The H1 Silicon Tracker

Benno List

ETH Institute for Particle Physics

Tracking In High Multiplicity Environments

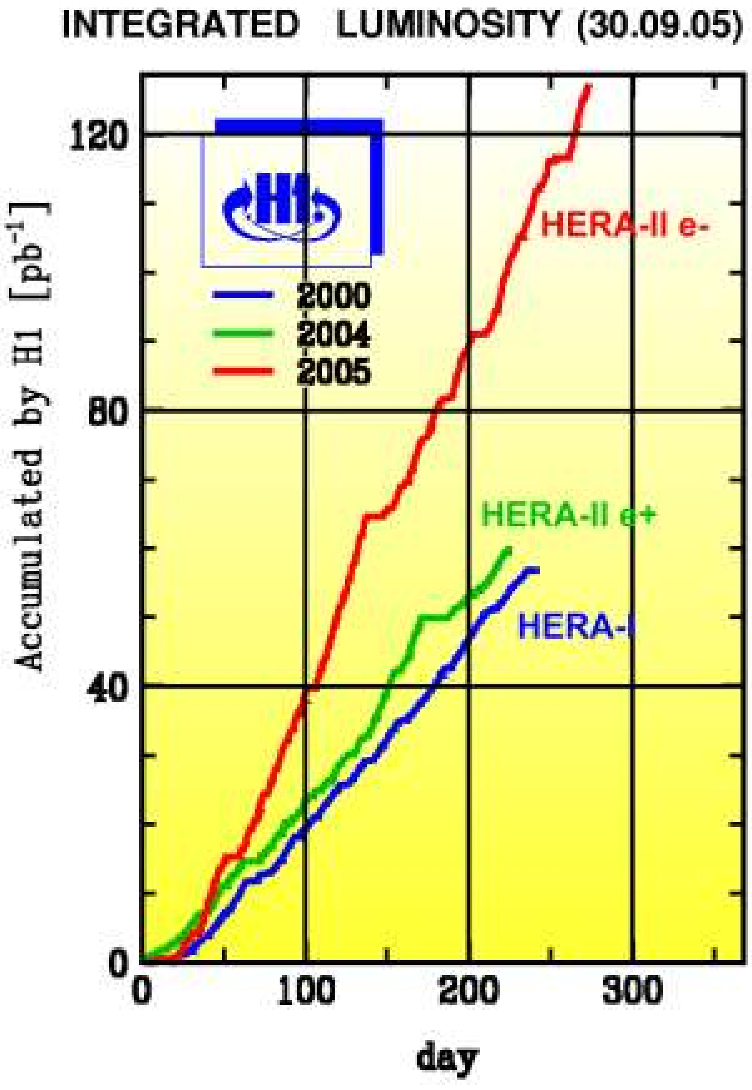
03-07 October 2005 Zurich, Switzerland

4.10.2005

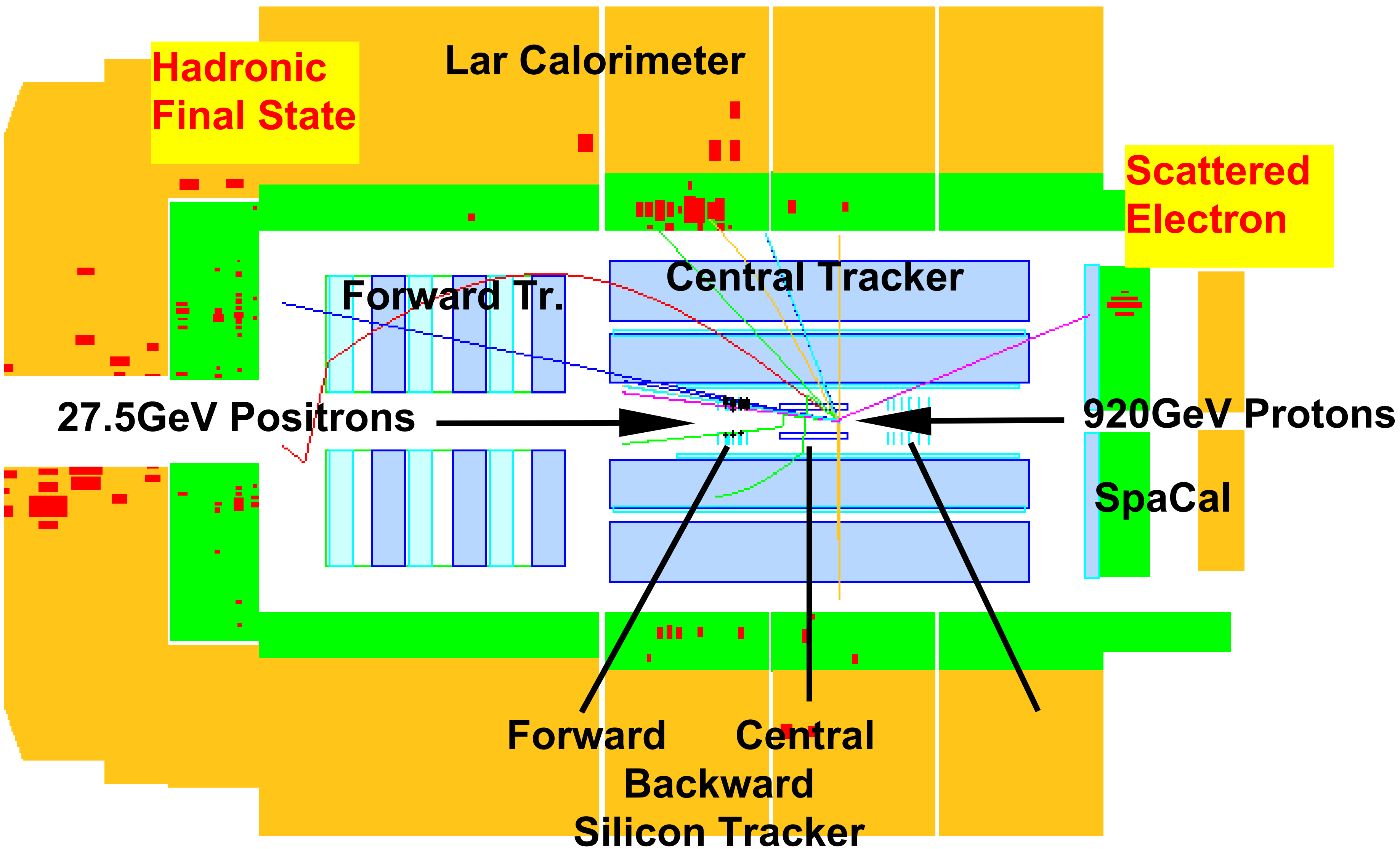
- HERA and H1
- The H1 silicon tracker
- Recent results
- Water damage
- Radiation damage

The HERA ep Collider

- Located at DESY in Hamburg
- 27.5 GeV electrons/positrons on 920 GeV protons
- HERA-I: 1992-2000, 120pb^{-1}
- 2000: Luminosity upgrade
- HERA-II: 2001-2007

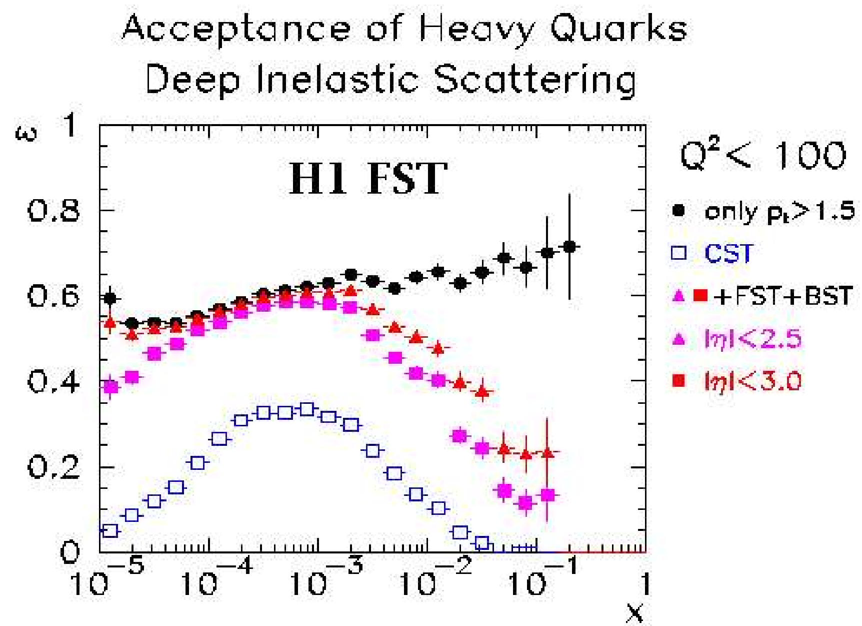


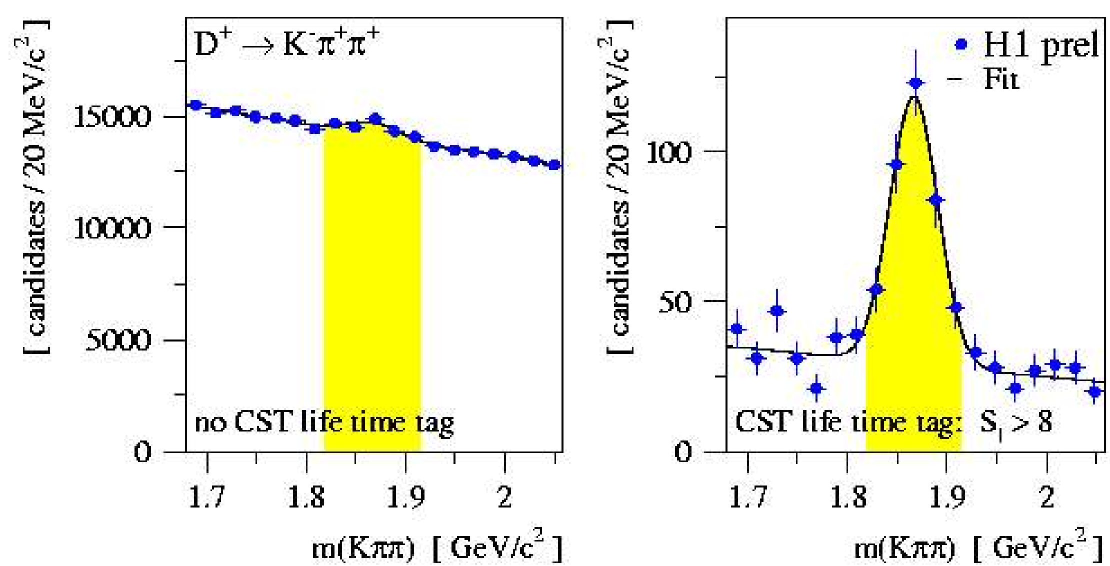
The H1 Detector



Physics Requirements (I)

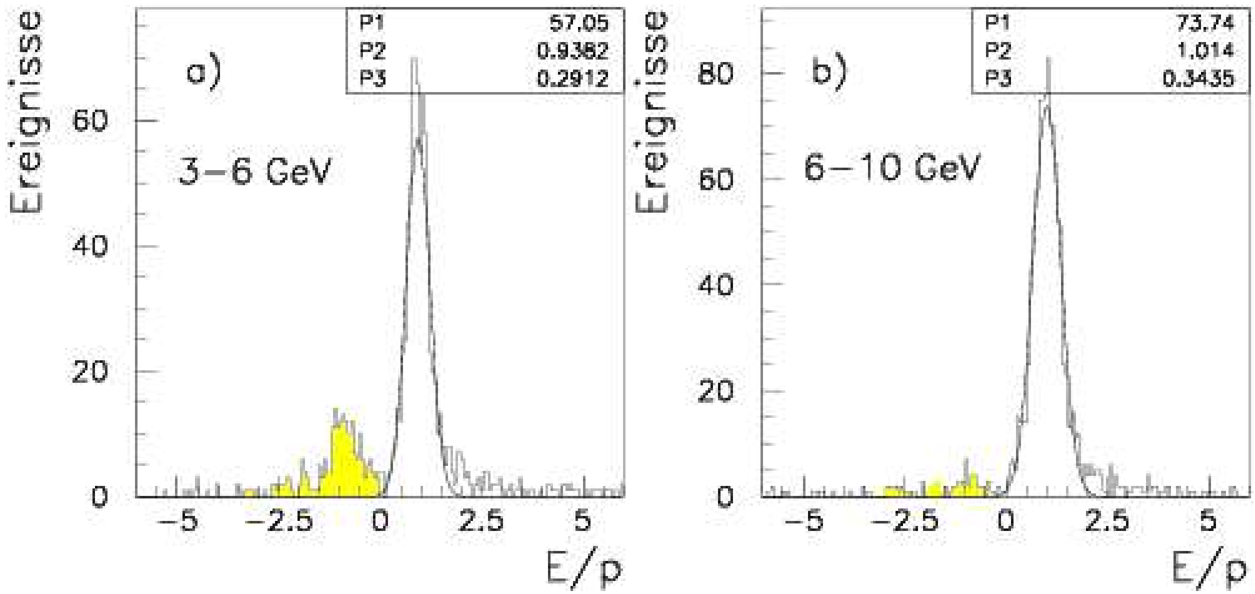
- **FST:**
  - Extend tracking (with vertexing capability) into forward direction: high track density!
    => good pattern recognition
- **CST:**
  - Provide vertexing capability in central region (charm, beauty)
  - Resolution dominated by multiple scattering: thin detector!





Physics Requirements (II)

- BST:
  - Measure and trigger scattered electron at low angles: suppress fake electrons from $\pi^0 \rightarrow \gamma\gamma$
  - Generally low track density in backward direction



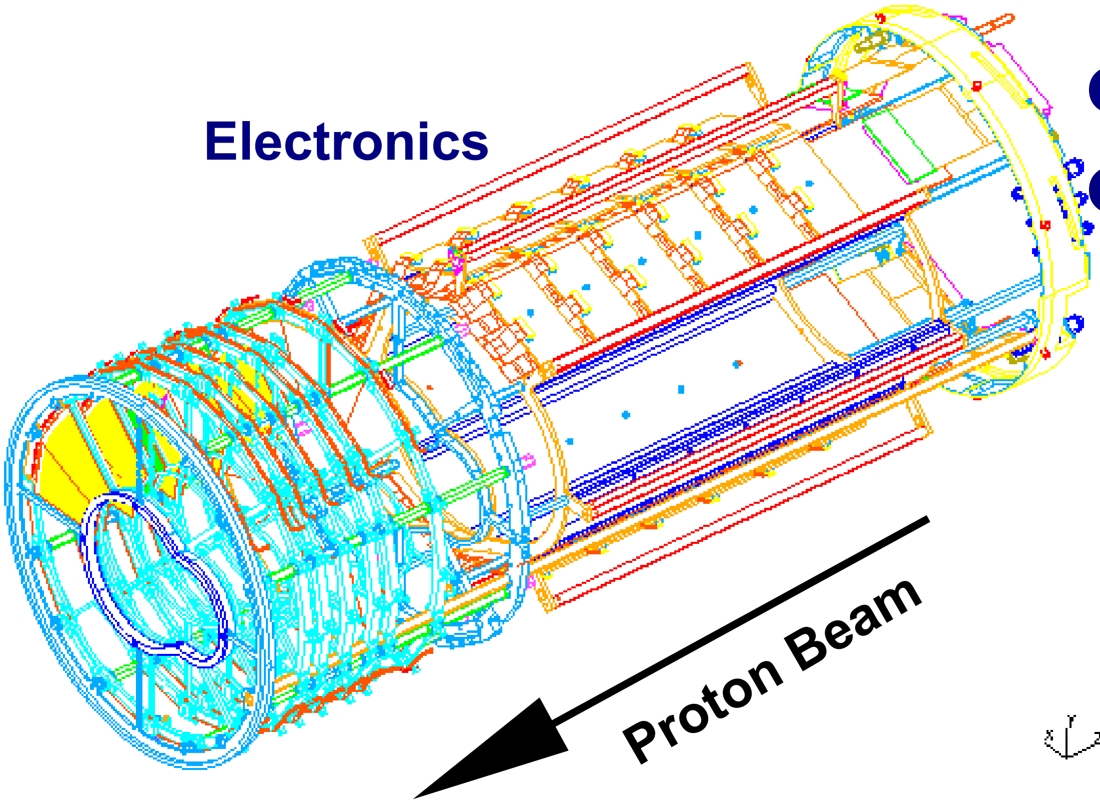
Separation of pions and elctrons by measuring energy E in the calorimeter and momentum p in BST.
D. Eckstein, DESY-THESIS-2002-8.

FST: Forward Silicon Tracker

Collaboration of
DESY-Zeuthen, DESY, Prag, RAL

Sensor Wheels

Electronics

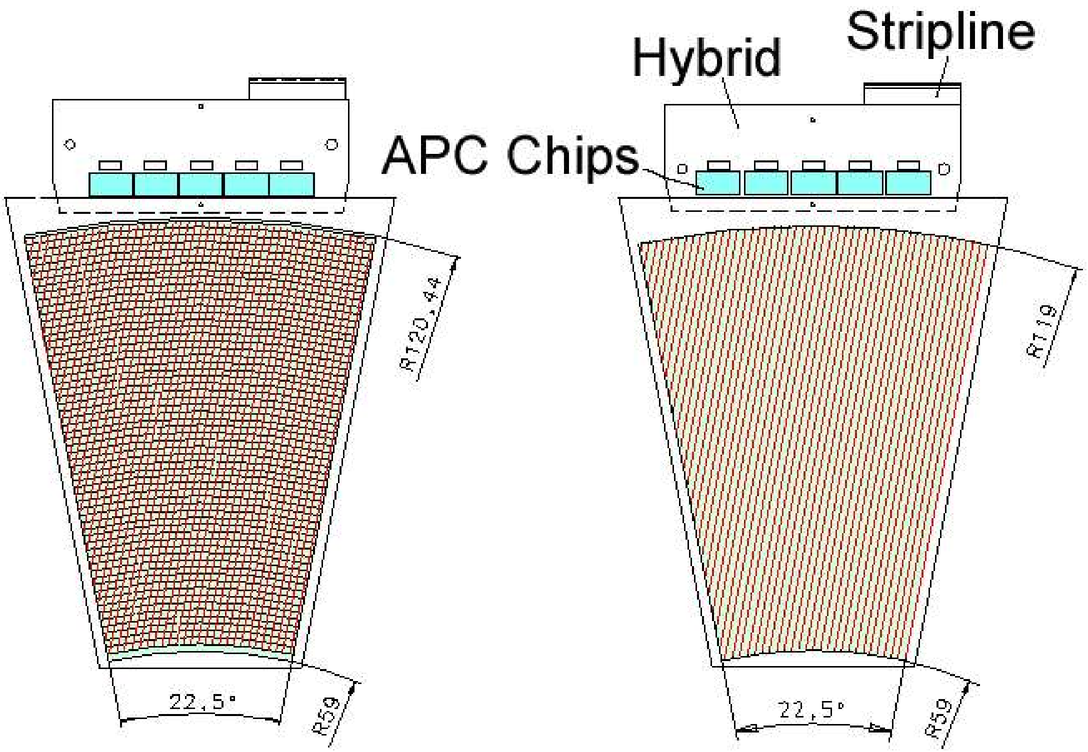


Connectors
(Electrical + Cooling)

- 7 sensor wheels,
  2 types: u/v and r
- 3384cm² silicon
  - from CIS (Erfurt)
- 92160 channels
- Readout with APC
  (Analog Pipeline Chip)
  - developed at PSI
  - SACMOS: 1.2μm CMOS
  - Manufactured by Faselec
  - Store signal in 128×32 capacitors, readout sequentially

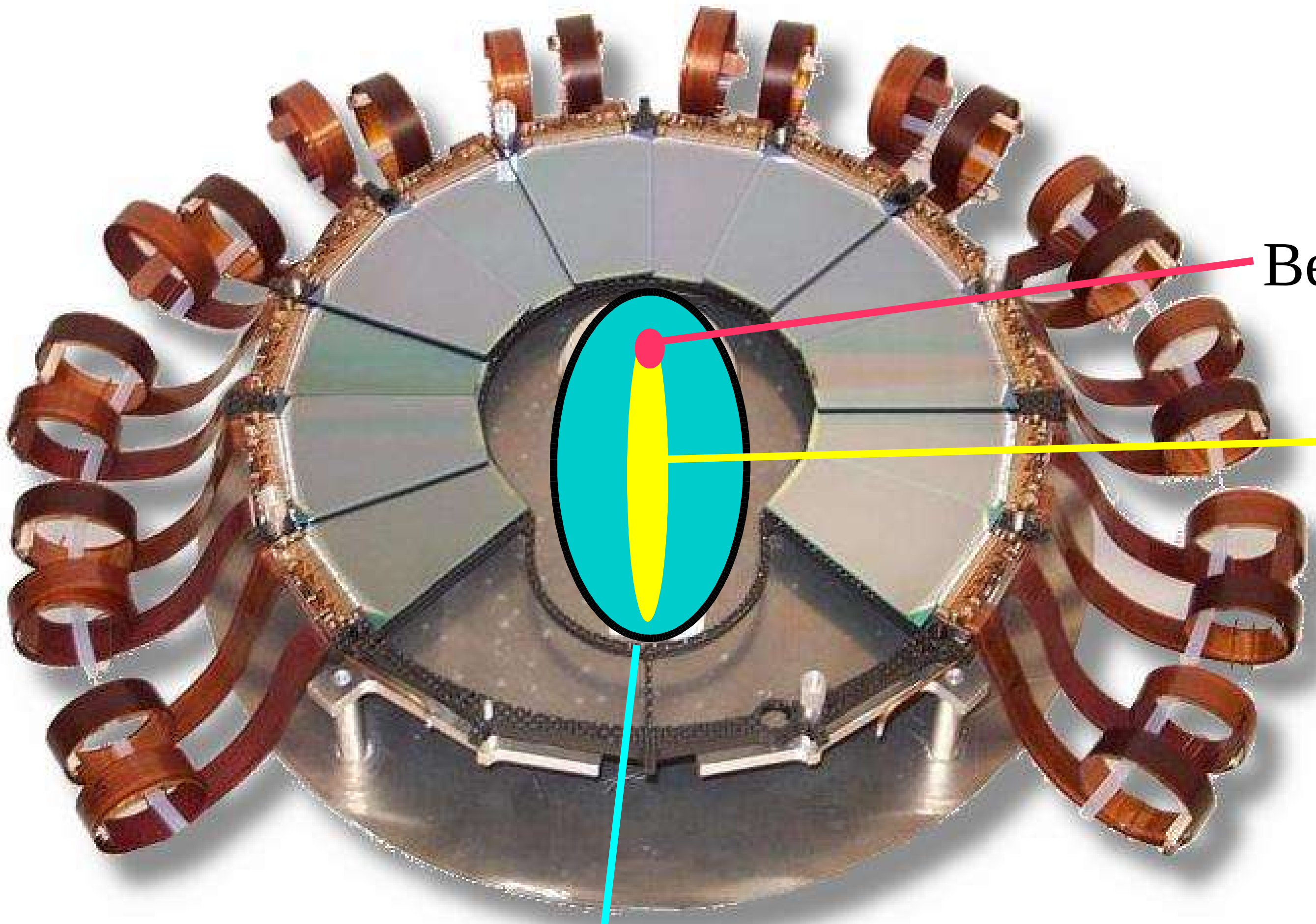
FST Sensor types

- 5 wheels with u/v coordinate:
  - single sided silicon
  - u and v sensors mounted back-to-back
  - good signal/noise
  - 72µm pitch
- 2 wheels with r strips
  - single sided silicon
  - readout with 2nd metal layer
  - reasonable S/N
  - needed for pattern recognition in high multiplicity events (ambiguity resolution)



r sensors u/v sensors

BST/FST Sensor Wheel

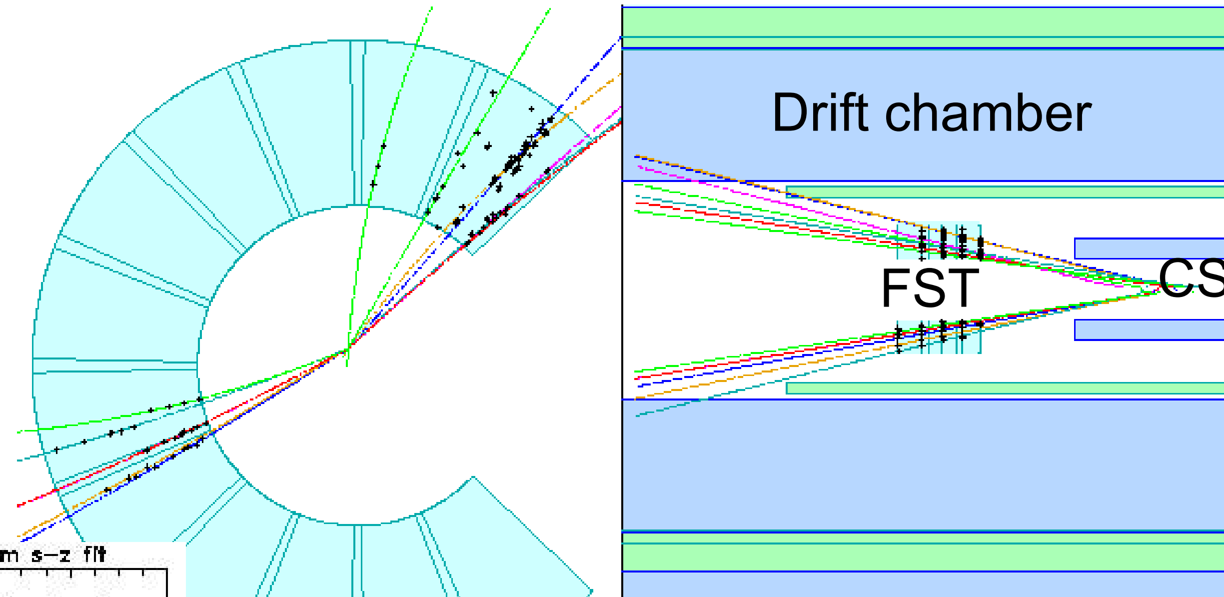


Asymmetric hole to accomodate elliptical beampipe

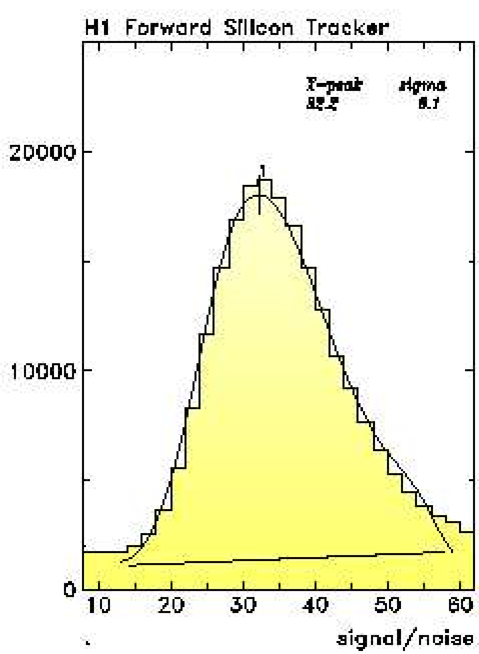
FST Performance

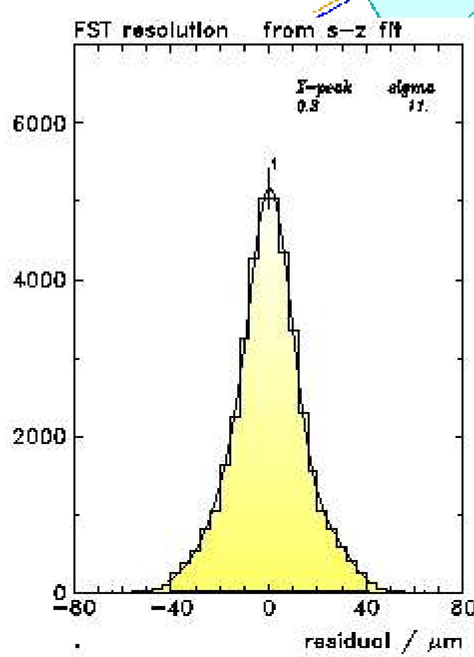
- Signal/Noise:
  - 30 for u/v detectors
  - 15 for r detectors
- Resolution 12μm (from triplet sagitta)

6 tracks in 1 ϕ sector



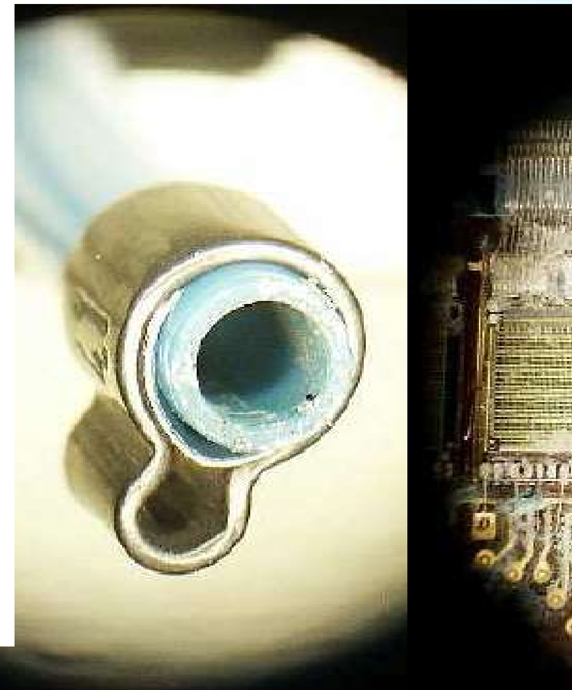
A multitrack event reconstructed in the FST

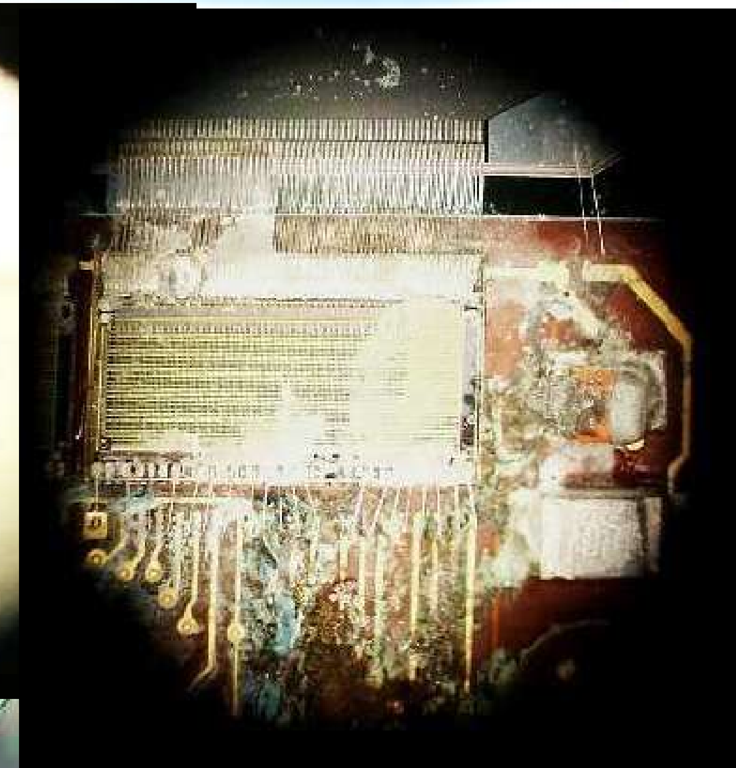


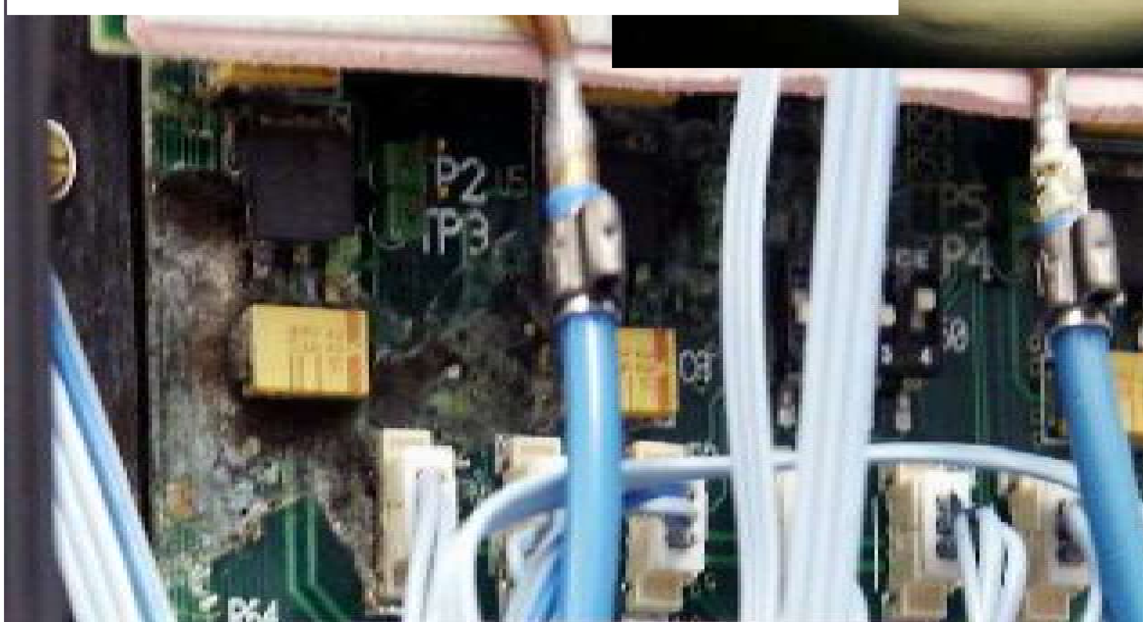


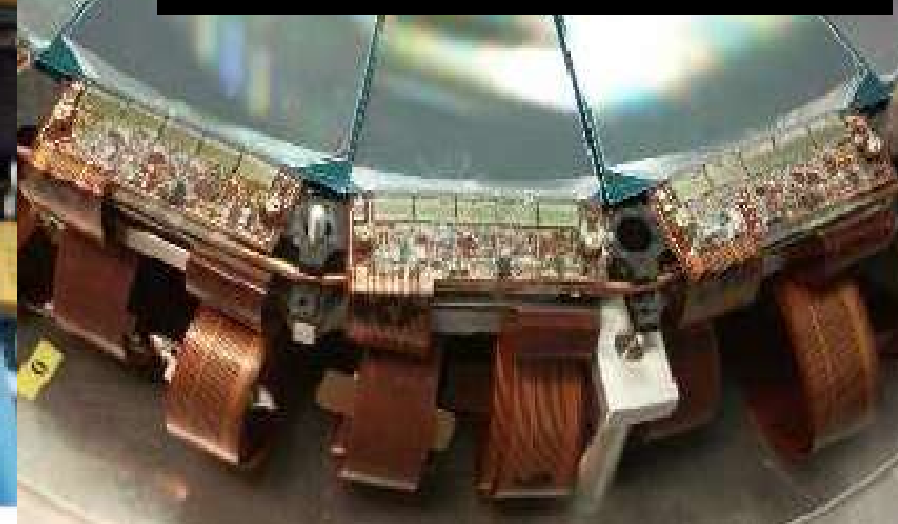
Water Damage to FST in 2004

- Imperfect crimp + hardening of plastic => water leak
- Water condensation => damage
- FST being rebuilt now
- Will be reinserted in Nov



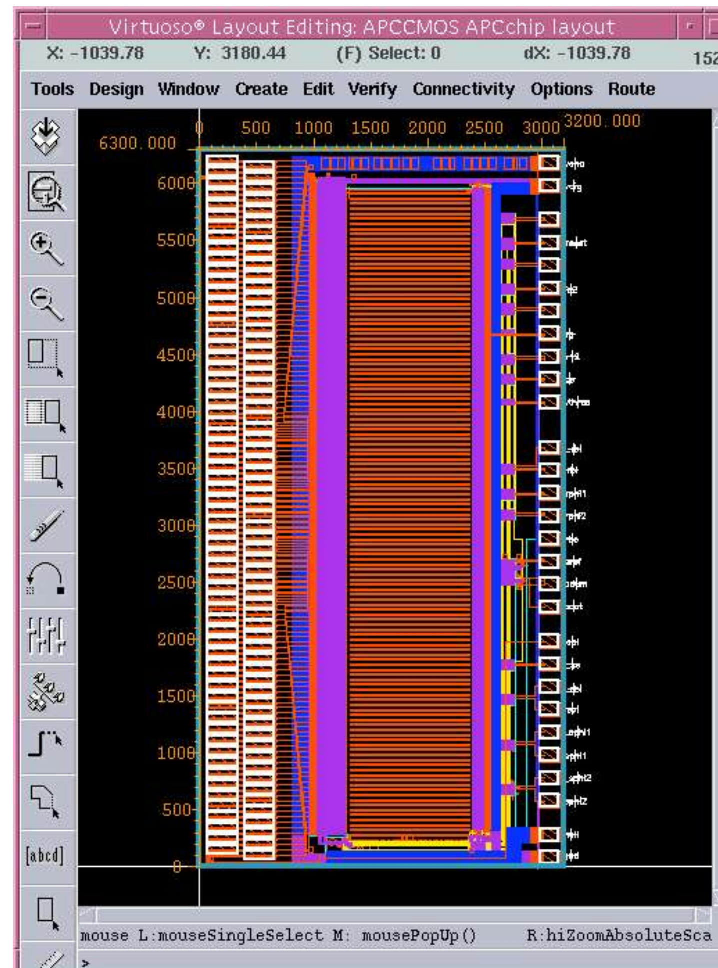


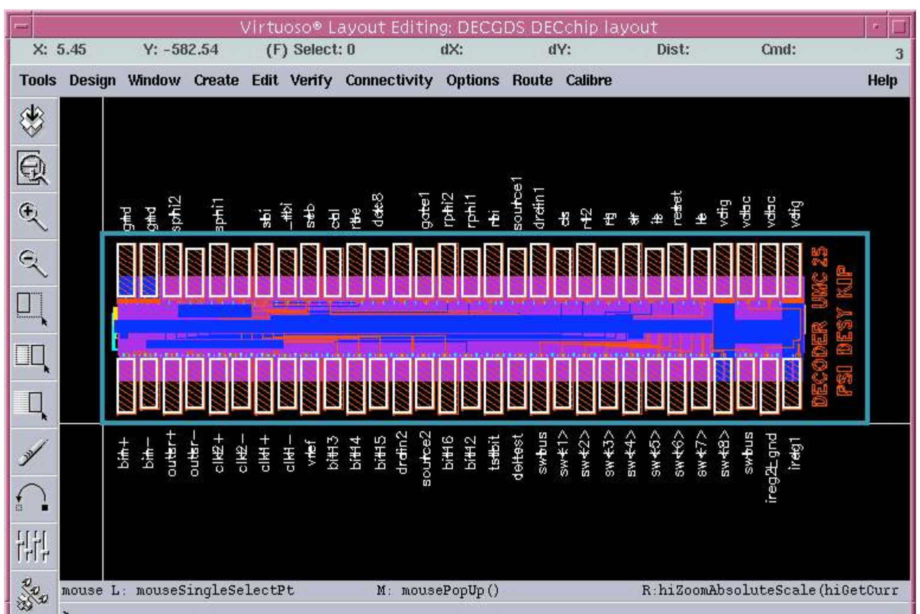




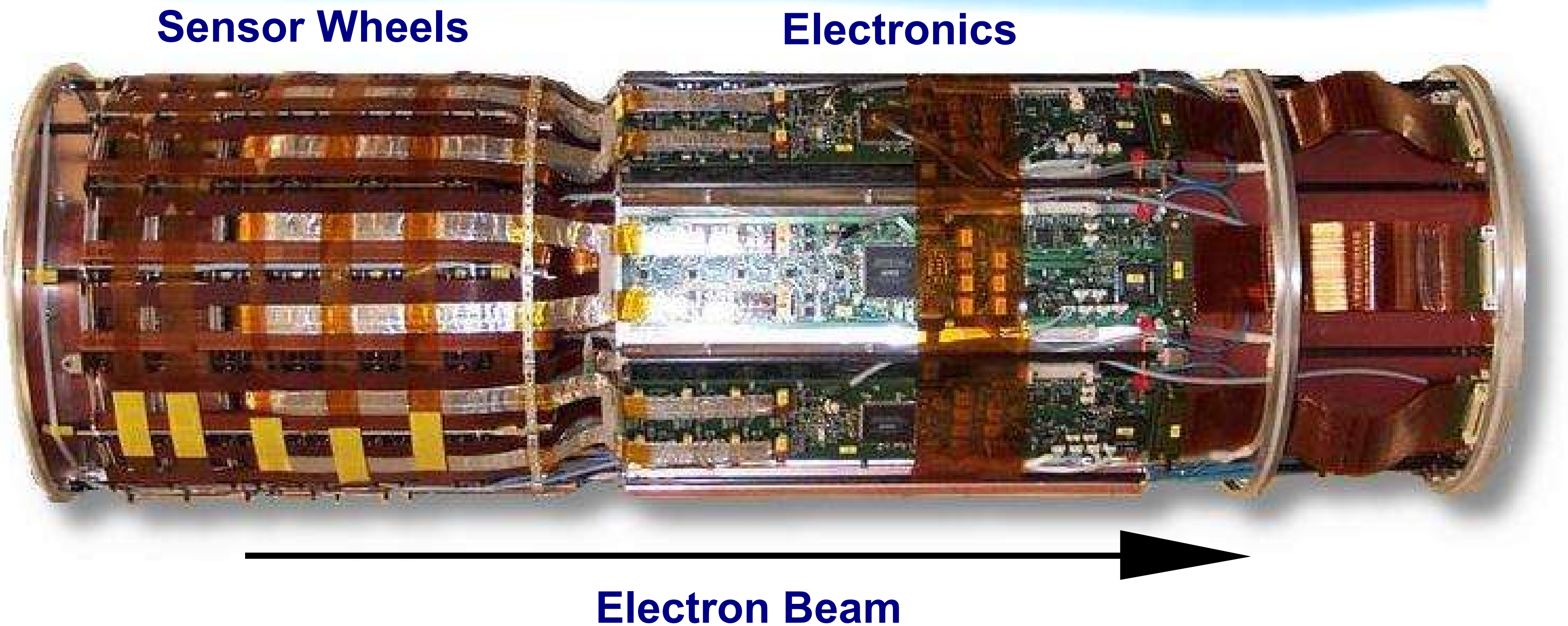
New Readout Chips in 0.25µm Technology

- Some radiation damage observed, vulnerability of SACMOS chips also seen in CST => Design new chips in 0.25µm technology
- Translation from earlier design in only 3 months (2 chips!) Sep-Dec 2004
- Joint project Zeuthen-PSI-KIP Heidelberg
- Fabricated by UMC
- Production finished



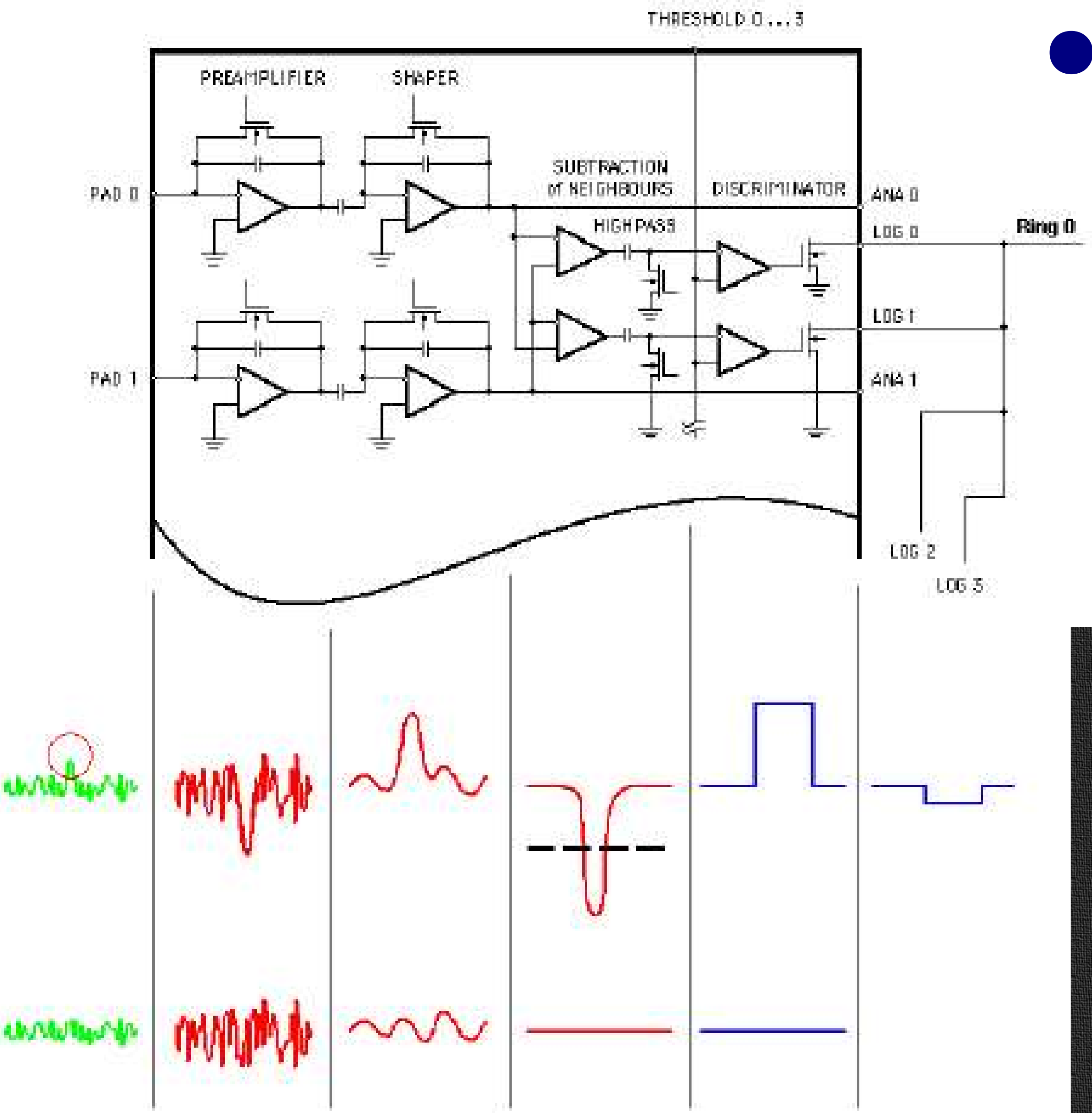


BST: Backward Silicon Tracker



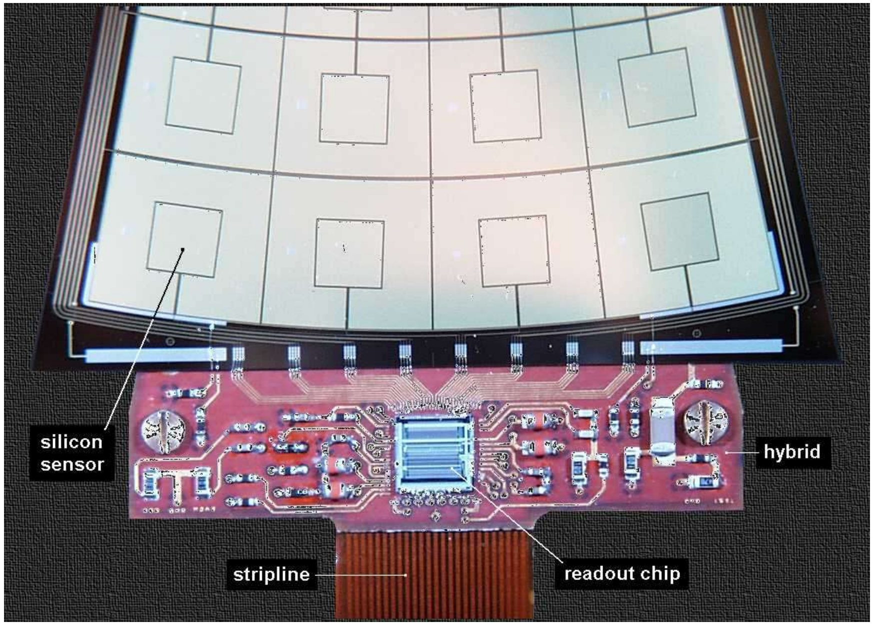
- 6 double wheels with u/v coordinates, same as in FST: tracking
  - no r wheels needed, typically low multiplicity in backward direction
- 4 wheels with pad detectors: triggering
  - Hit detection + track finding done on frontend, at 10.4MHz

BST Pad Hit Detection

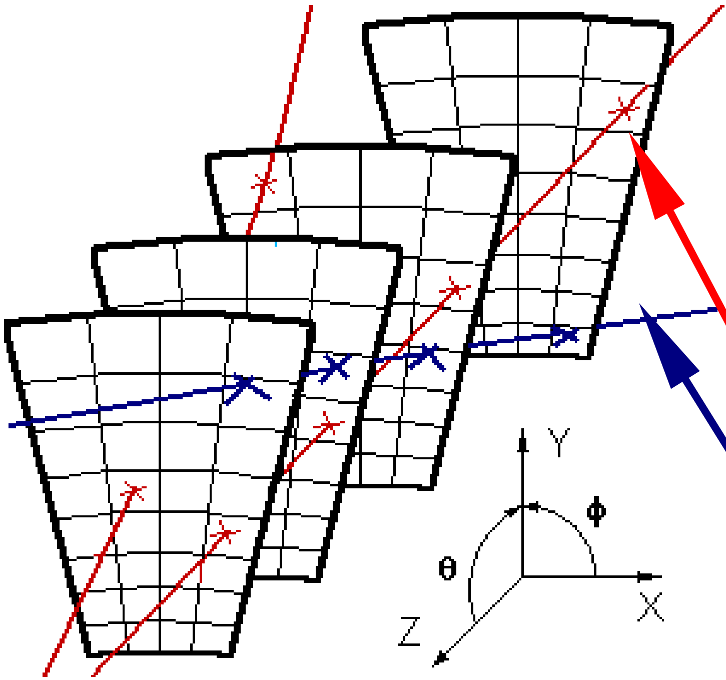


Pad sensors: 8×4=32 pads

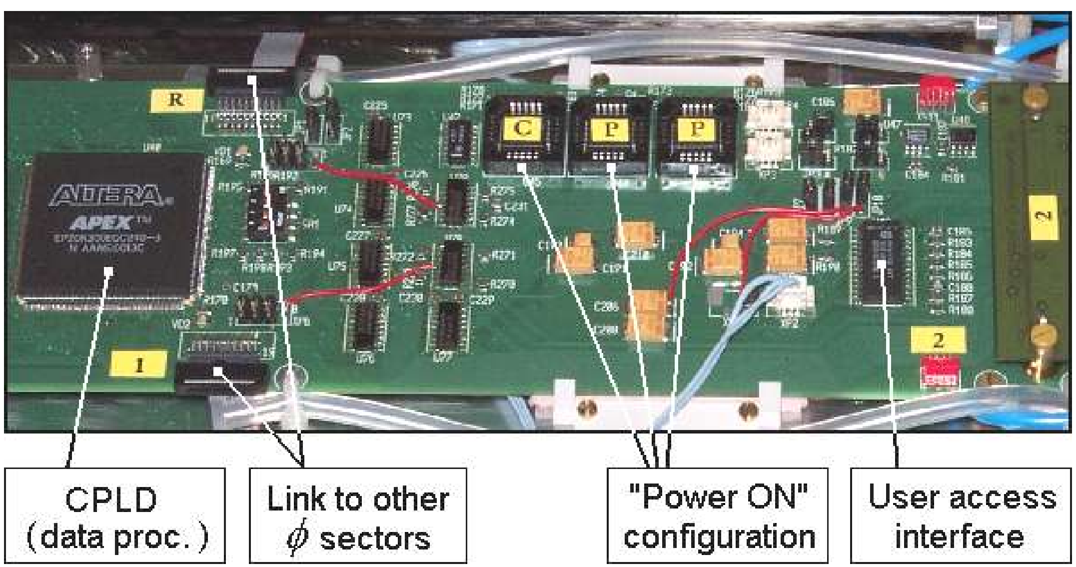
- ASIC PRO/A:
  - 1.2µm CMOS process
  - from IDE AS (Oslo)
  - 32 channels per chip
  - noise: 600e + 15e/pF
  - shaping time 30ns



BST Pad Trigger Concept

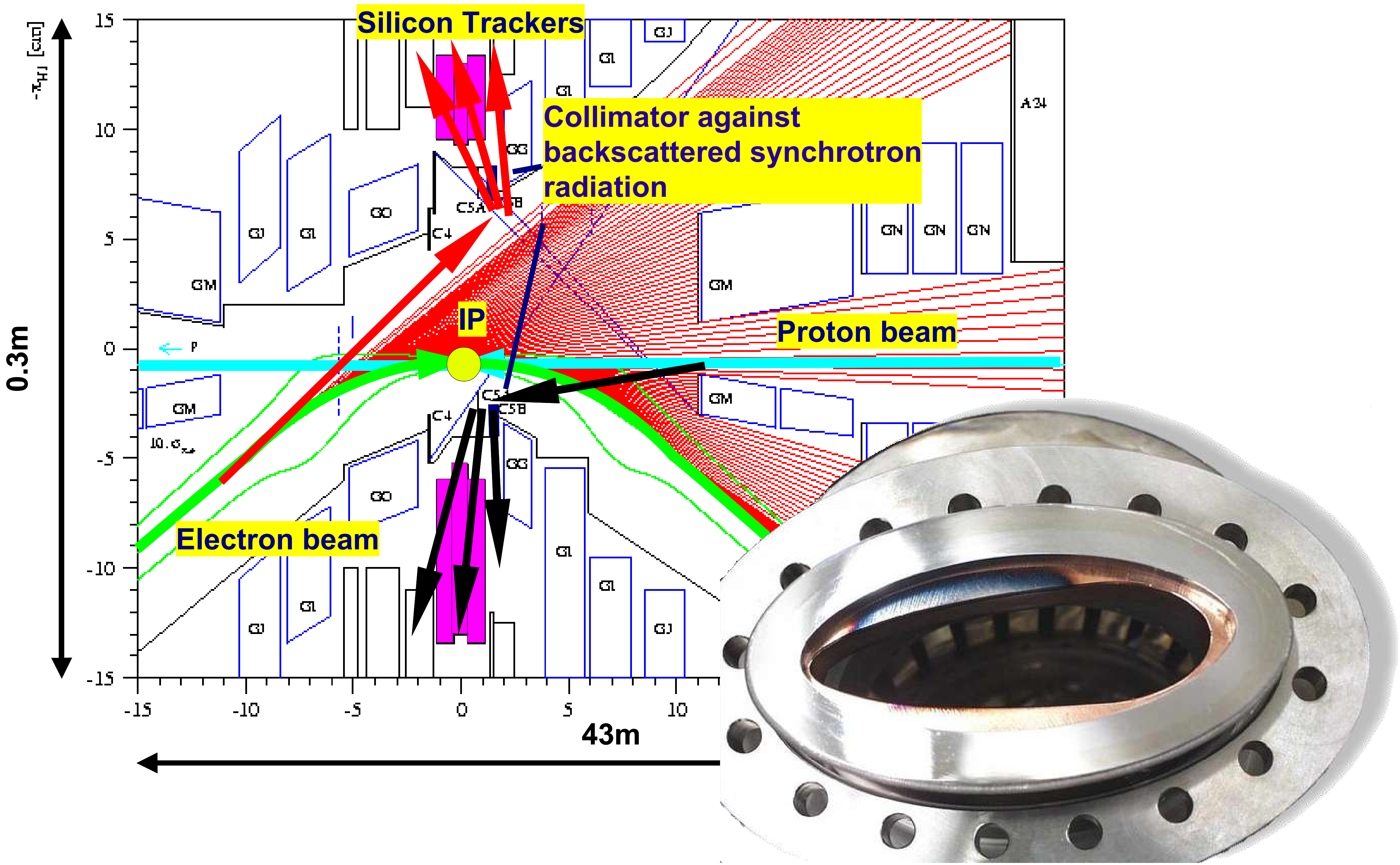


- One motherboard for 2 sectors (8 sensors), mounted directly behind sensor volume
- Complex Programmable Logig Devices (CPLDs) from ALTERA for trigger
  - Recognises tracks from IP
  - Rejects tracks from outside interaction region
  - Flexible, for shifted vertex runs



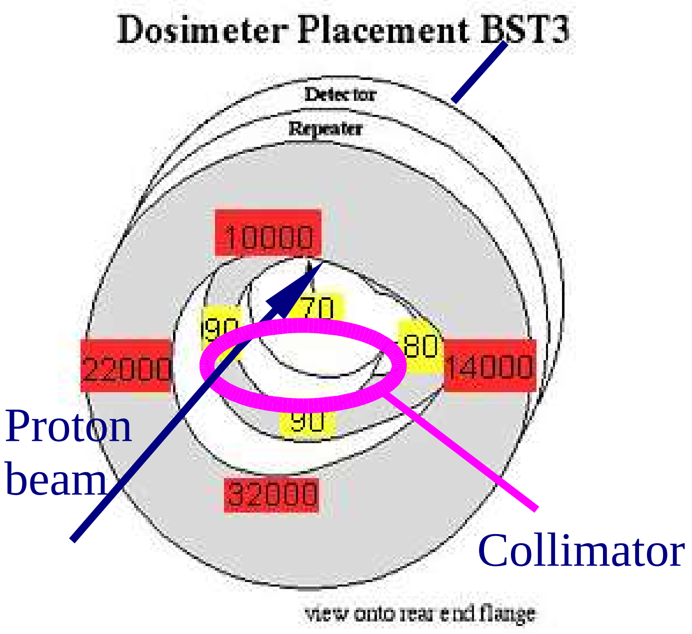
- Uses Content Adressable Memory (CAM) to compare hit patterns with predefined hit patterns from tracks

Backgrounds



Radiation Damage to BST

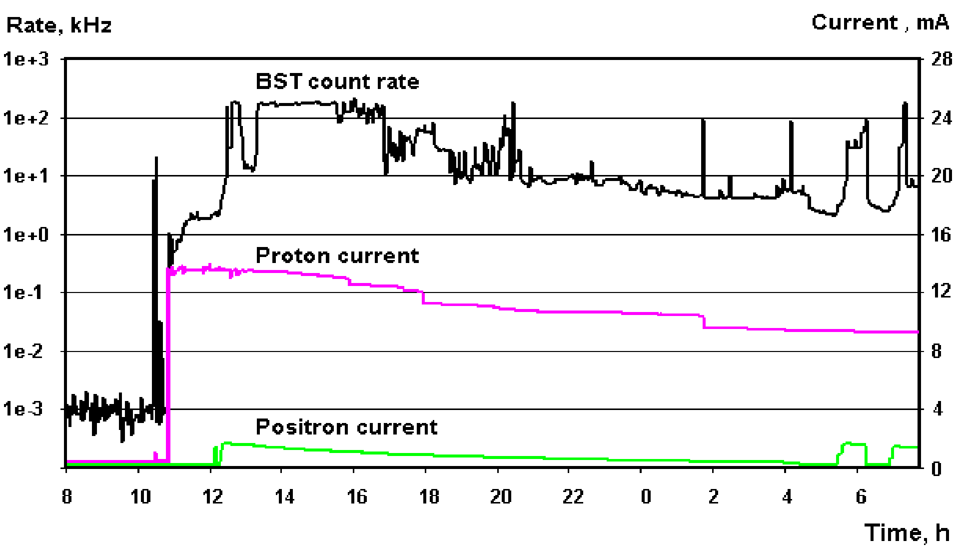
- In 2002: Dosimeters in BST showed up to 30kGy of dose
- High dose only in small region at -z end (around collimator), FST, CST, forward region of BST received <100Gy
- Damages:
  - APC chips of BST: do not hold charge long enough (1ms) for readout (same problem lead to installation of radhard chips in CST)
  - BST slow control circuitry damaged
  - line receivers, drivers damaged
  - ALTERA CPLD chips survived!
  - Voltage regulators for CST damaged (located at same *z* position as BST electronics)
- New hybrids+sensors inserted in 2003
- Now rad-hard design

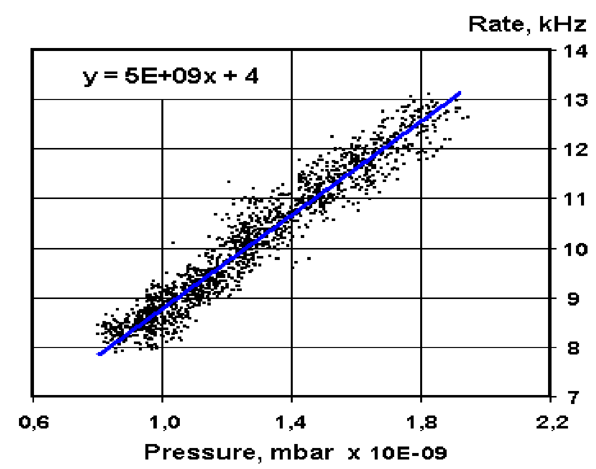


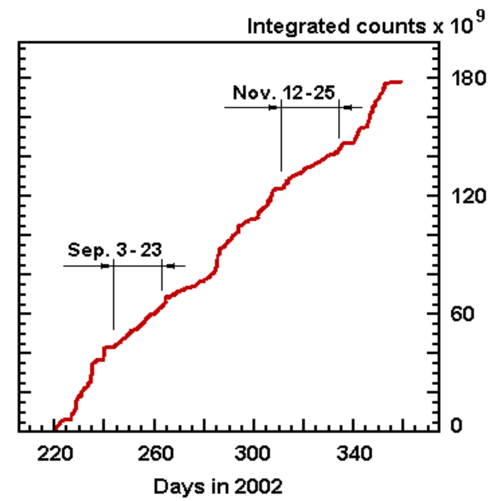
BST radiation doses in Gy

Beam optimization using BST Pad Rates

- Use single pad rate to monitor beam conditions
- Very useful for beam tunig
- Problem:
  - Large background spikes (from beam missteering) deprogram CPLDs
- This was an unforeseen application, shows advantage of CPLDs: can be easily adapted to new demands

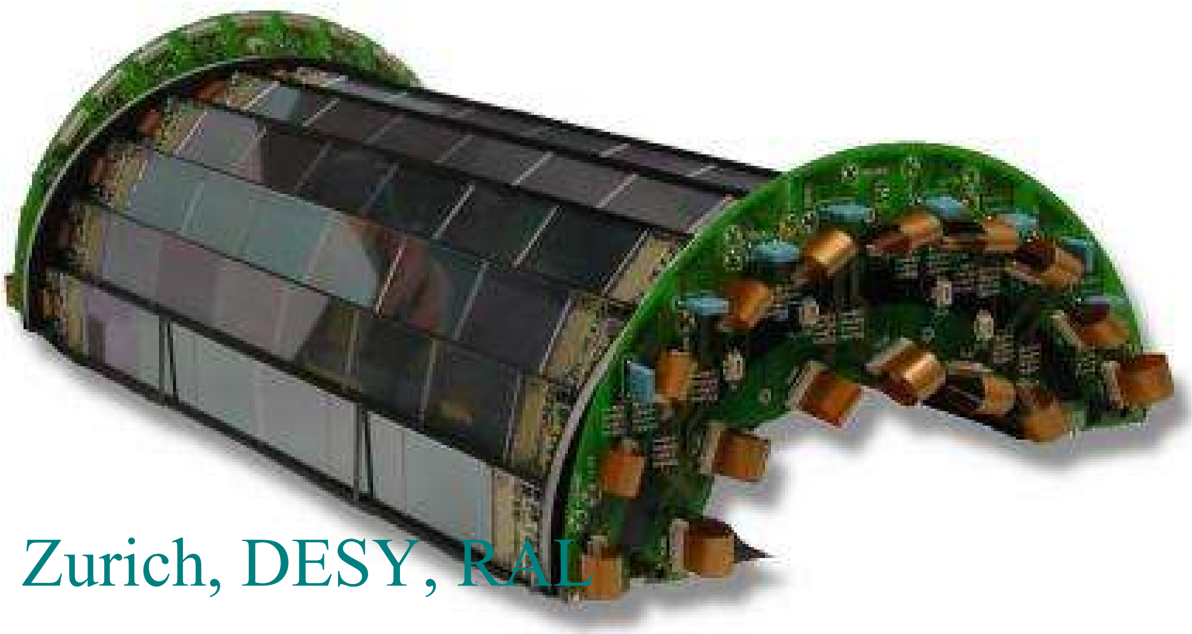






The CST

- 2 barrel layers, 12+20 ladders
- 192 sensors 3.4x5.9cm^2, 3850cm^2 silicon
- Double sided sensors, 50(φ)/88(z)μm pitch
- 3 sensors read out together: 81920 channels
- Very thin: 1.4% X_0 in radial direction
- Floating ground for readout circuitry

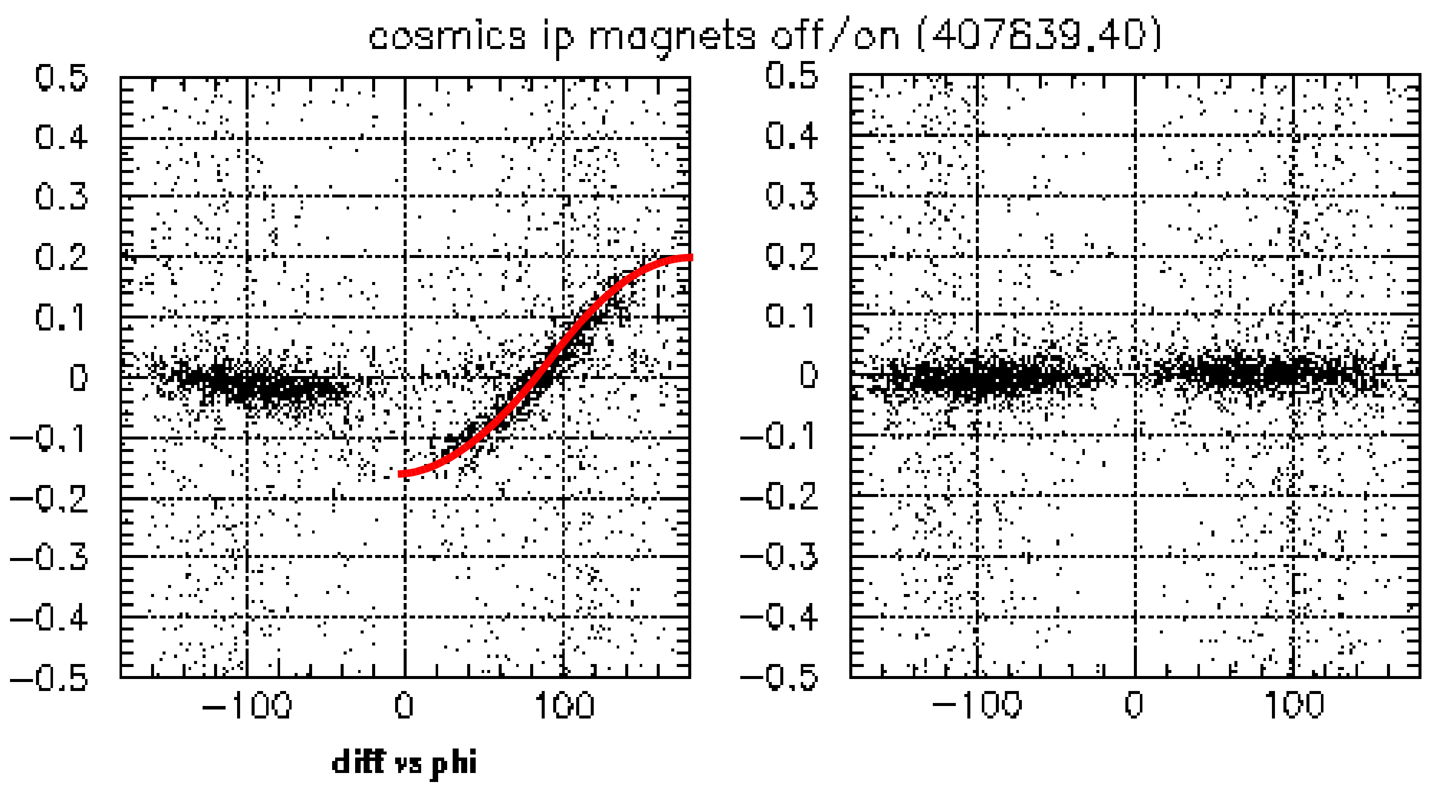


- Analog readout with rad-hard DMILL APC
  - manufactured by ATMEL
- Optical signal transmission

Built by ETH Zurich, PSI, Uni. Zurich, DESY, RAL

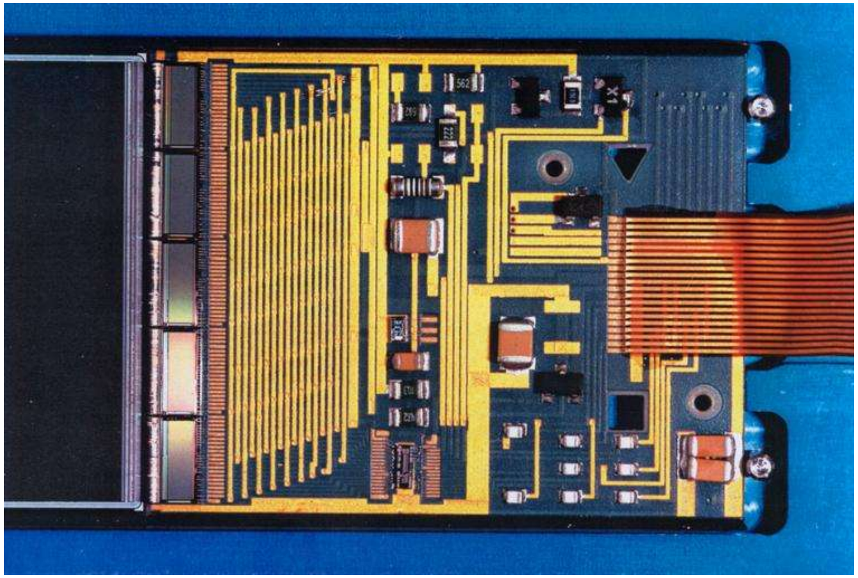
CST Movement

- A nasty surprise: H1 beampipe too high by 4mm
  since switch to e- operation last November, beampipe moves due to magnetic forces on superconducting final focus quadrupoles
  => alignment difficult, but possible (once per lumi fill!)
- Next shutdown in Nov: Change CST support to avoid moving



CST Hardware Problems

- Hairline fractures on capton cables
- Reason: Capton sticky tape put on capton cable for insulation
- Repair: New 3-layer cables (made by Dyconex)
- Will be *soldered* onto old cables
  (avoids difficult re-bonding of complete ladders)
- Planned for coming shutdown in November



Summary

- HERA-II had a slow start, but is now on track
- Radiation damage occured mainly from a single incident where synchrotron radiation directly hit a collimator
- Normal operation of HERA leads to doses ~100Gy/y
- Brittle cooling pipe -> water damage at FST in 2004
- Now complete rebuilding of FST + BST,
  including new rad-hard chips in 0.25µm technology
- CST fully equipped with radhard DMILL chips, running
- Alignment very difficult due to beampipe movement:
  Repeat global alignment for each lumi fill
- Fractures in capton cables in CST due to sticky tape & bending:
  Will be replaced in November

Reserve Slides

BST 1, 2, 3, 4

- BST-1: Installed 1995:
  - 4 wheels of r detectors × 16 sensors = 64 sensors, 40960 channels
- BST-2: Upgrade 1998:
  - 4 + 4 wheels of r detectors × 16 sensors = 128 sensors, 81920 channels
  - 8 prototype ϕ sensors (u coordinate): 5120 channels
- Upgrade 2001:
  - 8 wheels of r detectors × 12 sensors = 96 sensors, 61440 channels
  - BST-Pad: 4 wheels of pad detectors × 12 sensors: 48 sensors, 1536 pads
- BST-3: Upgrade 2003:
  - 5 $^1/_2$ double wheels of u/v detectors × 12 sensors = 132 sensors, 84480 channels
  - BST-Pad: 4 wheels of pad detectors × 12 sensors: 48 sensors, 1536 pads
- BST-4: Repair 2005
  - Compete rebuilding with new radiation-hard Chips

Some Lessons

Frontend electronics is subject to

- power glitches
- damaged control or power cables
- magnetic field changes
- particle bursts.

It must survive all these without intervention from outside:

- System must be in safe state at power-up
  - Missing voltages should not damage the electronics
- Reset by a single signal should bring it back to this state
- Software errors should not lead to electronics damage

Things to have

- Some **monitoring** lines (power, temperature, radiation) that are **independent** of running frontend, DAQ etc.
- **Redundancy** for vital power and control lines
  (vital: failure leads to failure of large part of the detector)
- Self-identifying frontend units (serial number on chip or module):
  - Simpler logistics during assembly and testing
  - Control over cabling and software errors

The HERA ep Collider

HERA (at DESY, Hamburg):

- ep collider: 27.5GeV e, 920GeV p
- 10.4MHz bunch crossing frequency

- HERA-I:
  - 1992-2000
  - 70pb^{-1} per year at end
- Lumi upgrade
  Nov. 2000-June 2001.
- HERA-II:
  - goal: 250pb^{-1} per year
  - magnets within experiments, complex interaction region
  - slow start:
    - understanding new machine
    - vacuum => background

HERA Status, cont'd

- 2002/2003: Background problems limited currents => low lumi
- Bad vacuum leads to proton-induced background (hadrons),
  - Limit of 2000Gy for sensors imposes similar limits as ageing of jet chamber
  - Most of dose received in incidents/accidents
- March-June 2003: Shutdown
  - Detectors opened, some systems repaired
  - Numerous improvements to machine
  - H1 silicon detectors: All removed, repaired/augmented
- Since July: Bakeout to improve vacuum, progressing well
- Restart lumi operation in October

Overview

- 3 Silicon detectors: FST, CST, BST (Forward/Central/Backward Silicon Tracker)
- FST:
  - 7 wheels with single sided strip detectors
- CST:
  - 2 barrel layers with double sided strip detectors
- BST:
  - 6 wheels with single sided strip detectors
  - 4 wheels with pad detectors for triggering

$\left.\right\}$ Analog readout after trigger