Silicon sensors procurement and quality assurance
WBS 1.1.1

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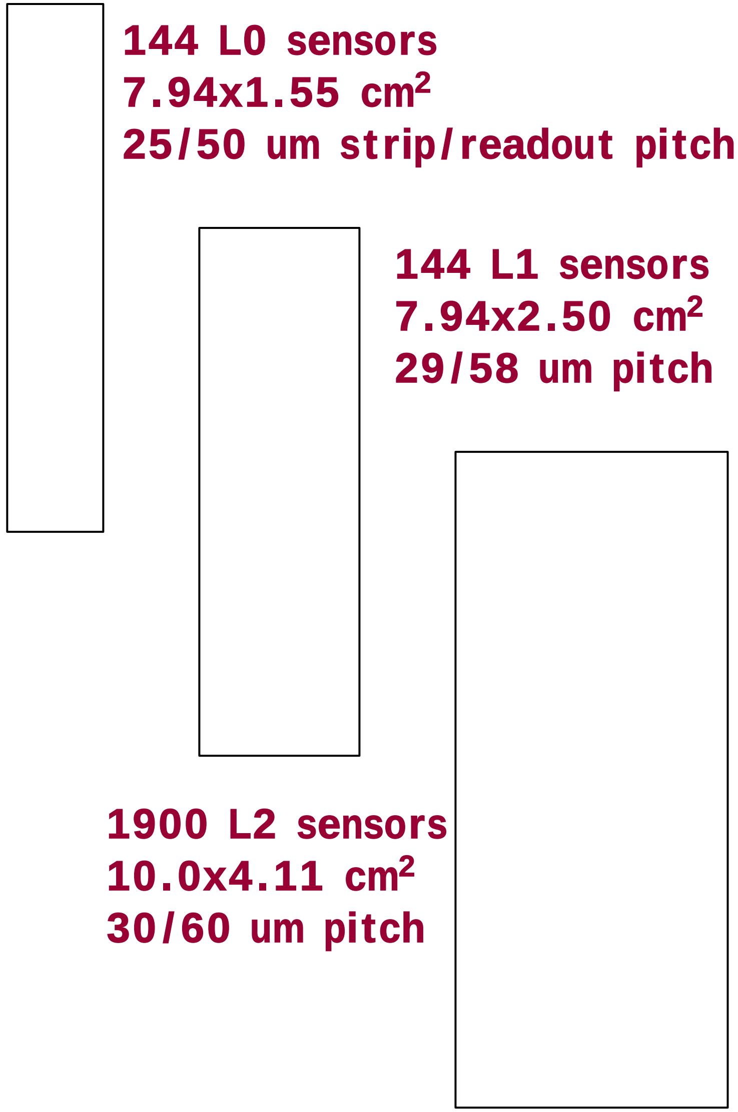
Outline

- Silicon sensor for Run IIb
- Radiation environment and silicon sensor specs
- Procurement strategy
- Quality assurance
- Irradiation studies and plans
- Conclusions

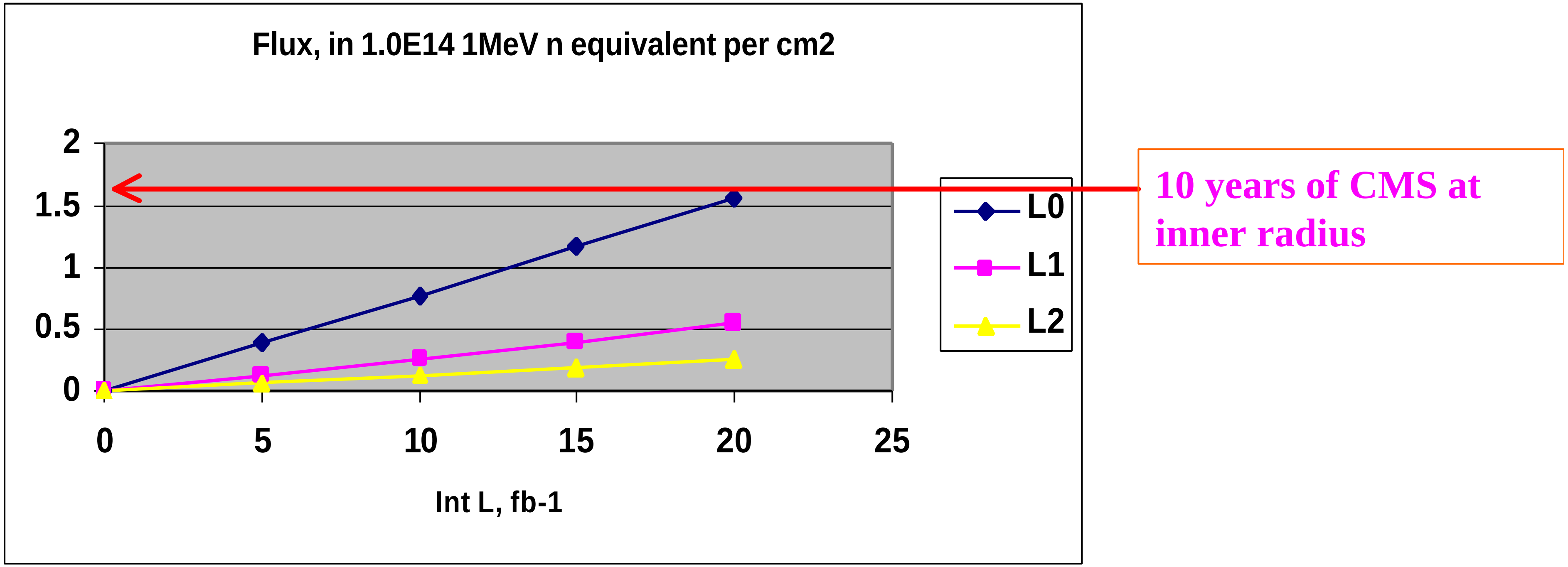
Silicon sensors for DØ IIb

- Very tight schedule → Simple, robust design
  - Single sided sensors
  - 3 sensor types – L0, L1, L2-5
- L0, L1
  - Inner radii → small sensors, high radiation
  - Essential for impact parameter resolution → fine pitch, intermediate strip
- L2-L5
  - Essential for efficient tracking → larger pitch, robust design
  - Large quantity → uniform design – one sensor type



Requirements for silicon sensors

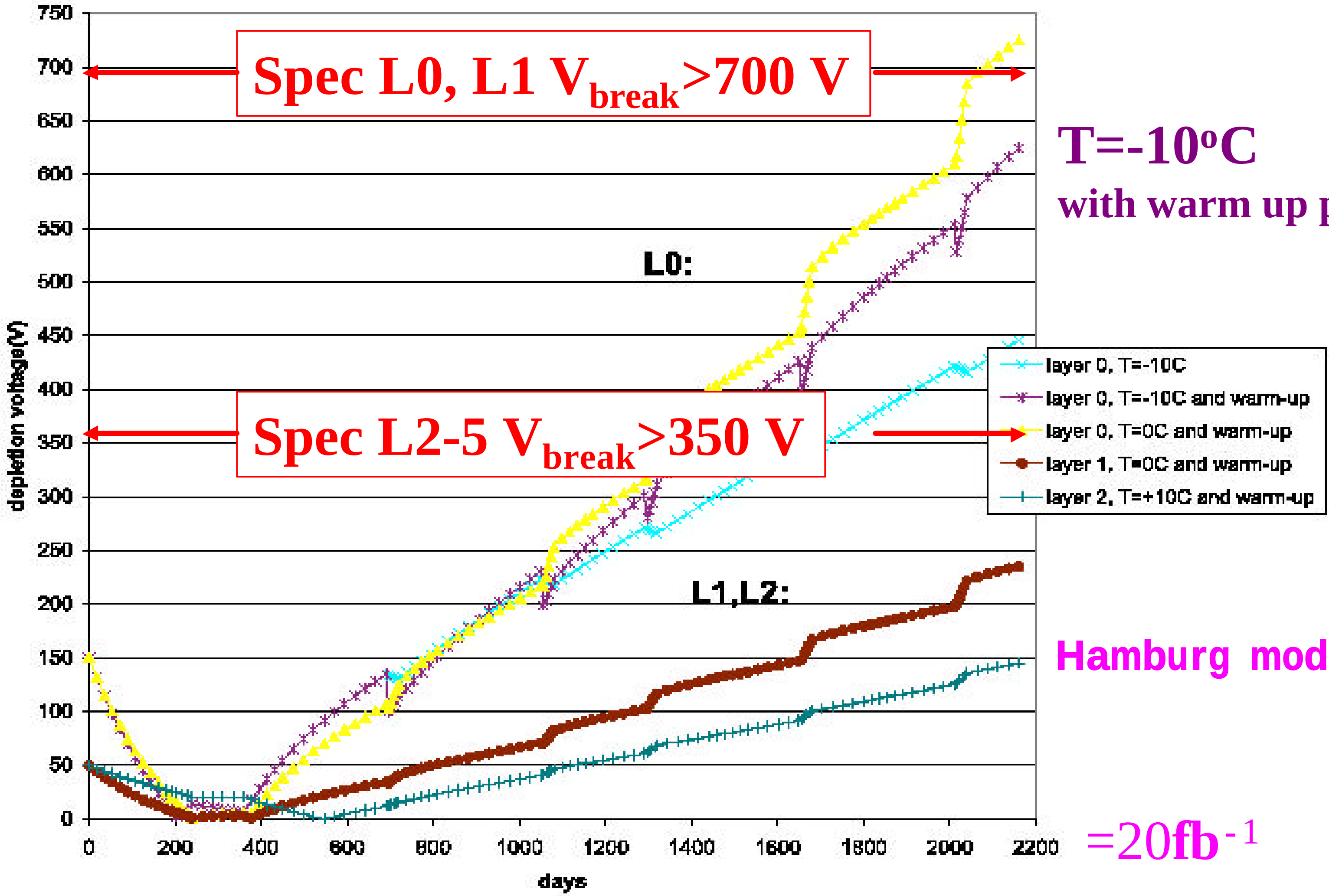
- Main challenge for silicon sensors - radiation
  - Depletion voltage (Φ)
  - Leakage current (Φ) → noise
- Doses comparable to LHC – use their R&D



- NB: Uncertainty in Φ estimate– conservative approach

Depletion voltage

Specification on breakdown voltage derived based on depletion voltage evolution

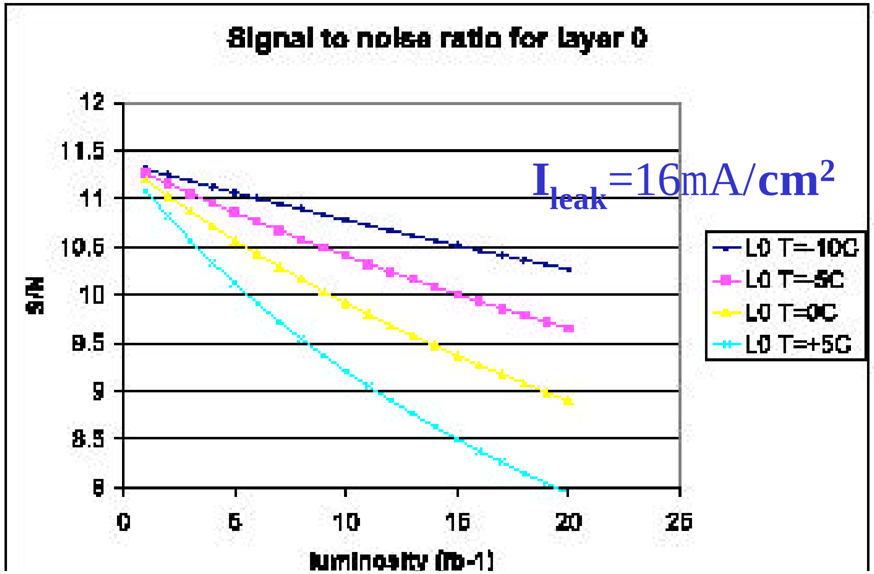


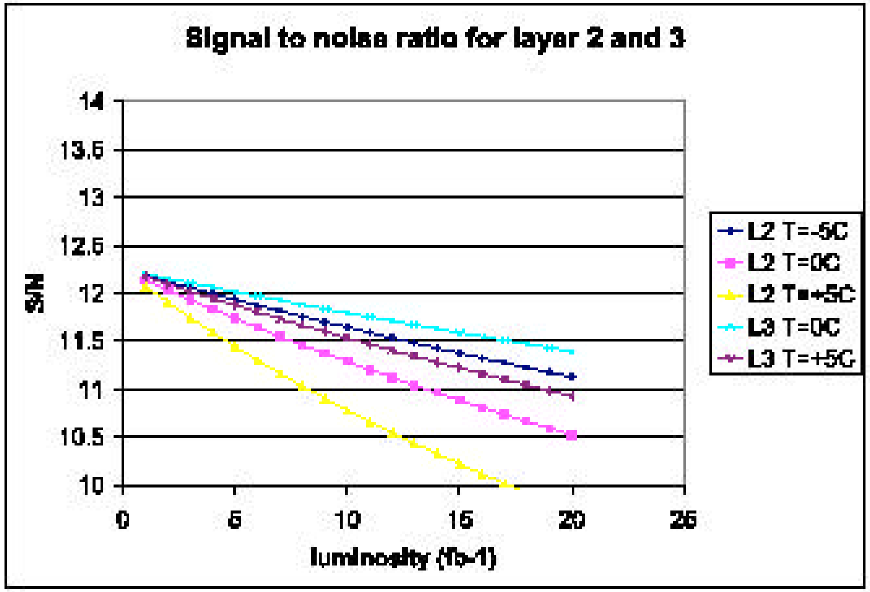
T=-10°C
with warm up periods

Hamburg model

$=20fb^{-1}$

Signal to noise ratio





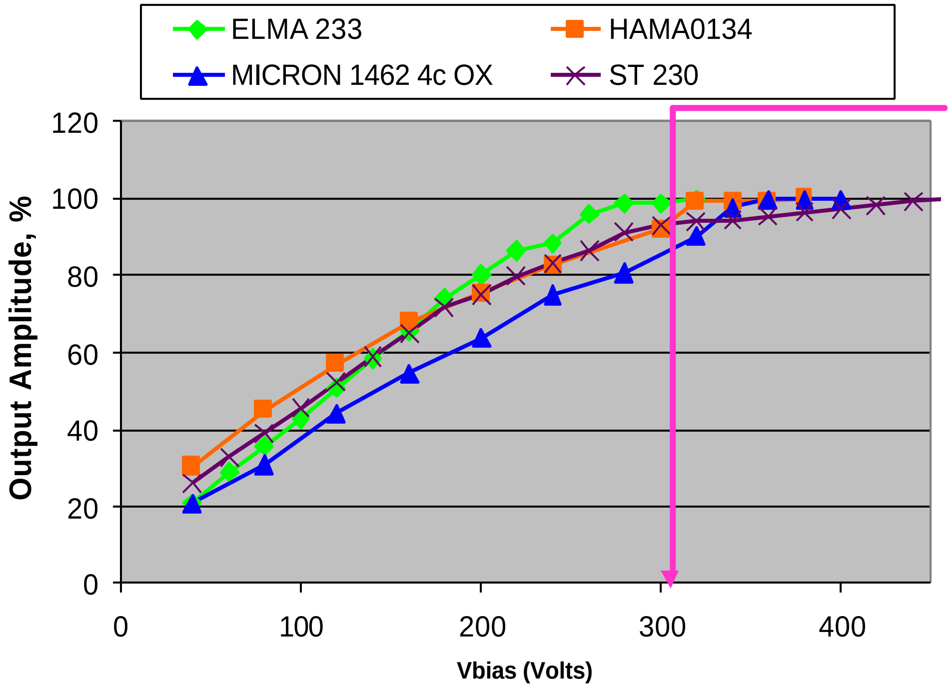
Noise contributions:

- Capacitive load: 450+43C(pF)
- Al strip resistance + analogue cables (L0)
- Shot noise $I_{leak}=I_0+\alpha F Ad$ (α=3E-17A/cm)
- Thermal noise in R_{bias}

Goal: S/N> 10
Possible if
T<-10°C for L0 and L1
T<-5°C for L2 – L5
Important to test I_{leak} after irradiation on prototype sensors and on test structures during production

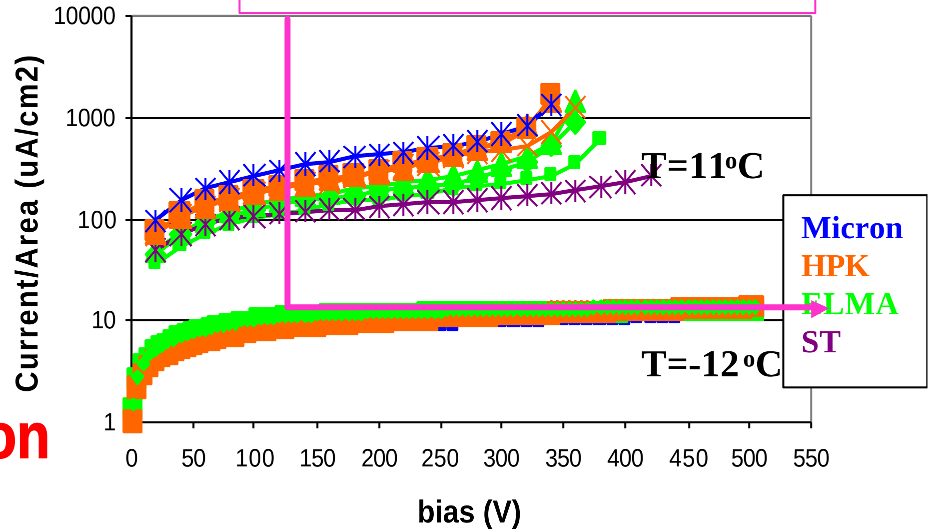
Radiation test results

- Sensors of L0-type geometry from 4 vendors (ELMA, HPK, ST, Micron) irradiated by 8 GeV proton beam – Fermilab booster area
- 10Mrad = 1.8 E14 1MeV n/cm^2 = 22 fb^{-1} at r=1.8cm



All sensors deplete at 300 V
Better than 600V used in estimations

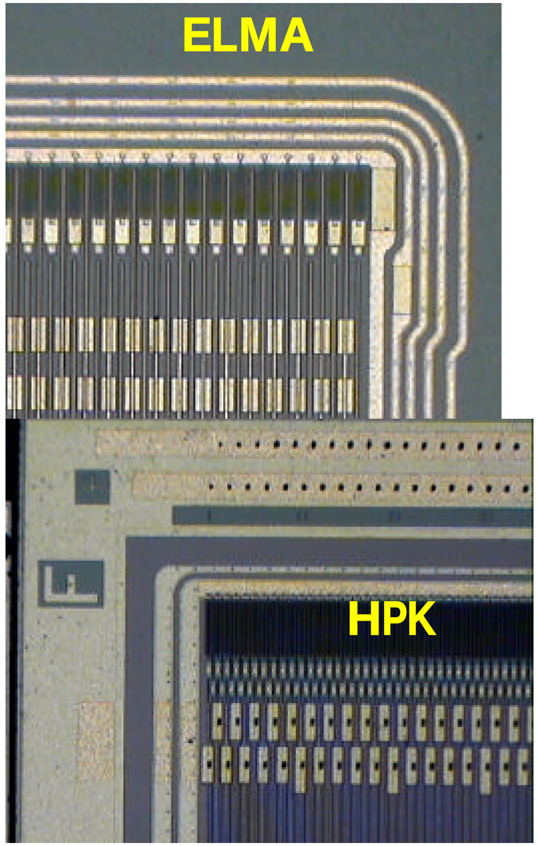
I_{leak}=16uA/cm^2 used in S/N calculation



Based on preliminary irradiation studies we expect our sensors to survive >22 fb^{-1}

Silicon sensors (L0, L1)

- single sided n+p
  - robust, simple, # of dead channels <1%
- pitch: 25 & 29 μm, every 2nd strip read out
  - improve single hit resolution
- integrated AC coupling and polysilicon bias resistor
  - both features work well after irradiation
- guard ring structure design for necessary radiation resistance:
  - either multi-guard ring structure
  - or single guard ring design with peripheral n-well (Hamamatsu development)
- overhanging metal on readout strips
  - significantly reduced risk of HV breakdown



Silicon sensors (L2-5)

- wafer:
  - 6”-wafer, n-type silicon, crystal orientation <100>
  - thickness 320±20mm
  - wafer warp less than 50mm
- depletion voltage: full depletion (FDV)<300V
- leakage currents:
  - <100nA/cm2 at FDV and RT
  - total <16mA at 350V
  - junction breakdown > 350V
- implant width 8mm with 2-3mm Al-overhang on R/O strips
- coupling capacitance > 10pF/cm
- interstrip capacitance <1.2pF/cm
- Polysilicon resistor 0.8±0.3 MW
- bad strips: <1%

Silicon sensor procurement strategy

Sensor design is essentially complete (FNAL, U Zurich, Moscow, KSU)
Prototypes ordered for all sensor types

L0 and L1 sensors

- critical for radiation → Qualify two vendors – HPK and ELMA
- prototypes received from ELMA,
- undergoing tests
- 2 L1 sensors used in full module prototype
- Choose vendor after irradiation of L1 ELMA and HPK sensors

L2-L5 sensors

large sensors, large quantity, more straight forward design → benefit from 6” technology One vendor – HPK

- Cost and schedule drivers
- Very conservative design, experienced vendor → low to moderate risk

Silicon sensor quality assurance program (QA)

- QA measurements
  - Key tests
    - leakage currents, depletion voltage and visual inspections
    - 100% on all prototypes and L0,L1 production, 10% on L2 production
  - Sensor subset tests
    - Leakage current stability over time, AC- and DC-scans, Rpoly
    - 100% on all prototypes, 10% on all production
  - Sensor diagnostic tests
    - detailed evaluation of sensors (e.g. interstrip C, R)
    - routinely done on small sample and on sensors missing specs to provide detailed feedback to vendor
  - Mechanical tests (on OGP at FNAL)
    - sensor thickness, warp and cut dimensions/accuracy
  - Irradiation tests on small subset of prototypes and test structures.

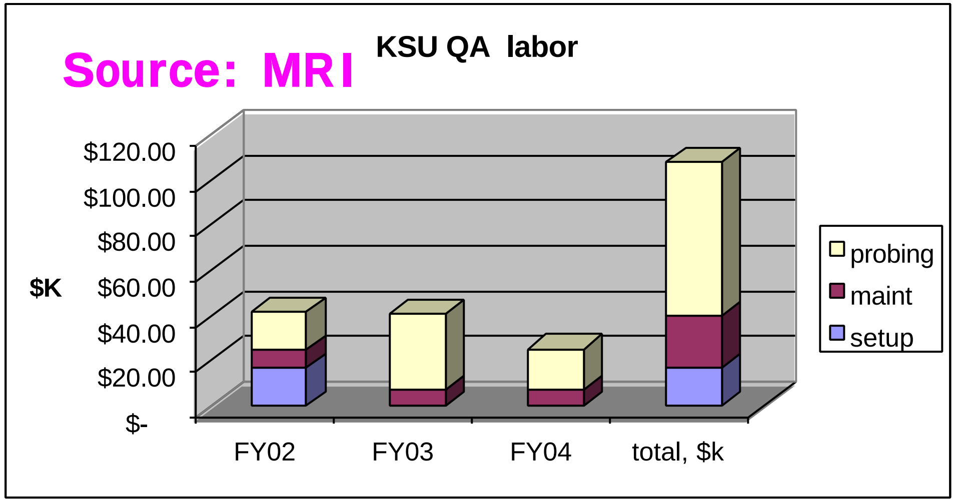
QA sites

Probing sites:

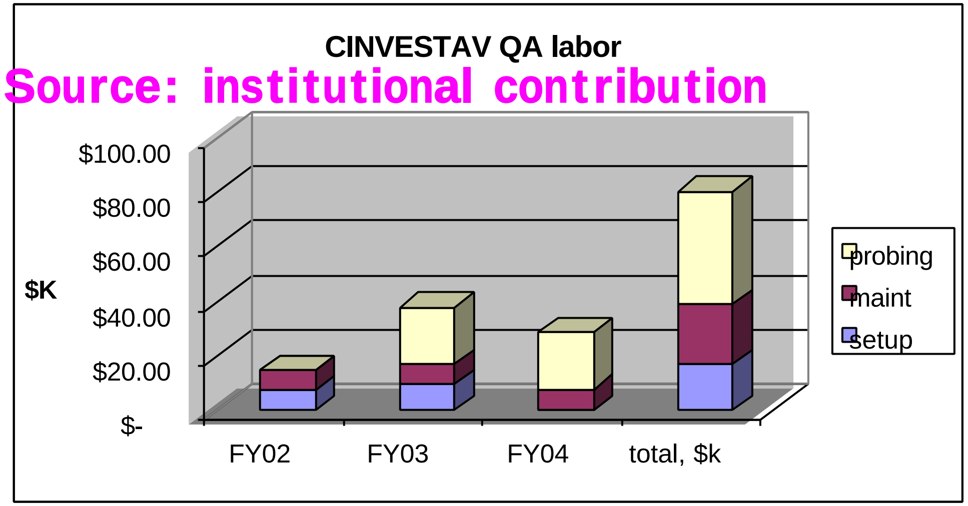
- KSU – setup complete, work on L0 and L1 prototypes underway
- SUNY at Stony Brook – setup in progress
- CINVESTAV in Mexico – setup in progress
- Fermilab – receiving, distributing, equipment exists
- Two back up sites – U of Zurich and Moscow State
- Equipment
  - Vibration-free table
  - R61 Alessi probe station
  - Keithley 237 ammeter/voltage source
  - HP4284 LCR meter GPIB interface
  - Dark box (not shown)
  - Guard box
  - Lab view based software

QA schedule and manpower

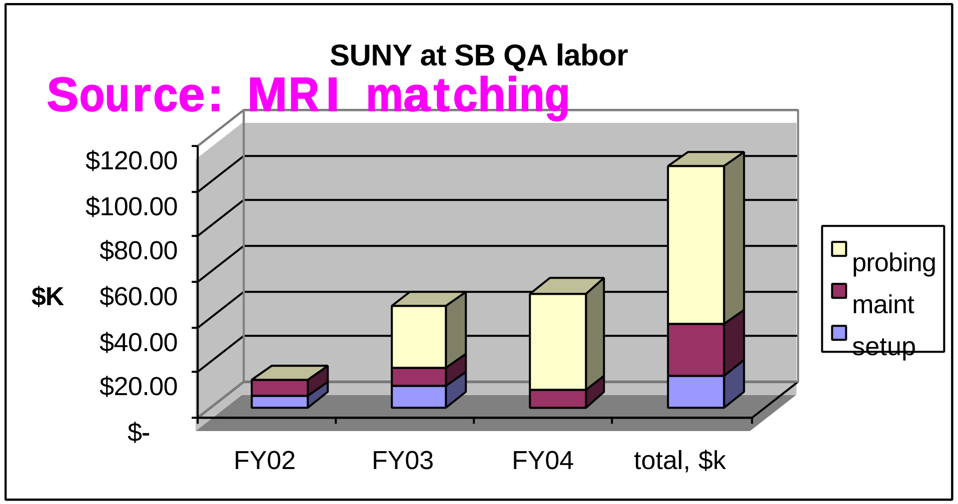
Source: MRI



Source: institutional contribution



Source: MRI matching



- BOE – experience with Run 2b prototypes, Run 2a and CMS sensors
- ~1 technician FTE/institution for 3 years, 3 tasks – setup, maintenance, probing
- Manpower for QA is identified at all sites

Irradiation at KSU JRM

Goals:

- Irradiation of prototype sensors to ensure sound technology and vendor choice
- Irradiation of test structures during production to ensure high quality of delivered sensors
- Possibly do a joint study of the "CDF" effect

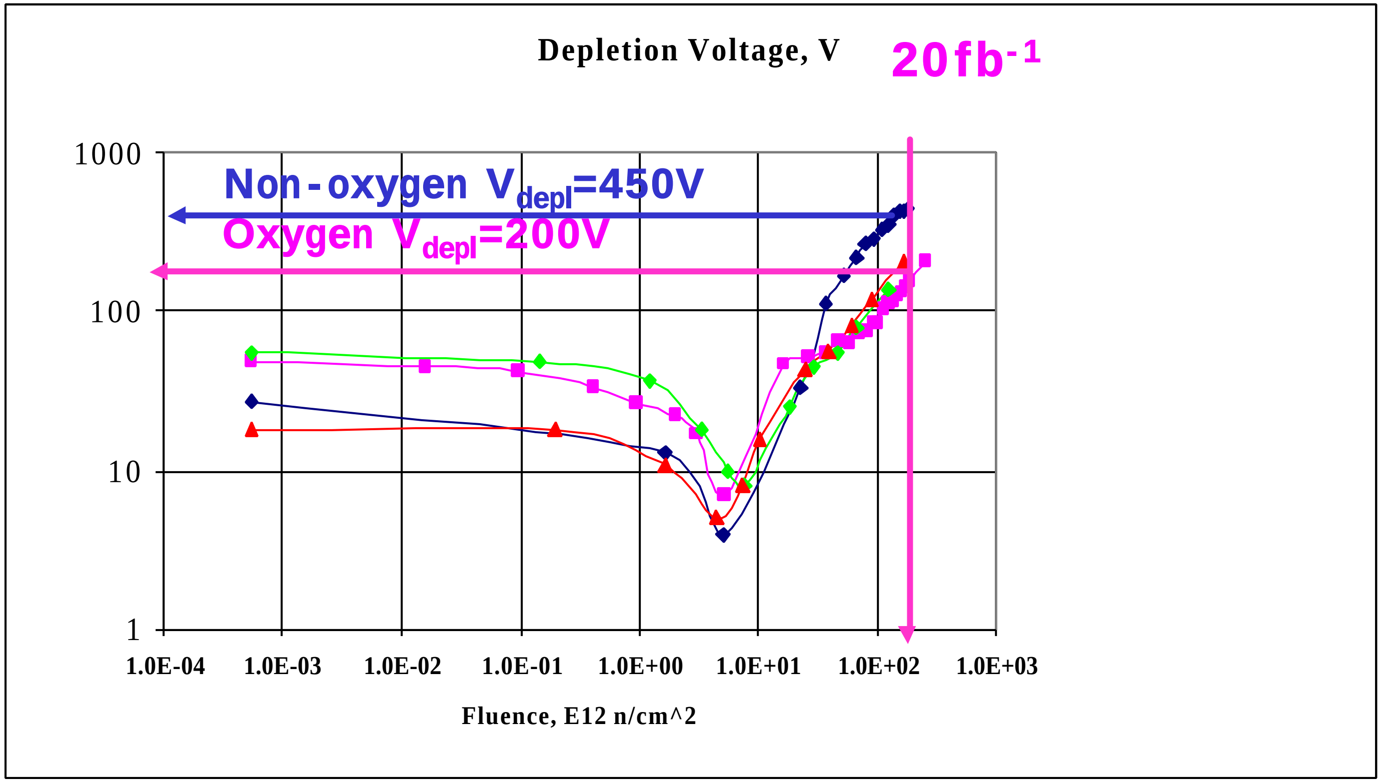
Facility: James R Macdonald lab at KSU

- 5-15 MeV proton beam
- Beam swept by electrostatic deflector for uniform irradiation
- can vary intensity to receive up to 1 Mrad/hour

Preliminary results from JRM

4 ELMA L0 prototype sensors – 3 oxygenated, 1 non-oxygenated irradiated to 1.8E14 n/cm^2

Preliminary results from JRM agree with earlier tests. Sensors are expected to last >20fb^{-1}



Conclusions

- Use simple design, established technology, experienced vendors
- Sensor design is essentially complete
- Orders placed for all prototypes
- First L0 and L1 prototypes received and are tested
- Irradiation facility setup is essentially complete
- Based on irradiation tests at Fermilab and at KSU sensors are expected to survive >20fb^{-1} of luminosity
- QA procedures are defined, one QA site setup is complete, two others in progress
- Manpower for QA and irradiation is estimated using prior experience, personnel is identified
- Silicon sensor schedule risk is low to moderate