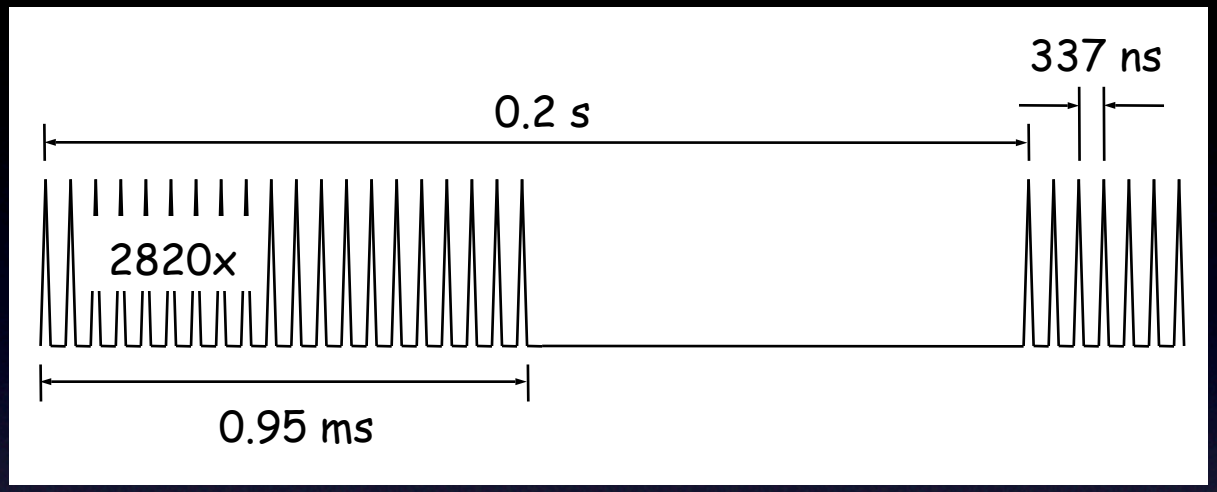

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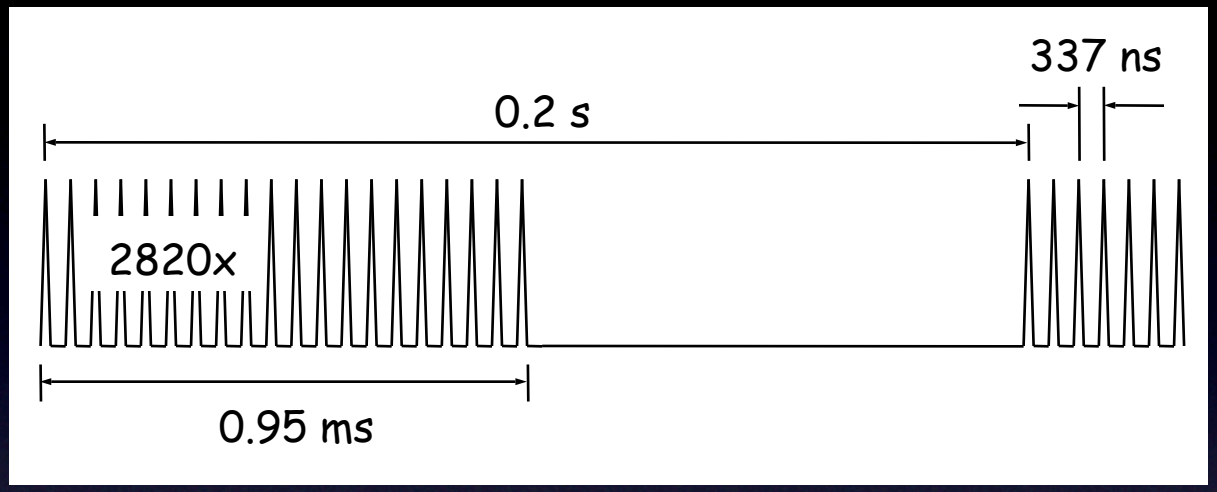

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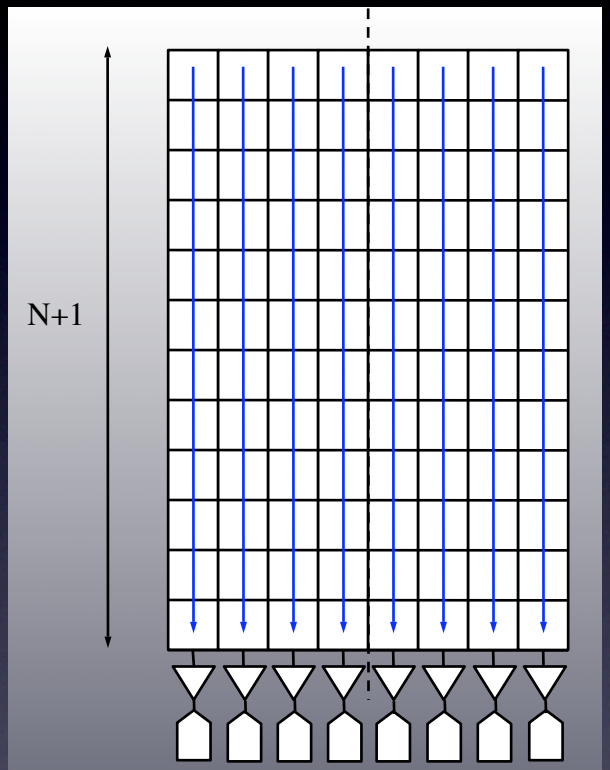
- *And gas cooled!*

Sensor R&D

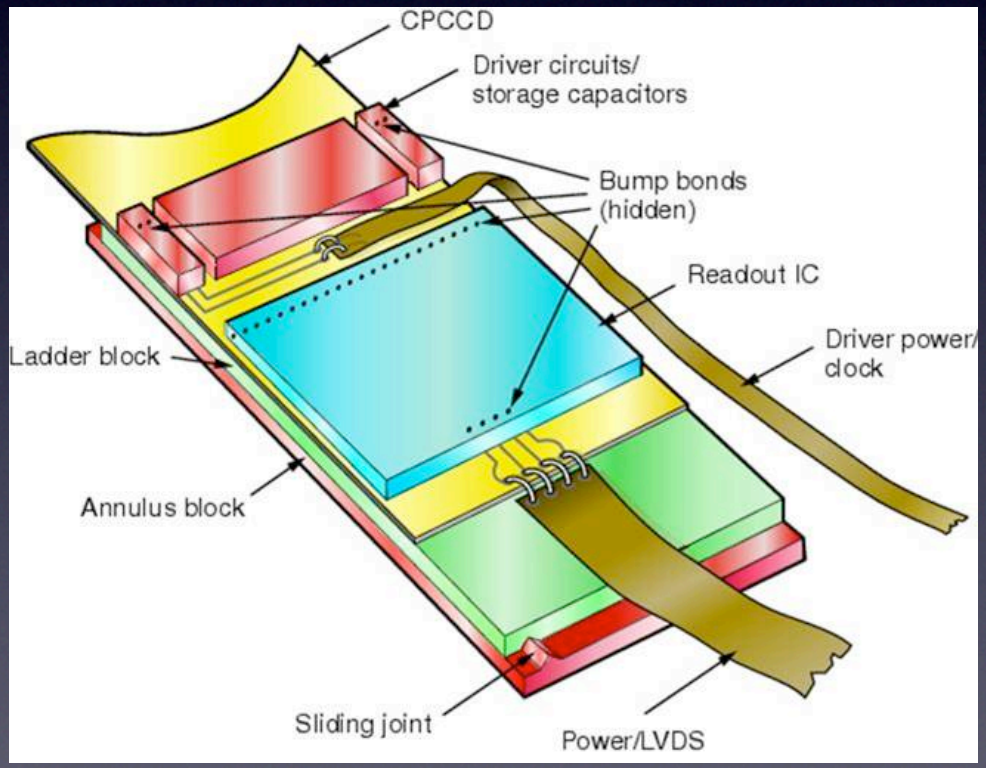
- Column Parallel CCDs
  - Focus so far - building on past experience
  - Readout during bunch train
- Image Sensor with In-situ Storage
  - Increased robustness
  - Reduced driver requirements

CP CCDs

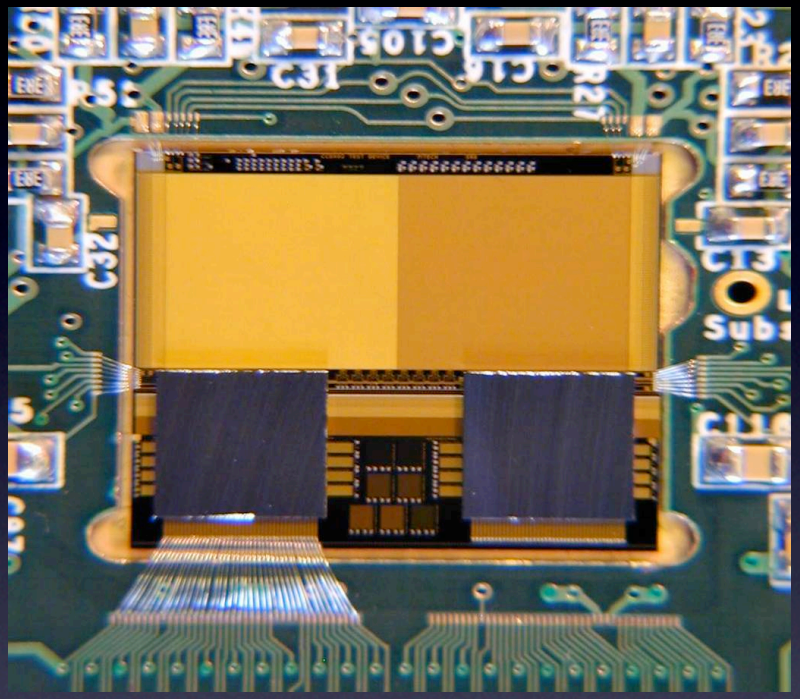
- Separate readout for each column
- 50 MHz clock rate
- Clock drive is real challenge



Column Parallel CCD
Readout time = $(N+1)/F_{out}$

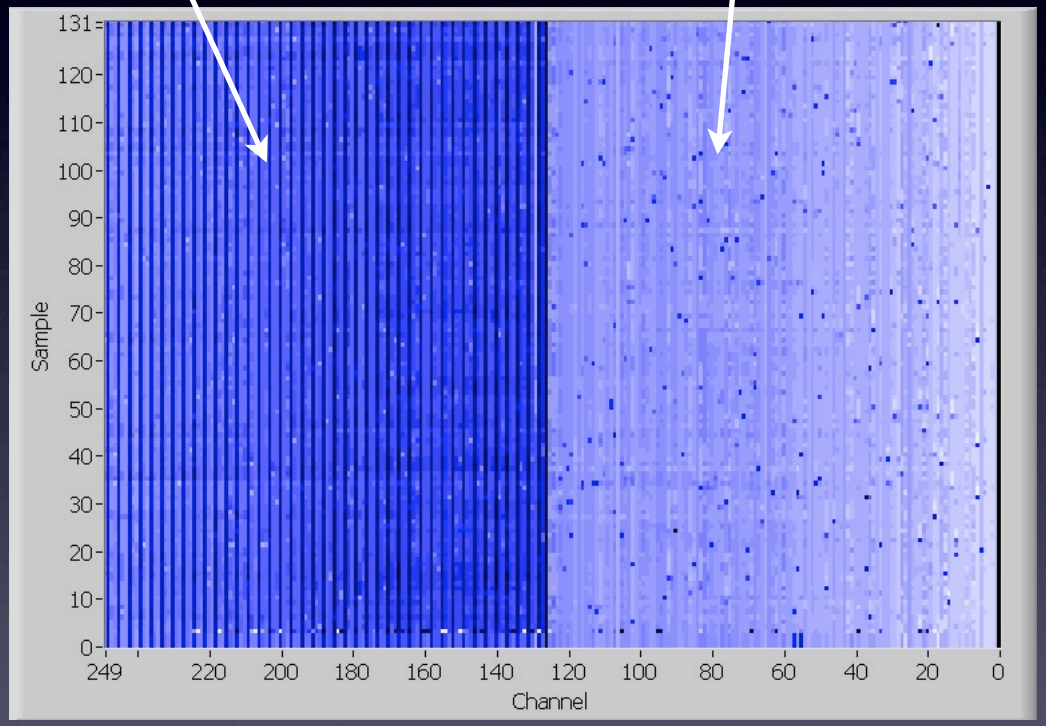


CPC-1



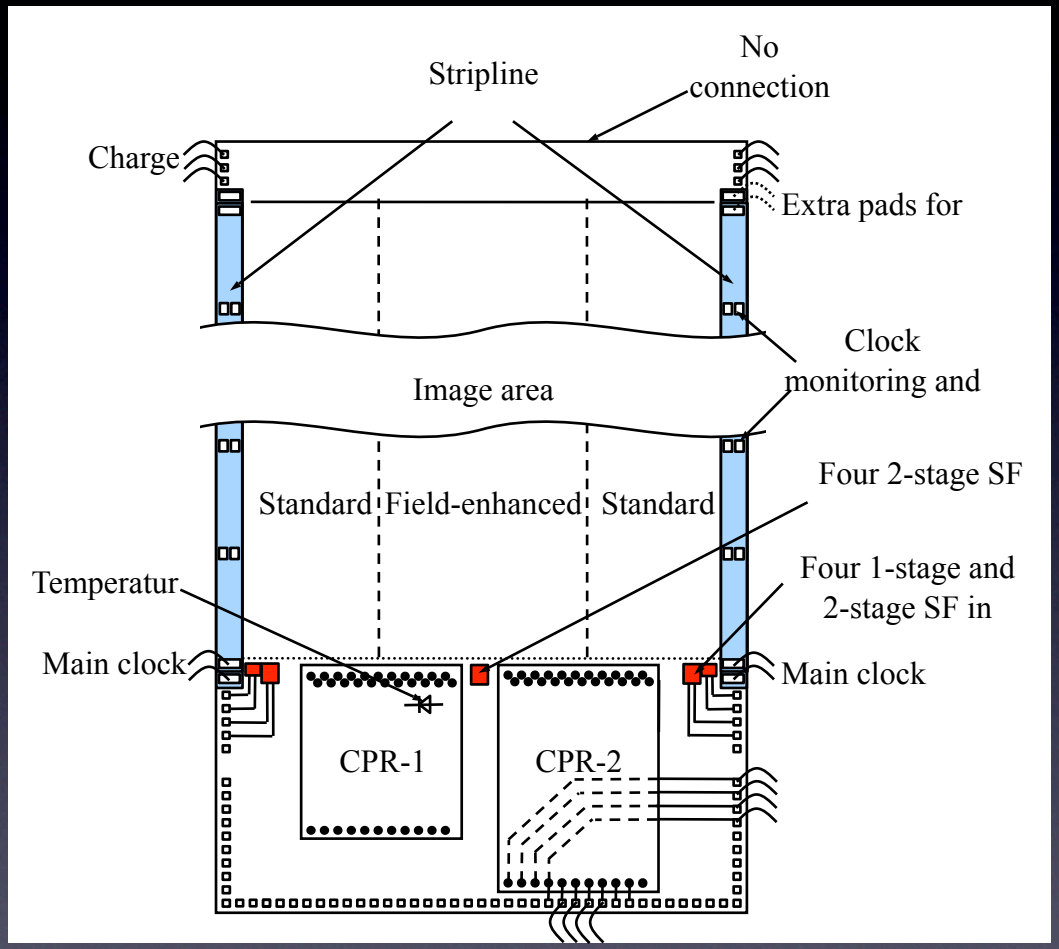
Charge Amplifiers (inverting)

Voltage Amplifiers (non-inverting)

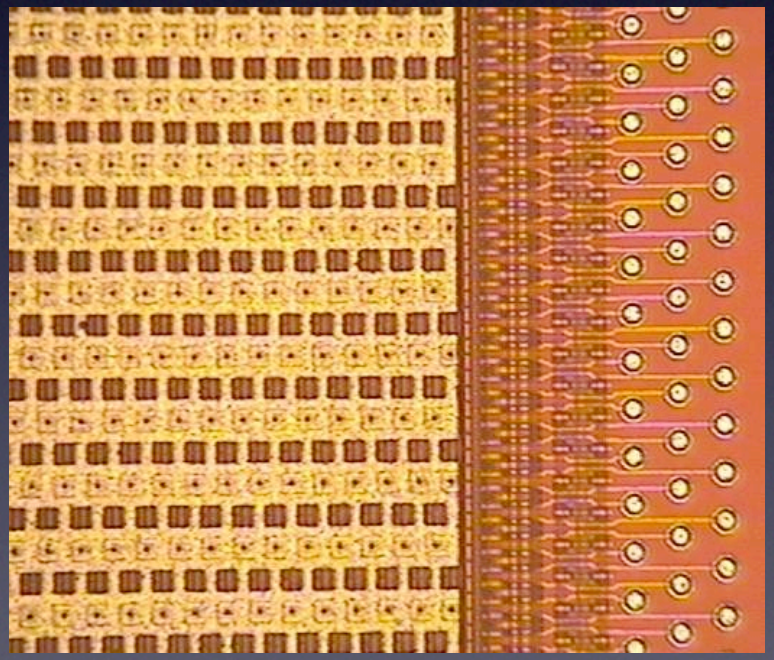


- RAL-designed ASIC
  - Bump-bonded on 20μm pitch
  - Latest has cluster finding

High Speed CPCCDs

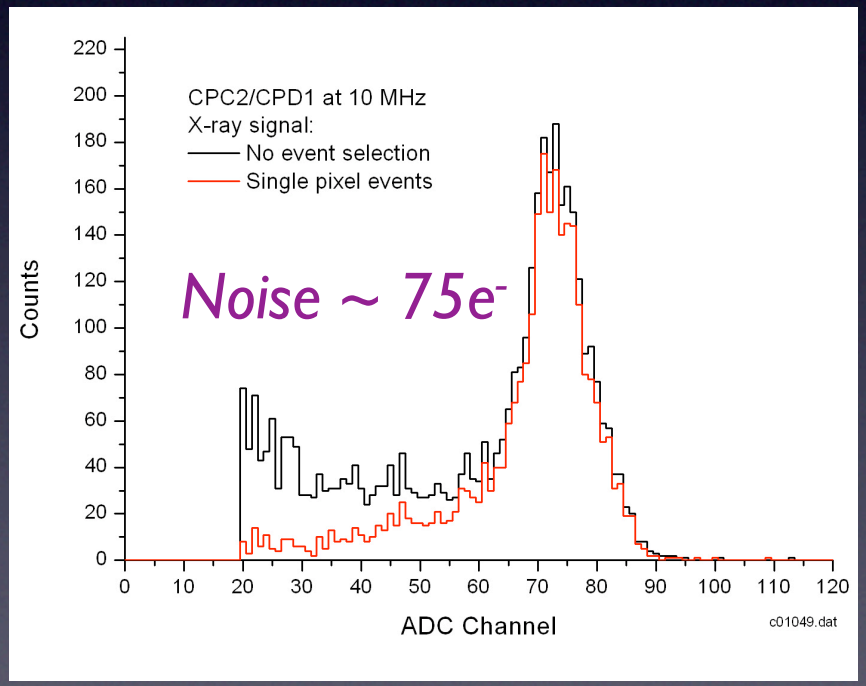


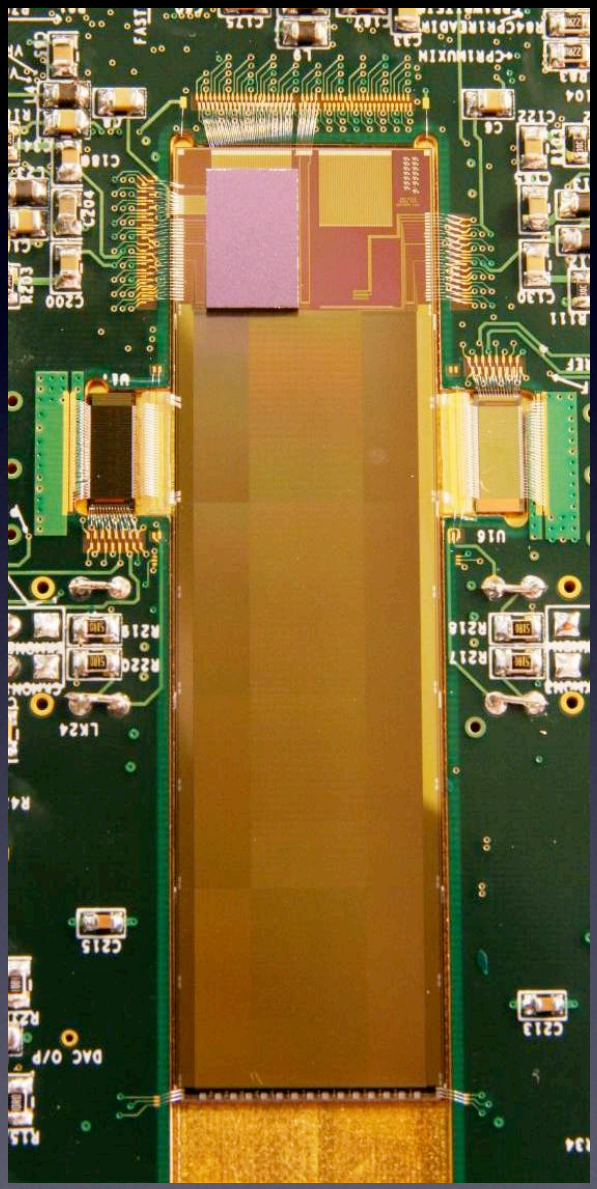
- Two metal layers
- Distributed clocks
  - Faster
  - More uniform
- Old and new ASICs



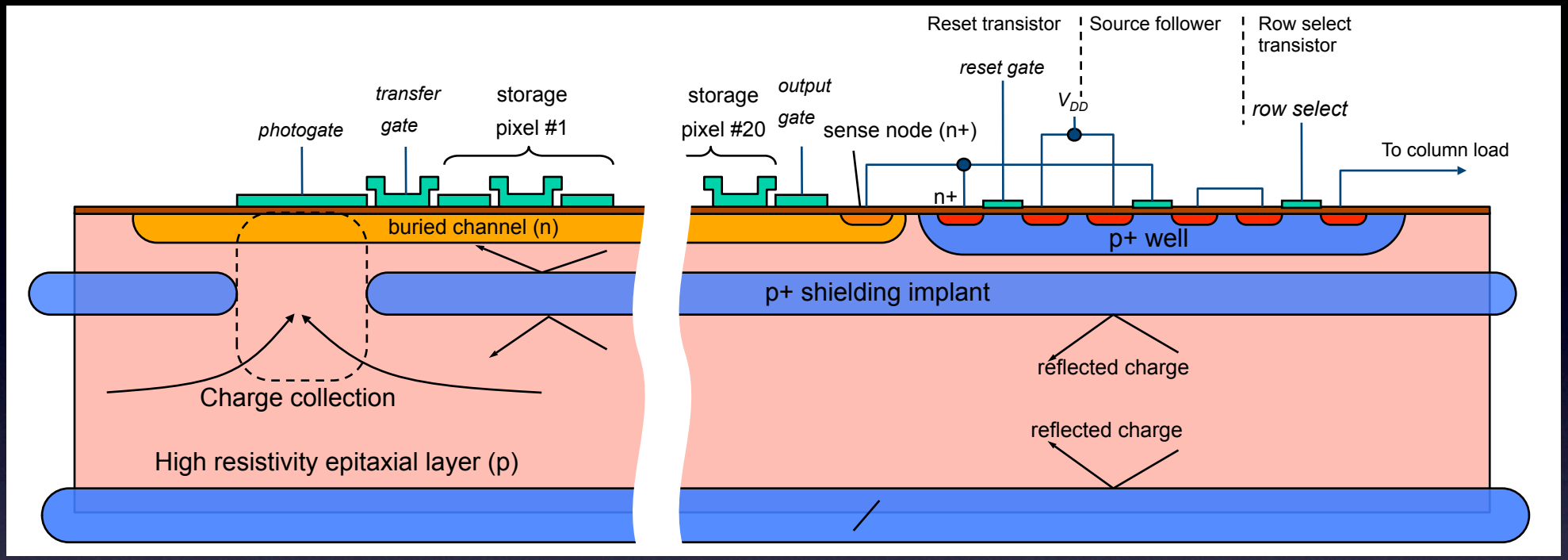
CPC-2

- 1, 4, 10 cm long variants
- Custom clock driver ASIC
- Tested up to 45 MHz





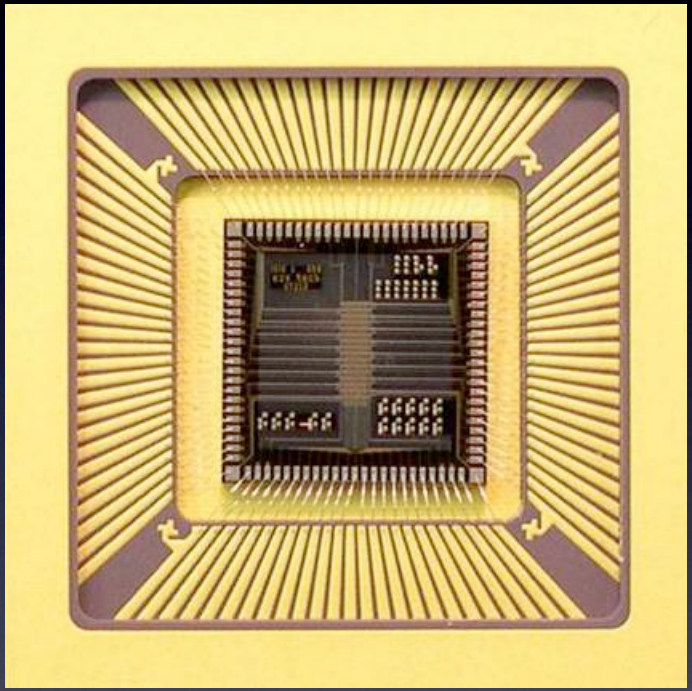
ISIS

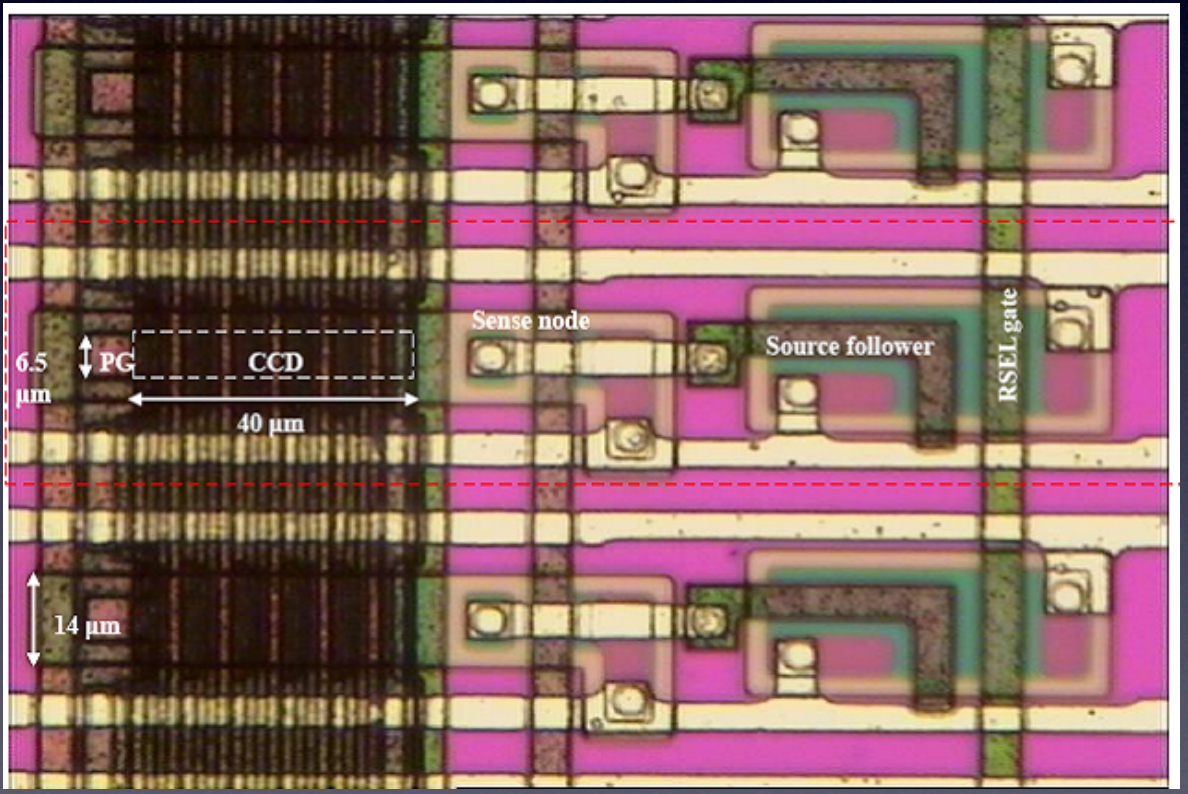


- Store charge in CCD register within each pixel
- Orders of magnitude increased resistance to RF
- Much reduced clocking requirements *(readout ~1MHz)*
- Combination of CCD and CMOS technology on small pitch

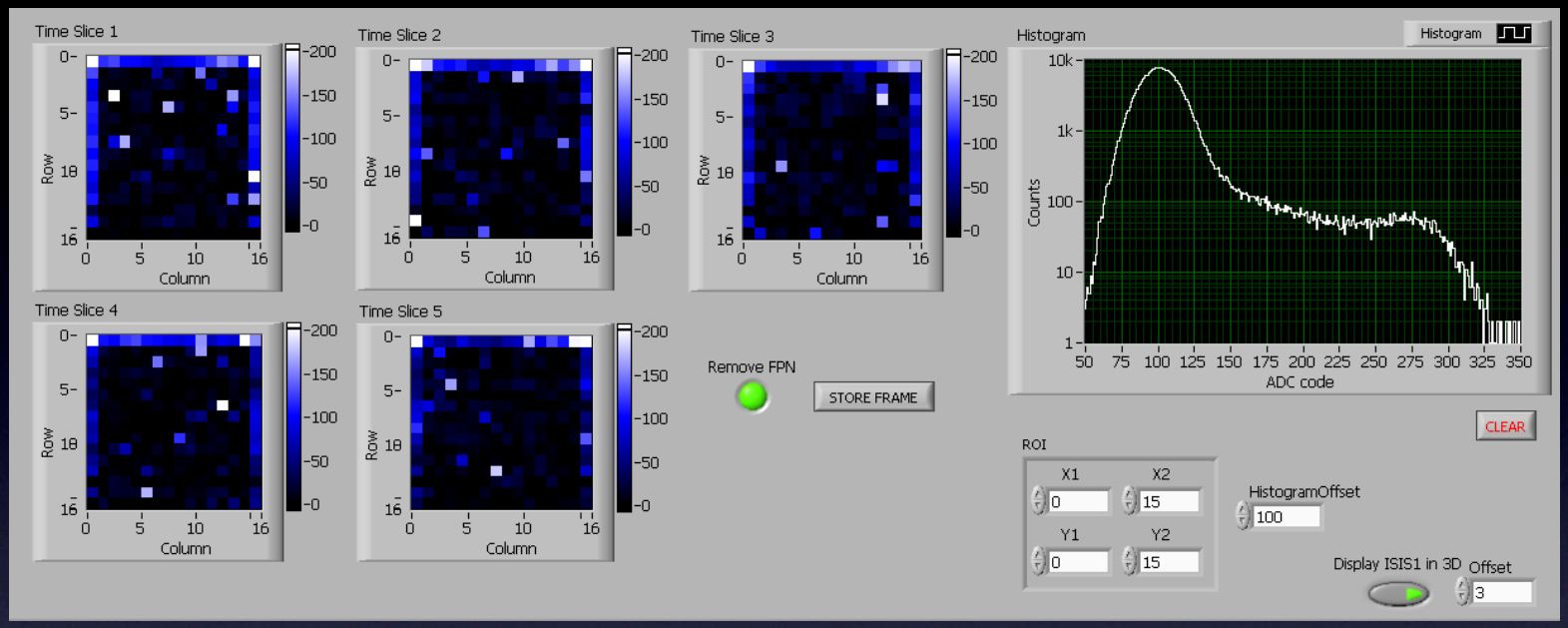
ISIS-1

- Proof-of-principle in CCD process
  - 16×16 array
  - 5 time samples

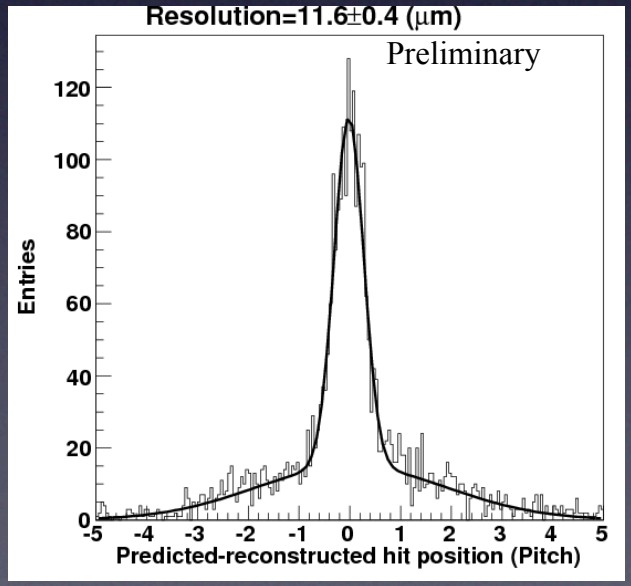




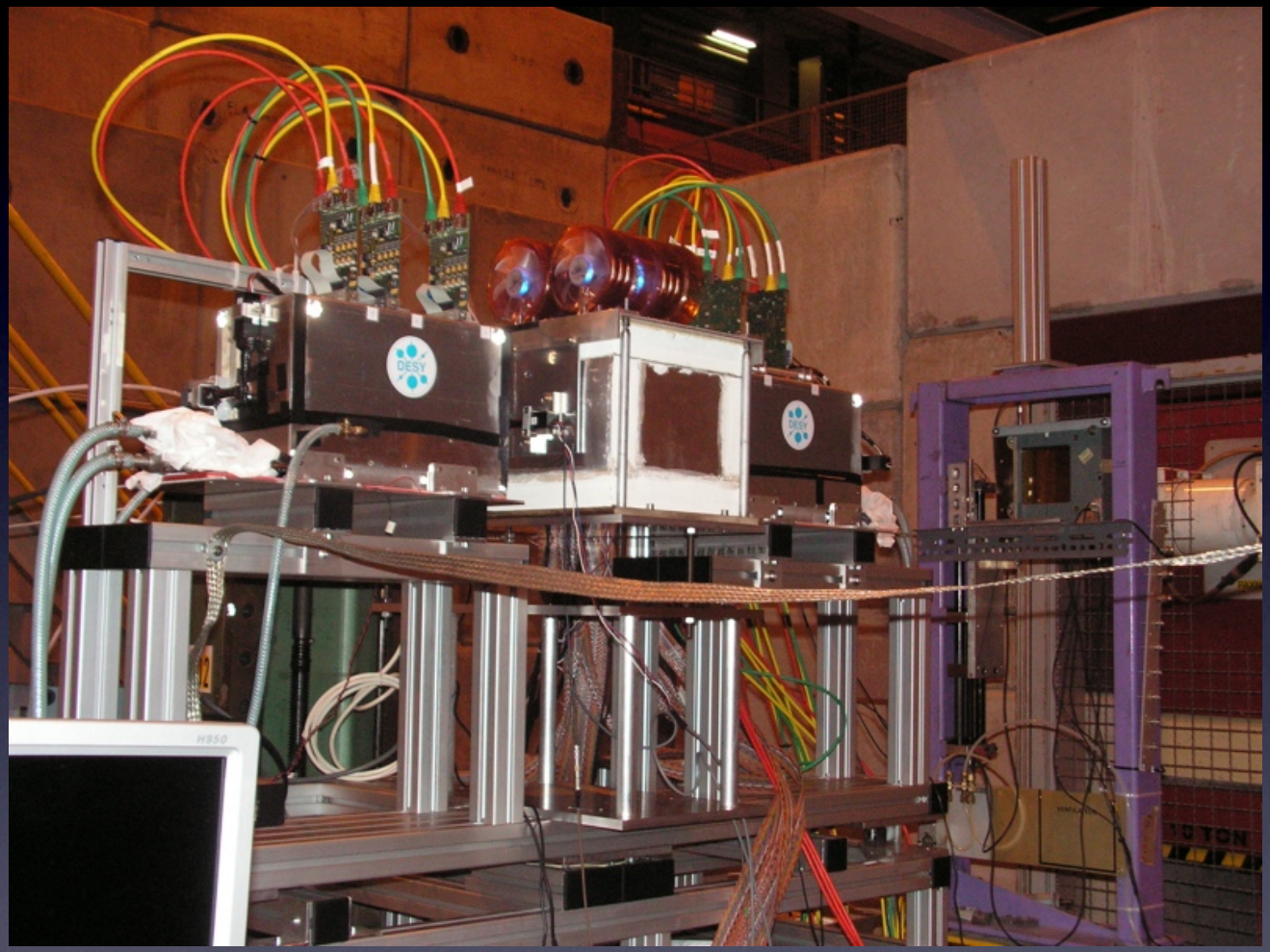
ISIS-1 Tests



- Tested with ^{55}Fe and 6 GeV e^-
- X-rays and MIPS clearly seen
- Position resolution ~ 12μm



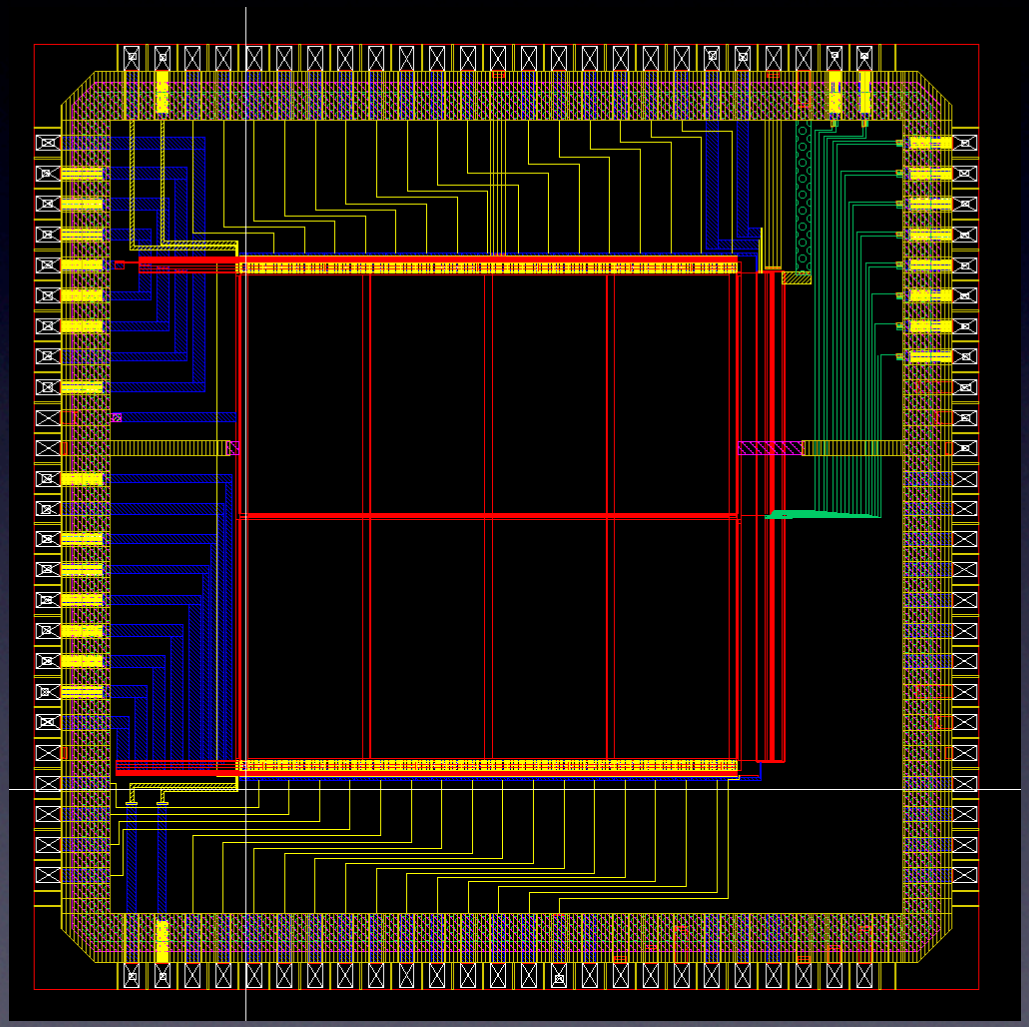
ISIS-1 at CERN



- Testing in CERN 120 GeV pion beam

ISIS-2

- Custom CMOS process
- 800μm^2 pixels
- 20 time samples
  - Close to targets
  - Wafers being diced



Summary

- Complete ILC vertex detector package
- Good progress in
  - Software and physics studies
  - Mechanics
  - Sensors
- Applicability beyond ILC
  - Continue much as generic R&D