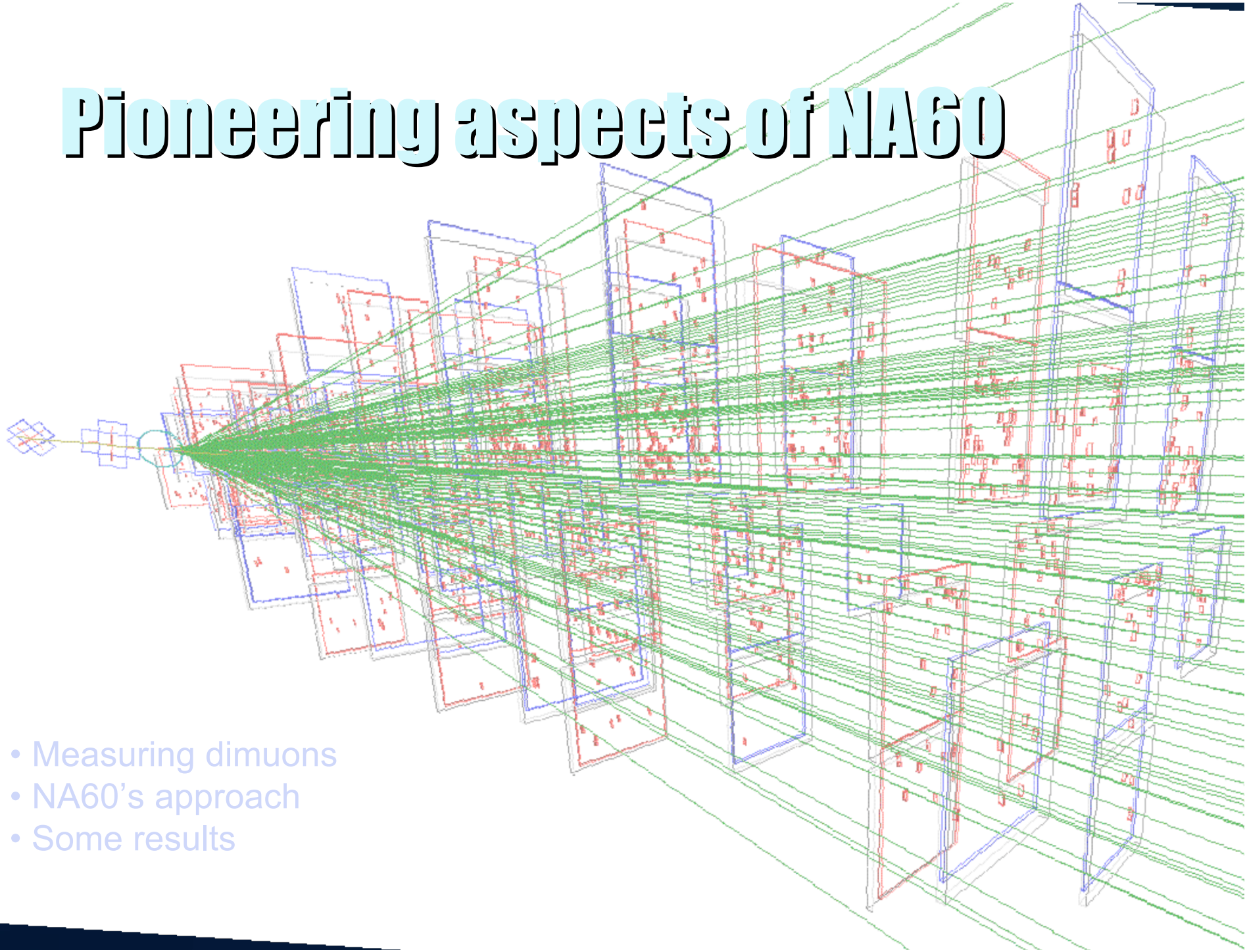
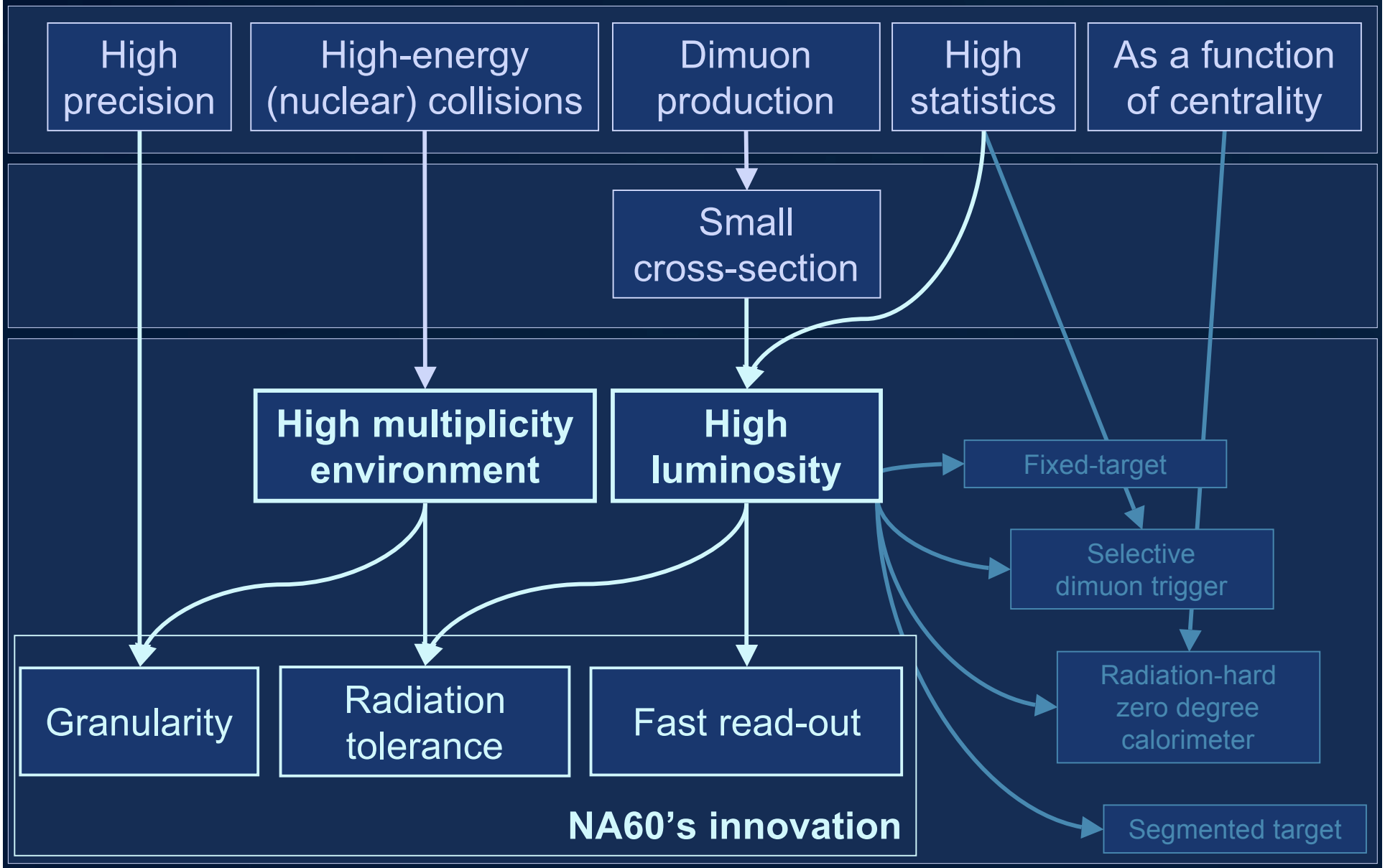
Pioneering aspects of NA60

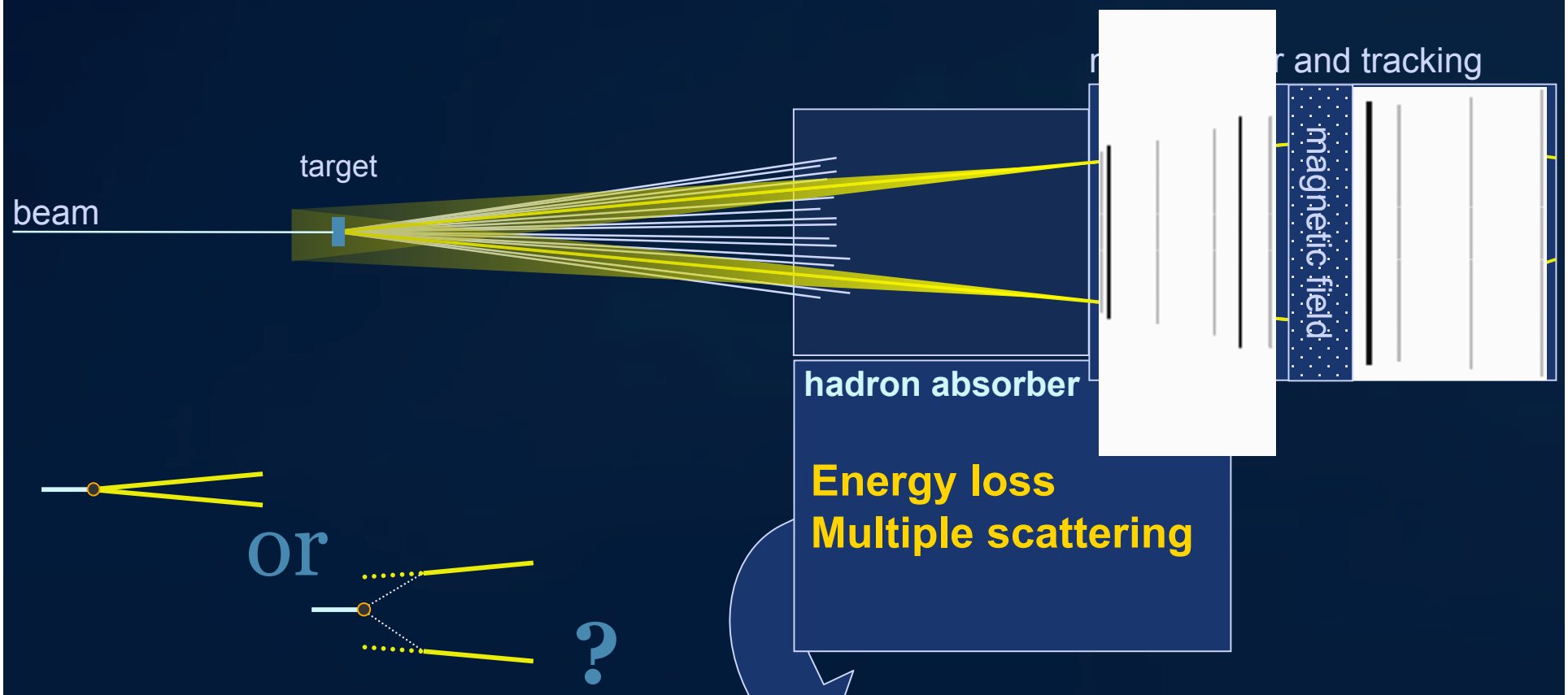


- Measuring dimuons
- NA60's approach
- Some results

Objectives and requirements

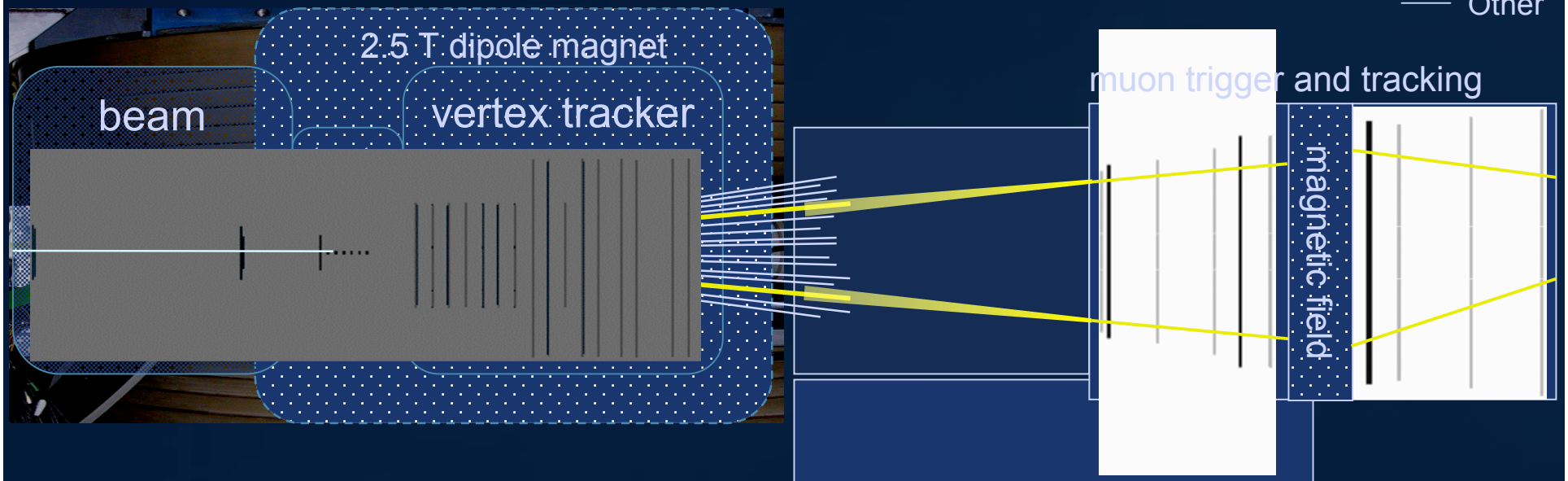


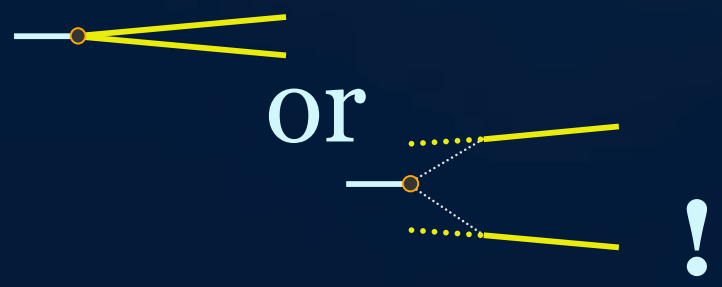
Measuring dimuons



- Cannot distinguish **vertex muons** from **decay muons**
- **Degraded** dimuon mass resolution

Measuring dimuons in NA60

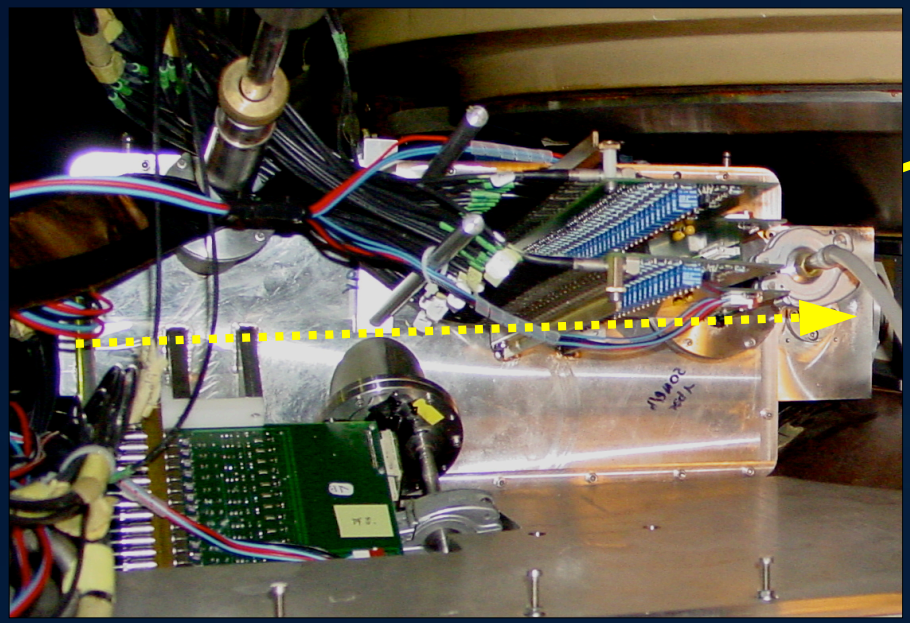


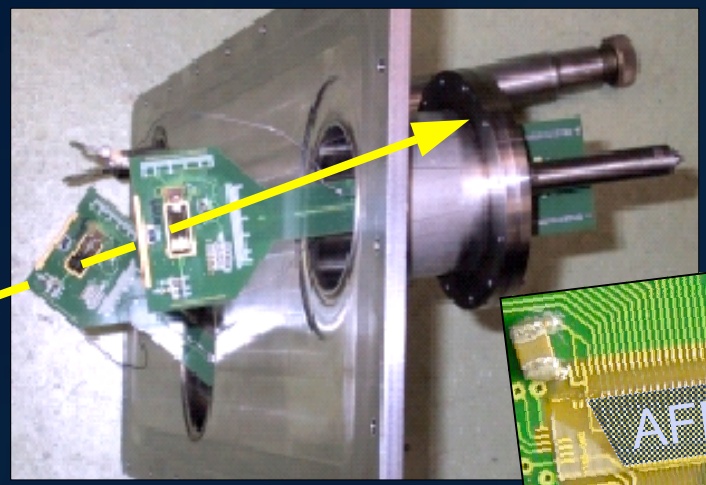


Matching in **coordinate** and **momentum** space

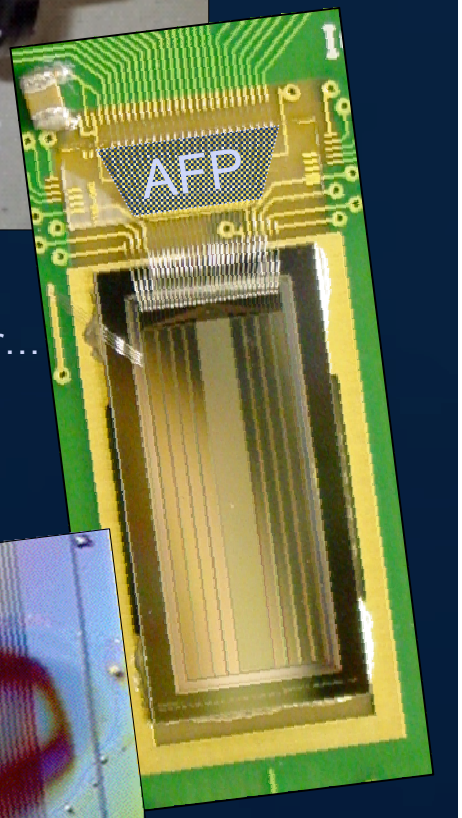
- **Origin** of muons can be **accurately determined**
- **Improved** dimuon mass resolution

Beam tracker

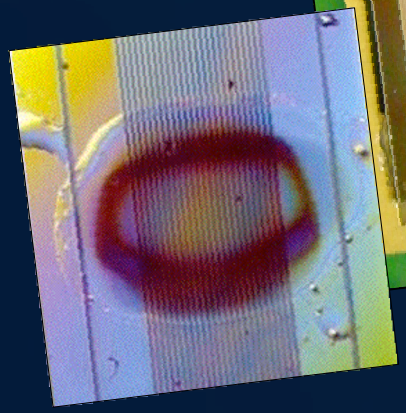




Beam tracker
HI module



A sensor…



…after 42 days
at $7 \cdot 10^7$ Pb
ions/burst
in year 2000
and still working !

- Two stations of x-y microstrip sensors
- 24 strips with **50 µm** pitch per sensor
- **Cryogenic operation** at 130 K
  radiation tolerance **> 20 Grad**
- **1.7 ns timing** accuracy
  beam pile-up rejection

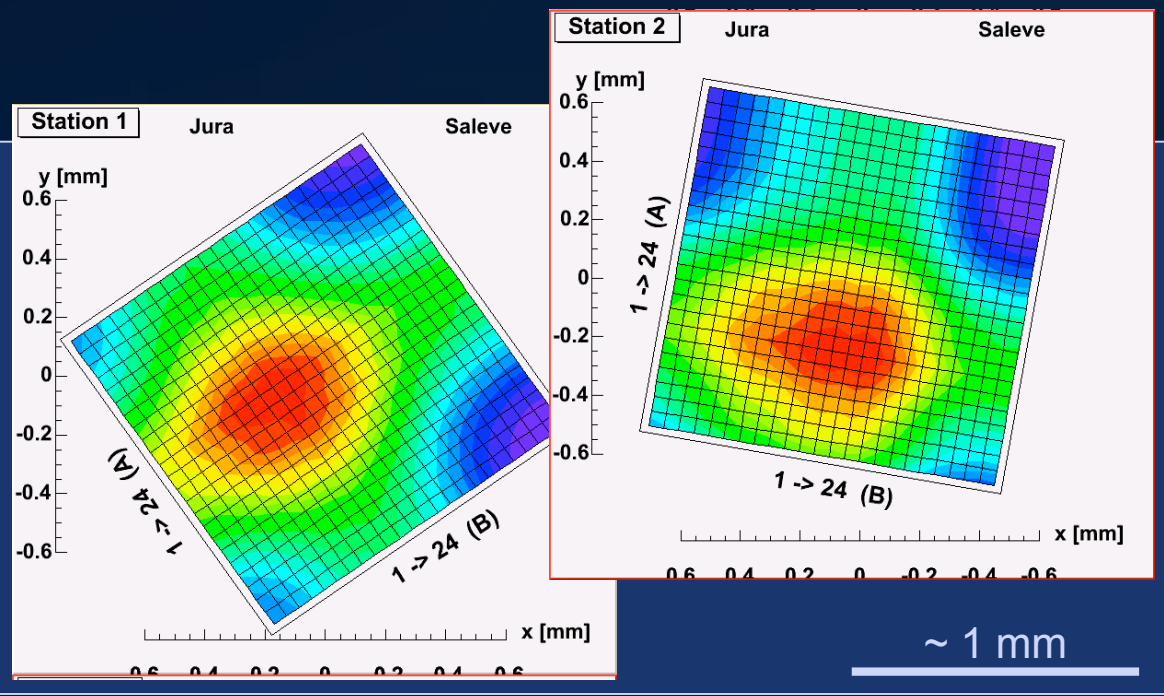
- AFP pre-amplifier chip in proton running

Beam tracking

Space-wise

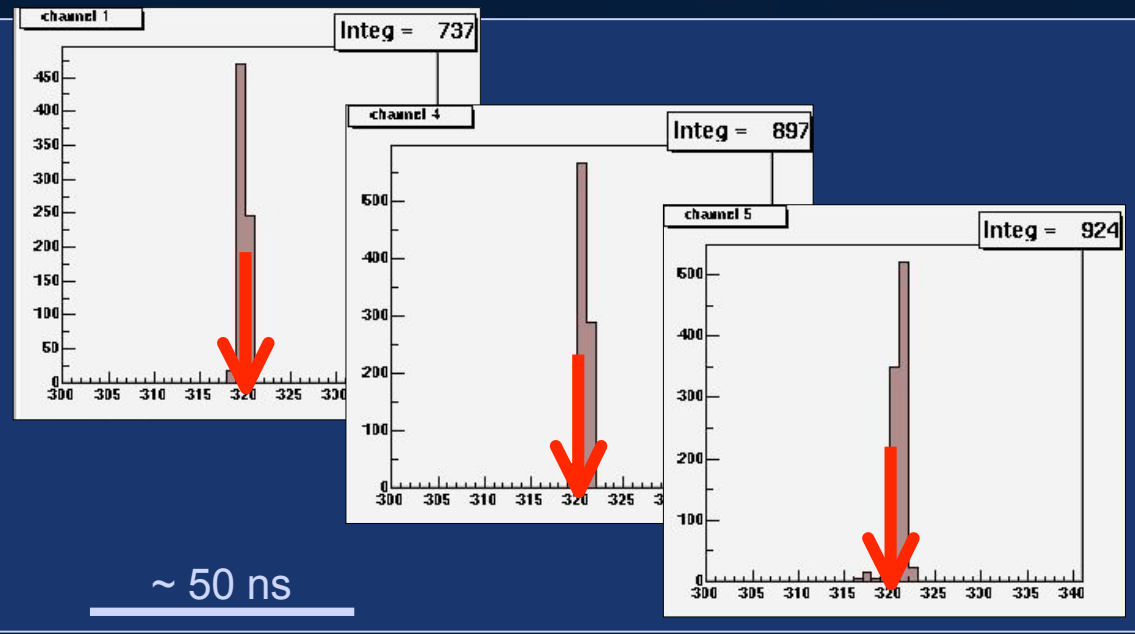
158 GeV Indium beam

24 ▯ 24 strips beam profile
in the two stations



~ 1 mm

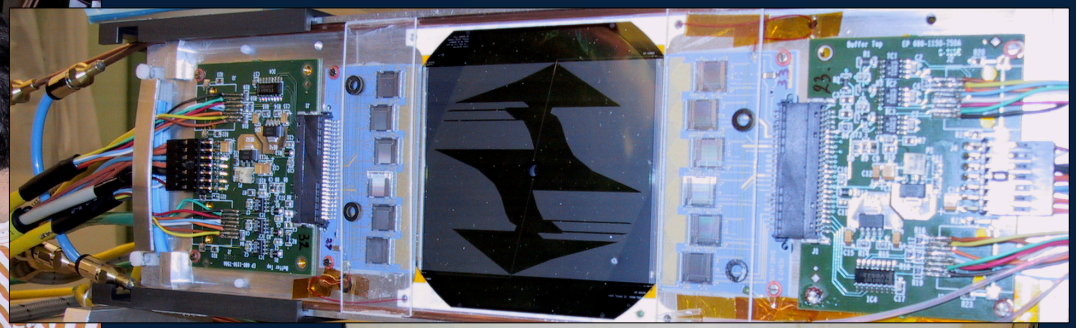
Time-wise



The same ion crossing
3 strips in different sensors

~ 50 ns

Silicon microstrip telescope



- 8 double planes of 300 µm silicon sensors
  ~ 0.3% X_0 per plane
- Low-multiplicity pA collisions
  25’000 strips keep **occupancy < 3%**
- ATLAS SCTA read-out chips
  40 MHz operation
  analog sampling

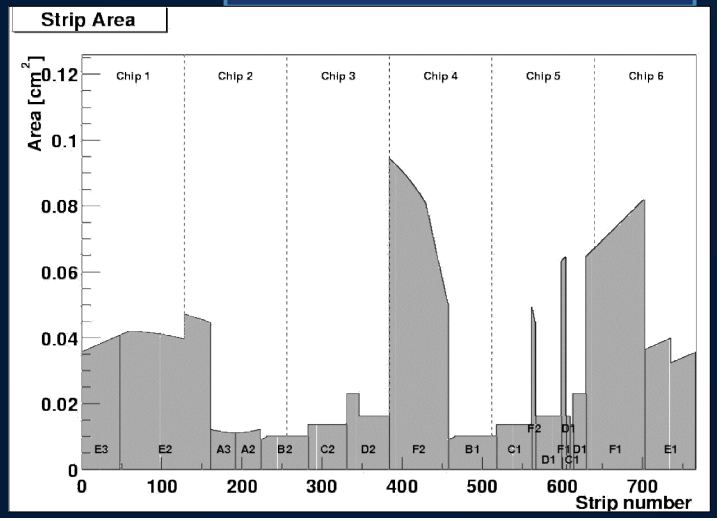
Silicon microstrip sensor

Double metal layer
DC coupled
Al/p$^+$/n/n$^+$/Al structure
300 µm thickness

90 mm diameter provides acceptance coverage at 40 cm from target

1536 strips
tilted for optimized momentum and angular resolution

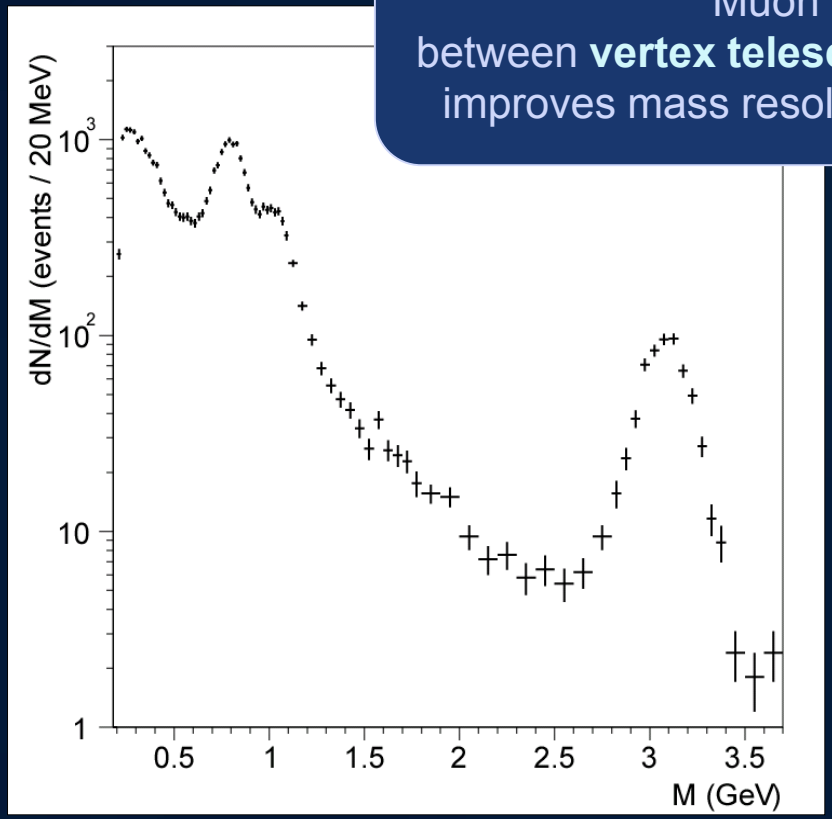
Inhomogeneous strip pitch and length keeps occupancy < 3%

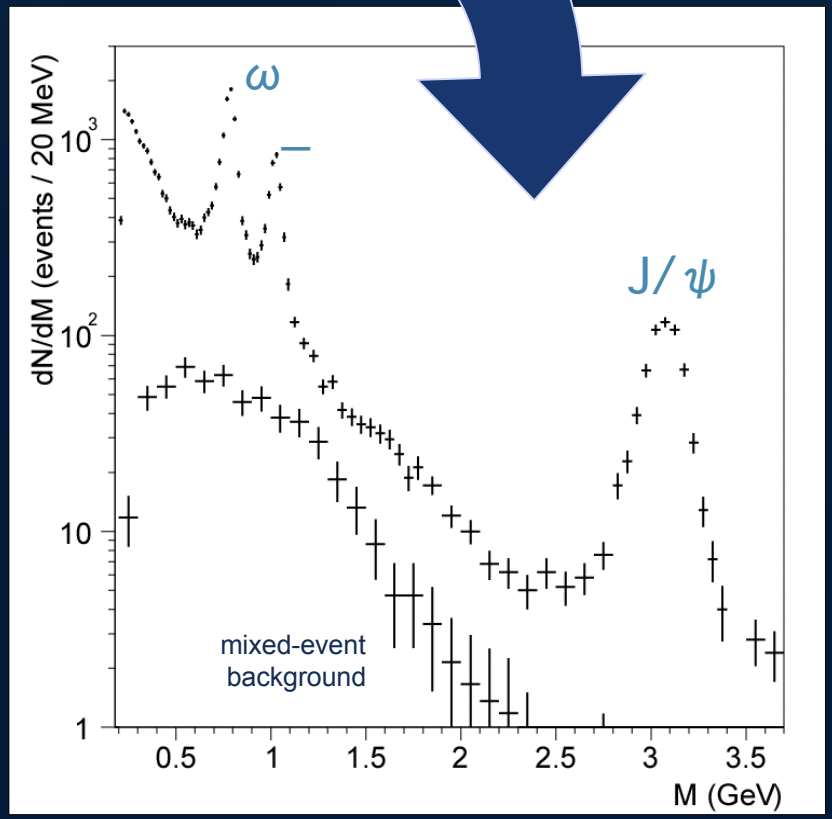


Microstrip telescope data

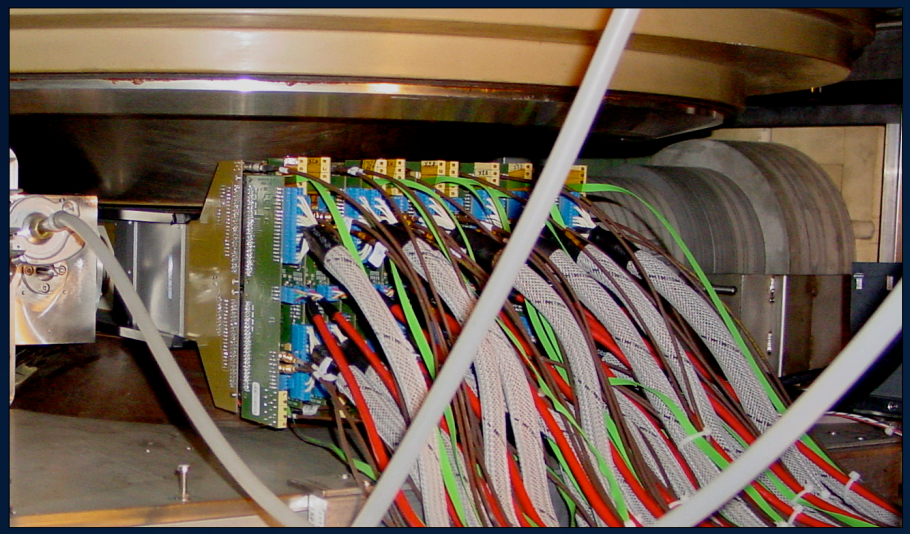
- Data collected in June 2002 with 400 GeV **protons**

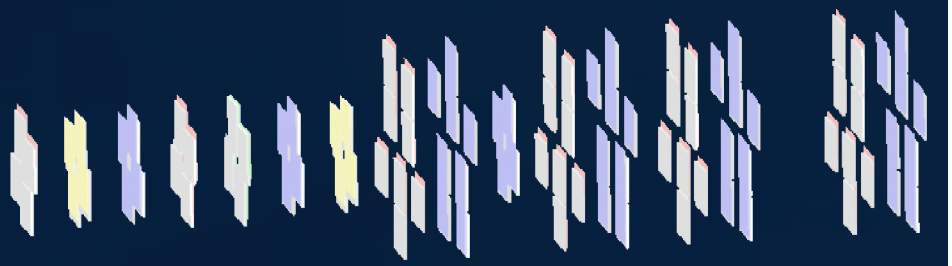
Muon track matching
between **vertex telescope** and **muon spectrometer**
improves mass resolution and signal / background



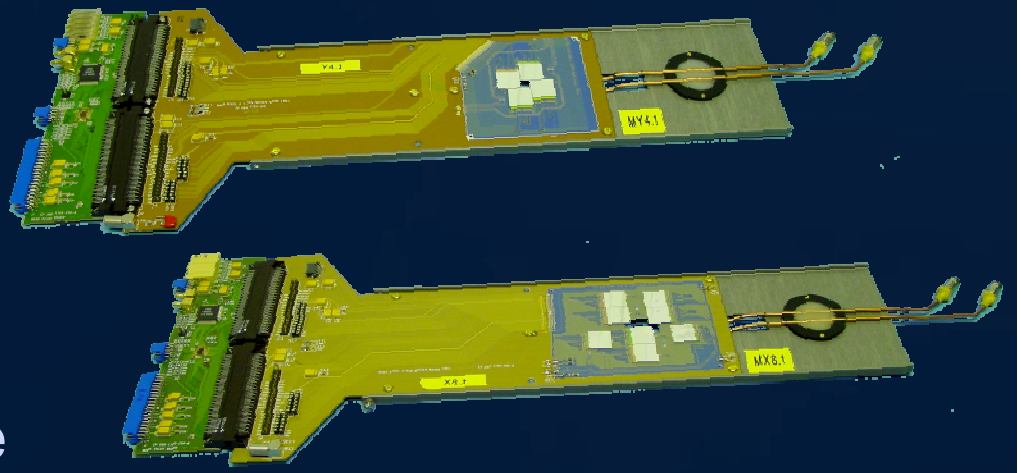


Silicon pixel telescope





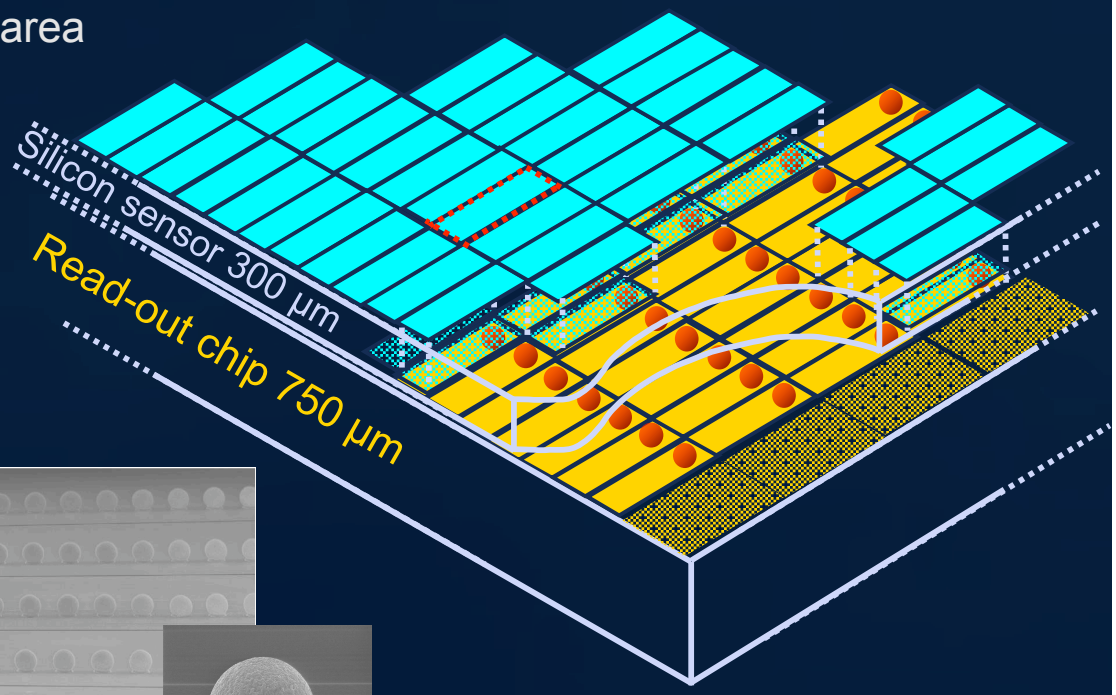
- **11 tracking points** with good acceptance
  - 8 “small” 4-chip planes, plus
  - 8 “big” 8-chip plane
- **~ 3% X_0** per plane
  - 750 µm Si read-out chip
  - 300 µm Si sensor
  - ceramic hybrid
- **800’000 channels** telescope
  - 96 pixel detector assemblies

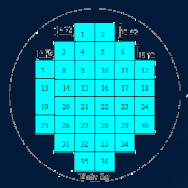


Silicon pixel detectors

Pixel sensor

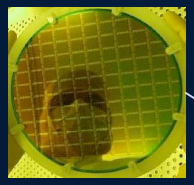
- 12.8 ▯ 13.6 mm^2 active area
- 32 ▯ 256 cell matrix
- 50 ▯ 425 μm^2 cell size

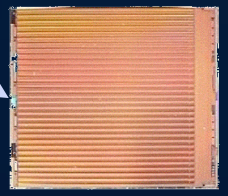




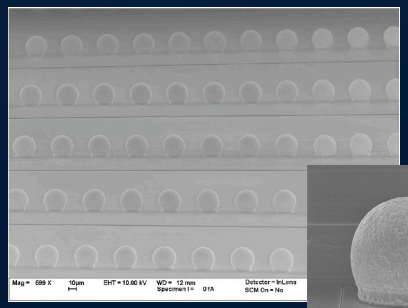
5” sensor wafer (layout)

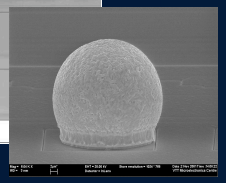
8” read-out chip wafer





+





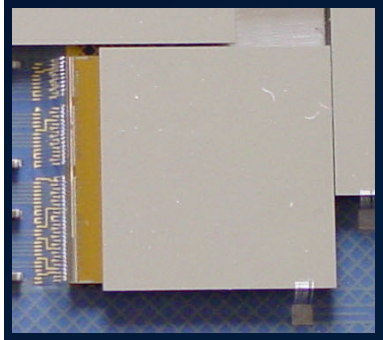
25 μm solder bump

=

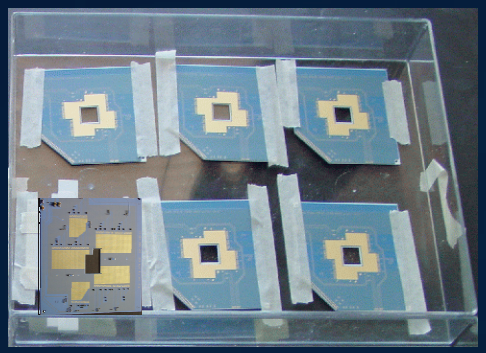
ALICE1LHCB read-out chip

- Operated at 10 MHz
- Radiation tolerant up to ~ 30 Mrad
- 32 columns parallel read-out

Pixel module assembly

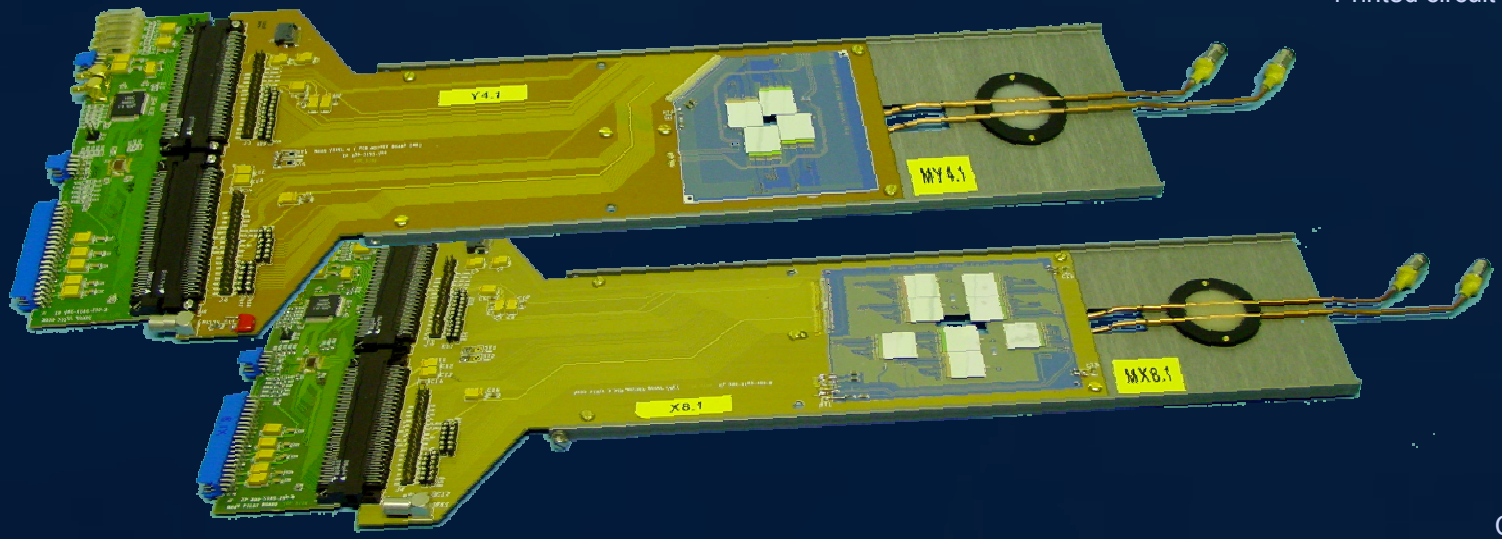


Pixel detectors

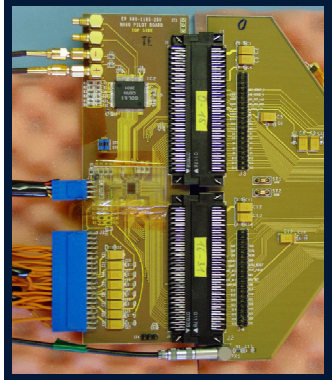


Ceramic hybrids

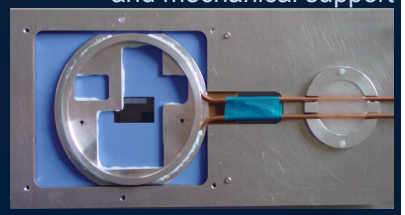
Printed circuit boards



Readout electronics

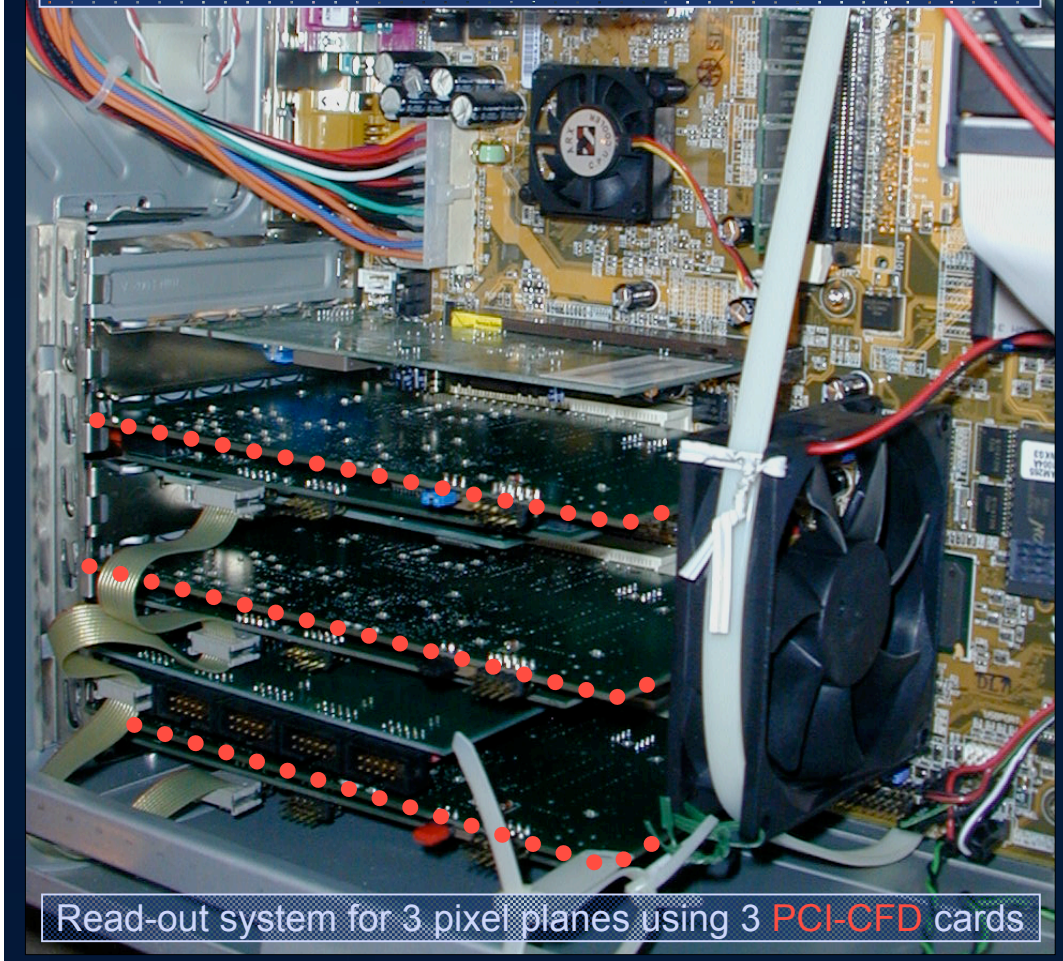


Cooling
and mechanical support



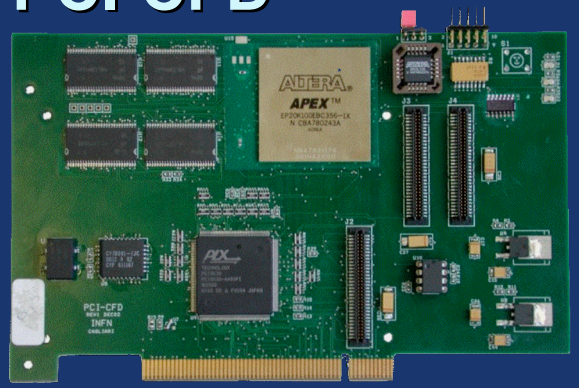
PCI read-out system

- High bandwidth
- Any PC becomes a “crate”
- Easy integration with DAQ software



Read-out system for 3 pixel planes using 3 PCI-CFD cards

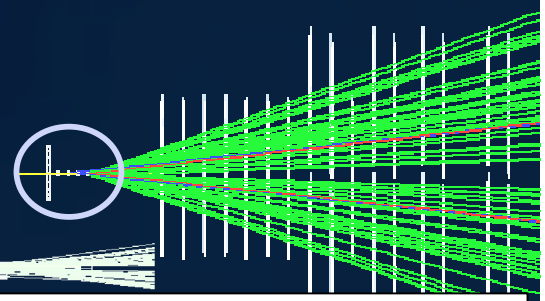
PCI-CFD



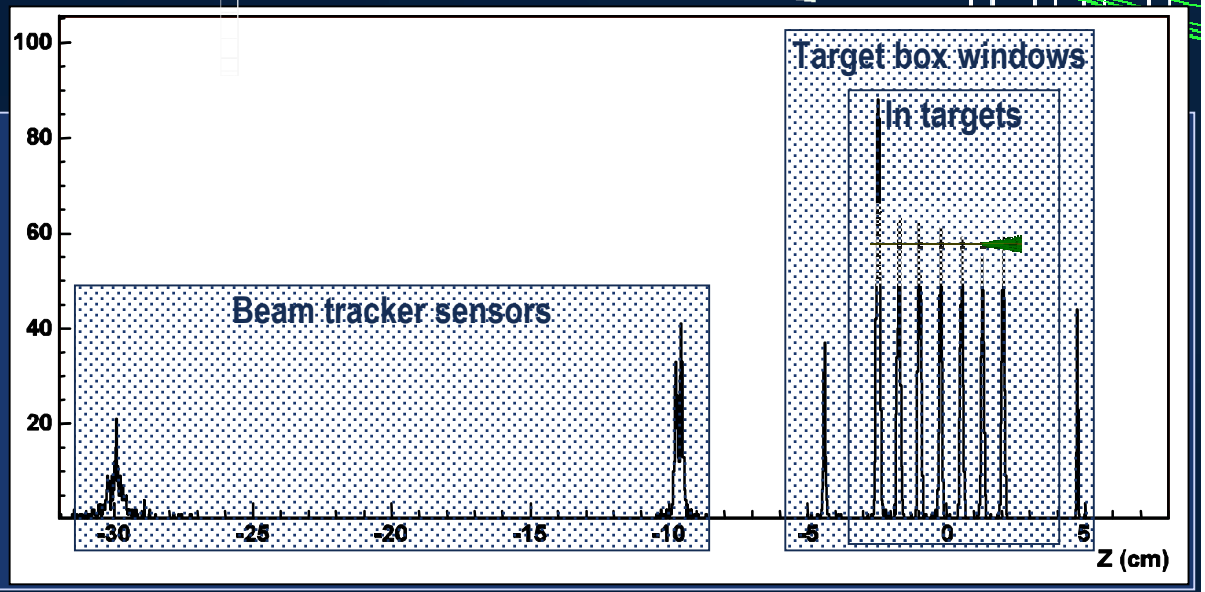
- **40 MHz logic**
- **64 MB on-board** SDRAM
  1000 events/s
- **~ 30 MB/s** read speed
- **Modularity**
  Support for mezannine daughter-cards
- NA60 uses it in
  Pixel telescope
  Beam tracker
  Zero degree calorimeter

Pixel telescope vertexing

- Data collected in October 2003 with 158 GeV Indium beam

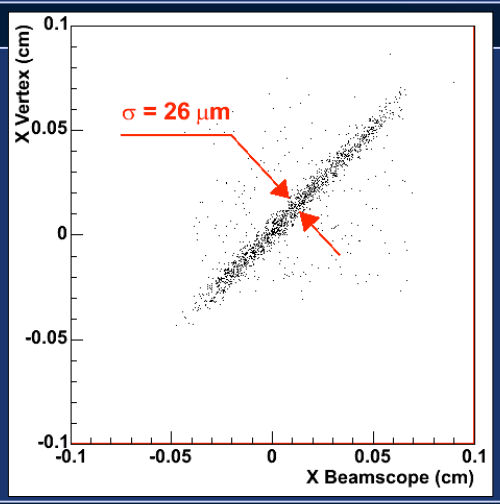


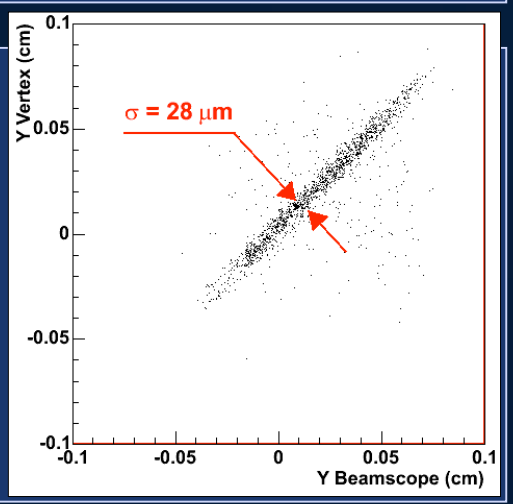
Z-vertex
determination
from pixel telescope



σ_z = 300 μm

Transverse coordinates
measured
by the pixel telescope
and the beam tracker



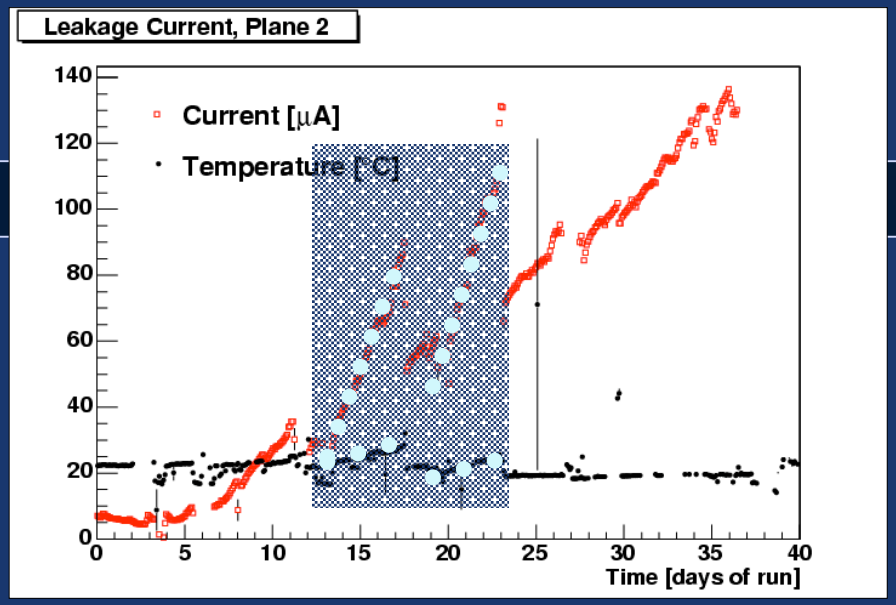


σ_{bt} ~ 20 μm σ_{vt} ~ 18 μm

Radiation effects

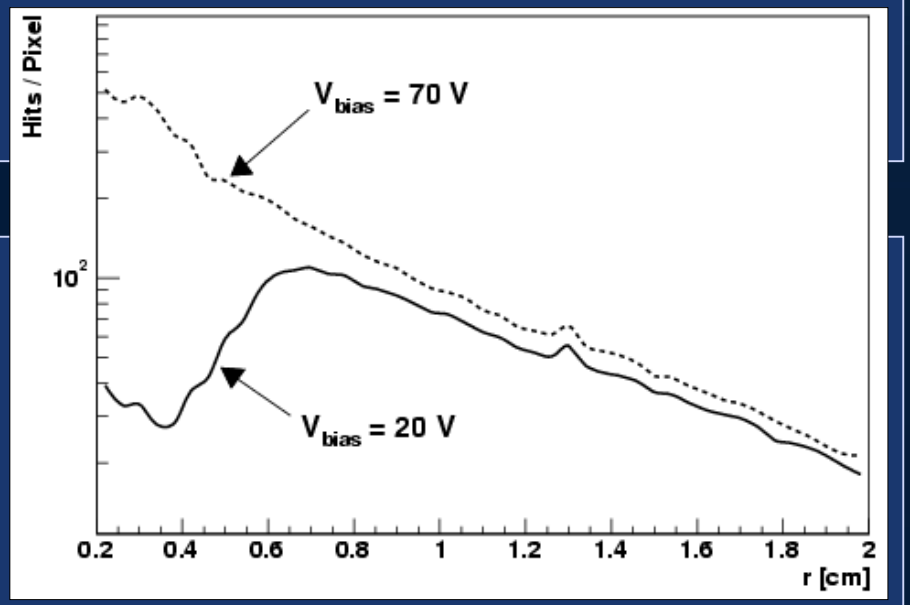
- 158 GeV SPS **Indium beam** in October 2003
- **~ 4 ▯ 10^{12} ions** delivered over **5 weeks**
- Performance was **closely monitored**
- Sensor **type inversion** was **expected**, **seen** and **understood**
- The detector **will be re-used in 2004** for proton running

Leakage current vs. time



- increase with integrated dose
- strong temperature dependence

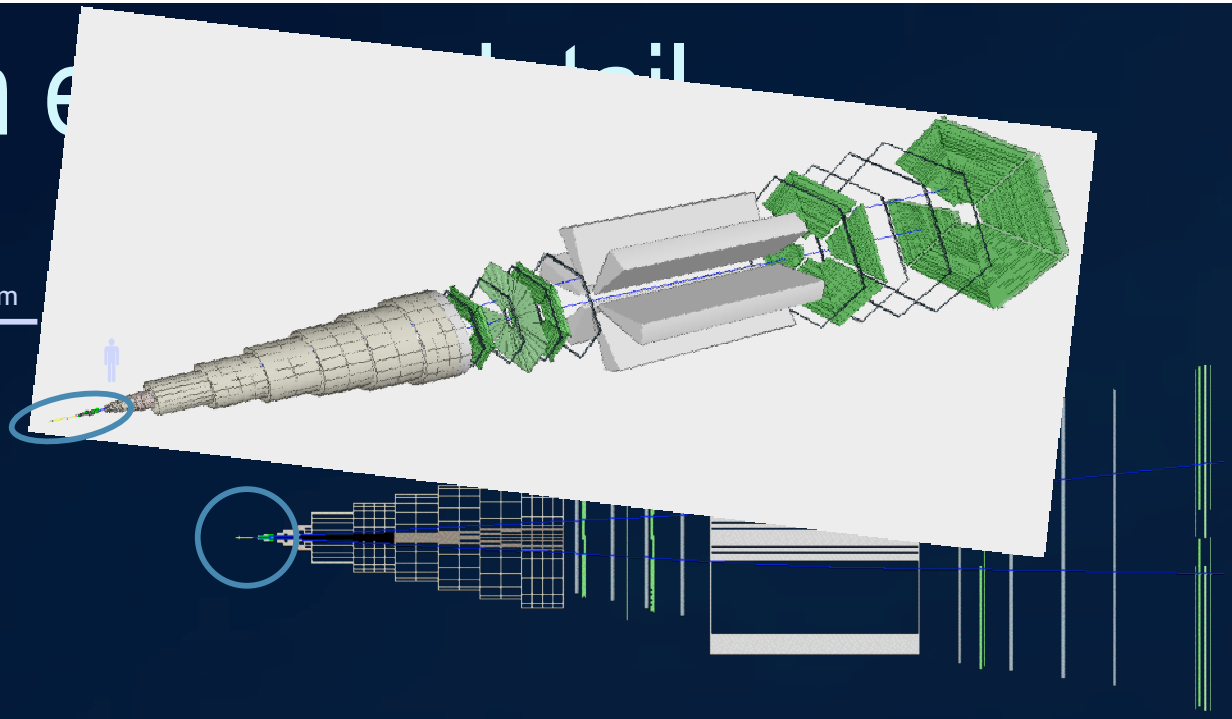
Hit efficiency vs. bias voltage



- inner region needs increased bias voltage after 5 weeks running

An e

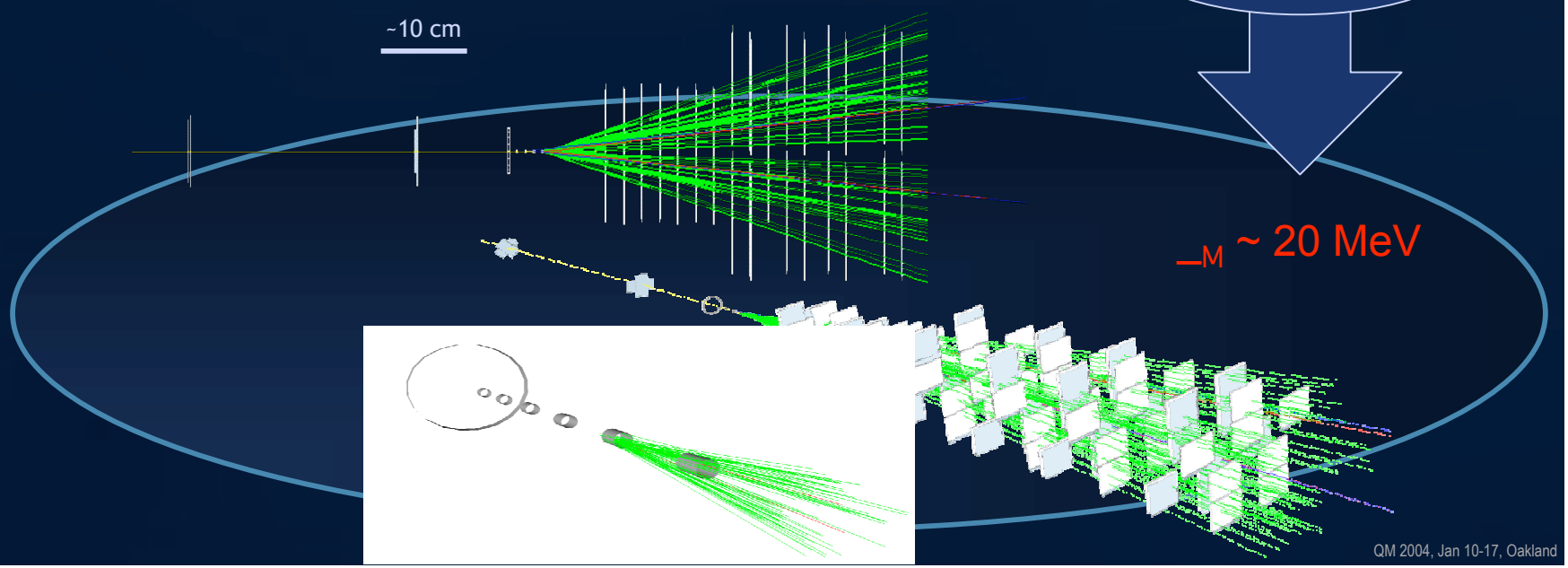
Event 5987
Burst 33
Run 6935



At the _ mass

$_{M}$ ~ 70 MeV

muon track matching



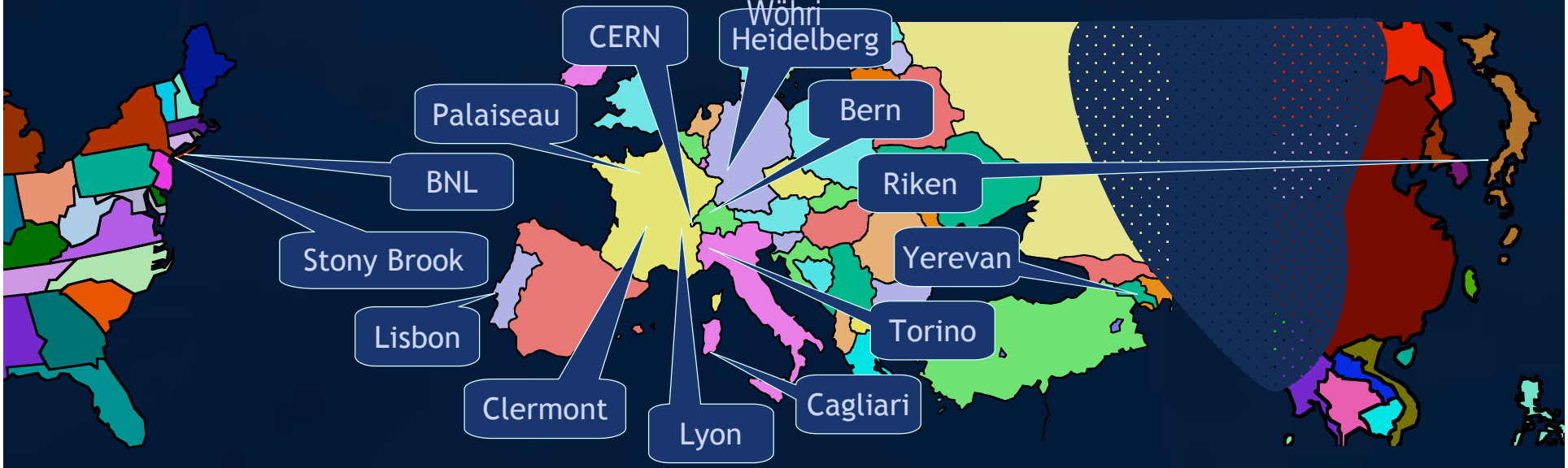
$_{M}$ ~ 20 MeV

The NA60 Collaboration

htttp://cern.ch/na60

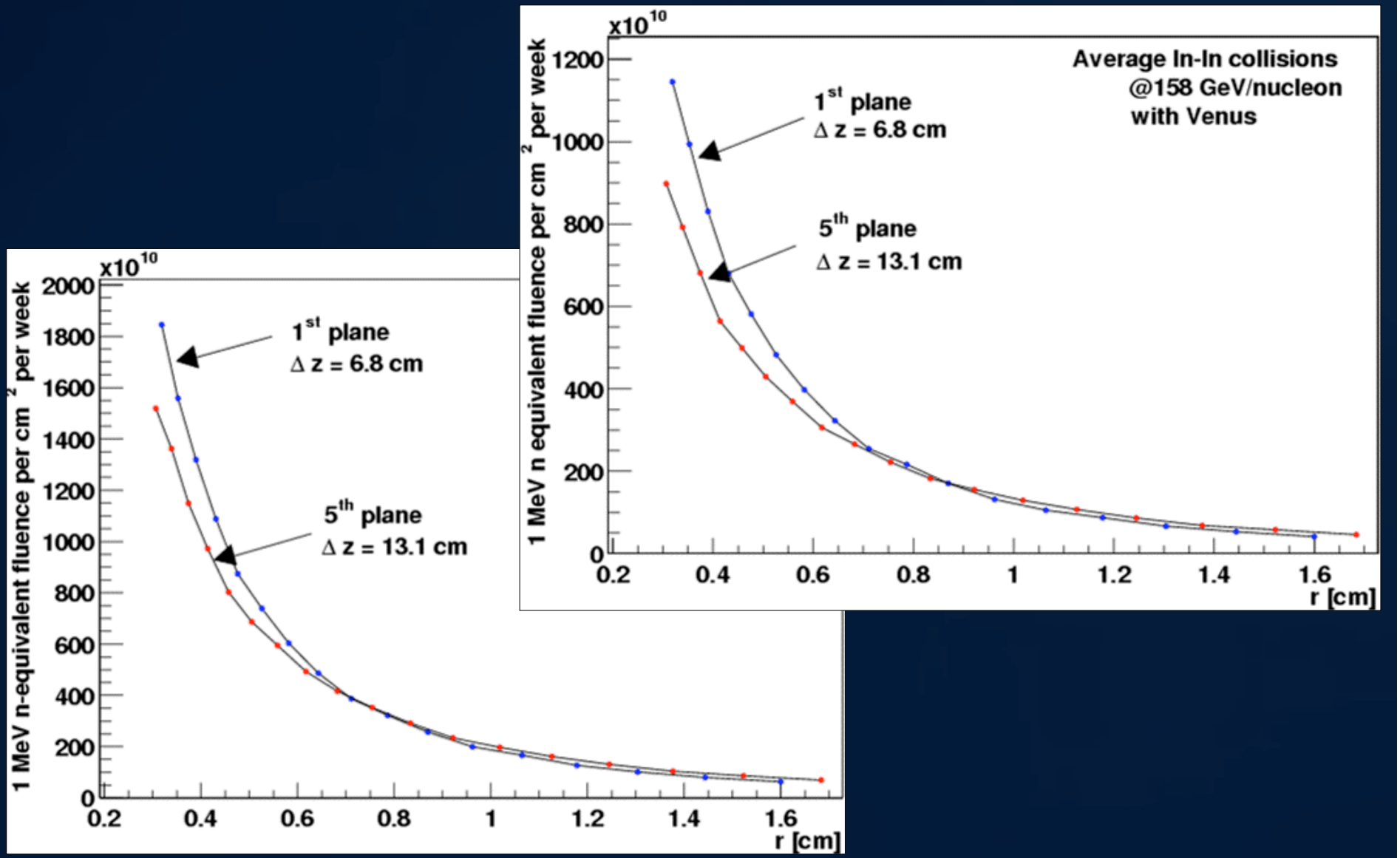
8 countries, 13 institutes, 57 people

R. Arnaldi, R. Averbeck, K. Banicz, K. Borer, J. Buytaert, J. Castor, B. Chaurand, W. Chen, B. Cheynis, C. Cicalò, A. Colla, P. Cortese, S. Damjanovic, A. David, A. de Falco, N. de Marco, A. Devaux, A. Drees, L. Ducroux, H. En'yo, A. Ferretti, M. Floris, P. Force, A. Grigorian, J.Y. Grossiord, N. Guettet, A. Guichard, H. Gulkanian, J. Heuser, M. Keil, L. Kluberg, Z. Li, C. Lourenço, J. Lozano, F. Manso, P. Martins, A. Masoni, A. Neves, H. Ohnishi, C. Oppedisano,
P. Parracho, G. Puddu, E. Radermacher, P. Ramalhete, P. Rosinsky, E. Scomparin, J. Seixas, S. Serci, R. Shahoyan, P. Sonderegger, H.J. Specht, R. Tieulent, G. Usai, H. Vardanyan, R. Veenhof, D. Walker and H. Wöhri



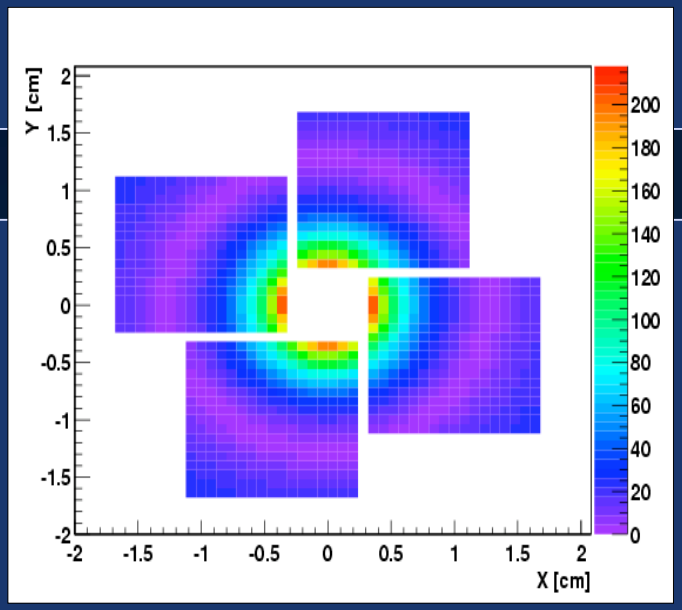
Off-talk

Radiation damage fluence simulation



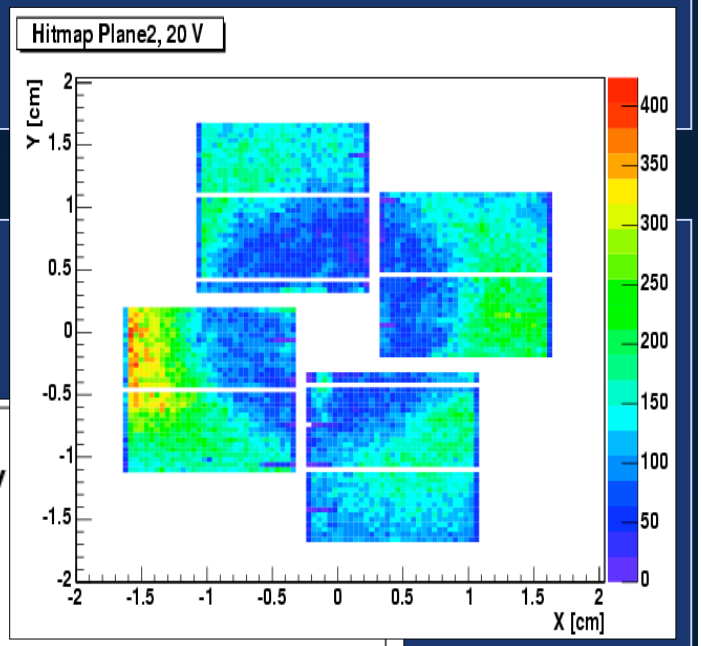
Radiation effects – depletion voltage

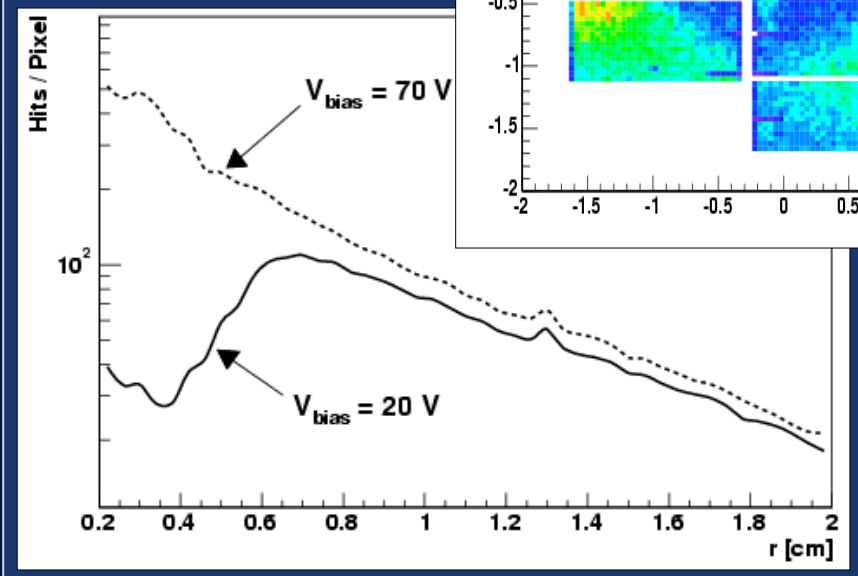
Simulated **depletion voltage**



- after 4 weeks In running
- fluency estimate from Venus minimum bias events
- type-inversion expected

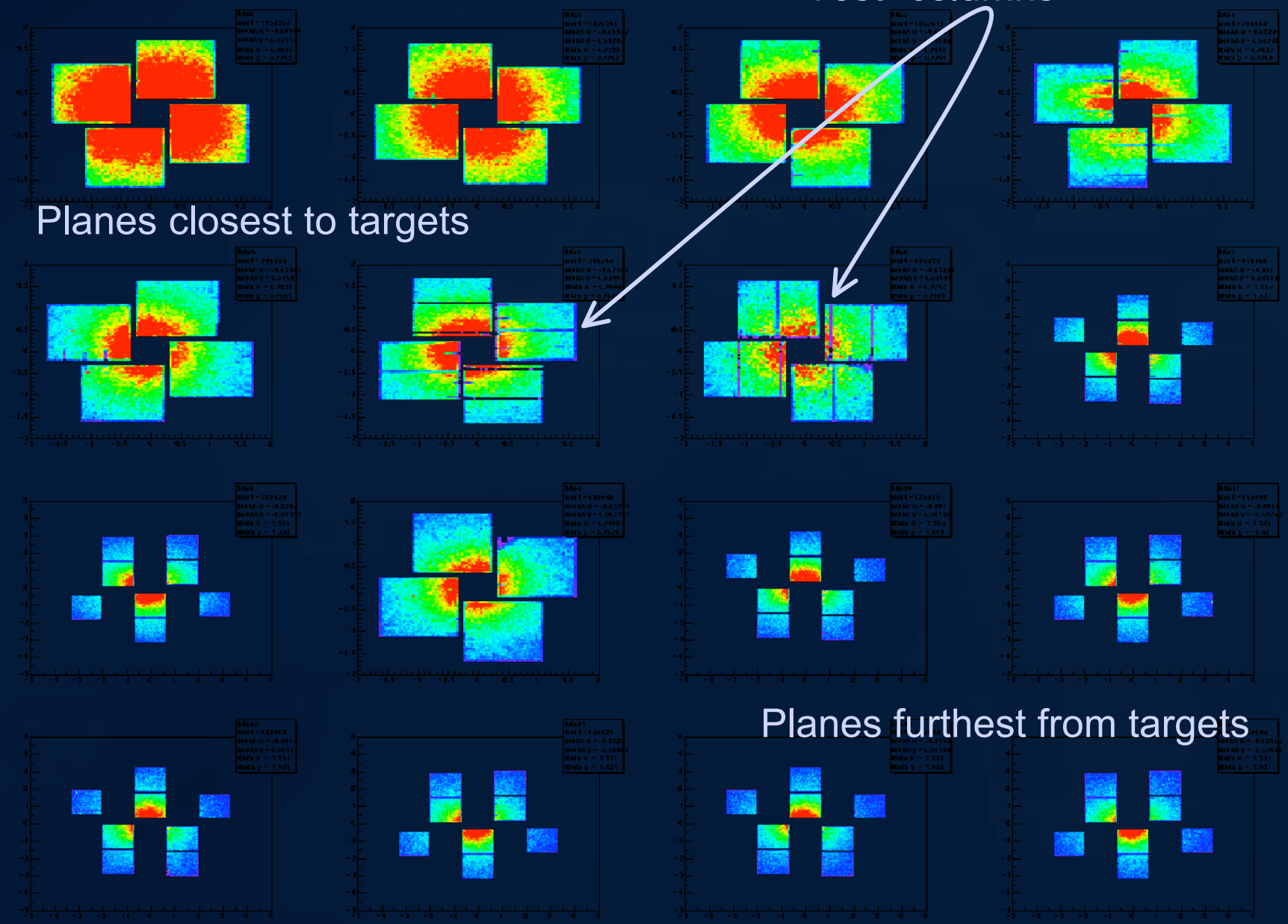
Measured **hit rate**



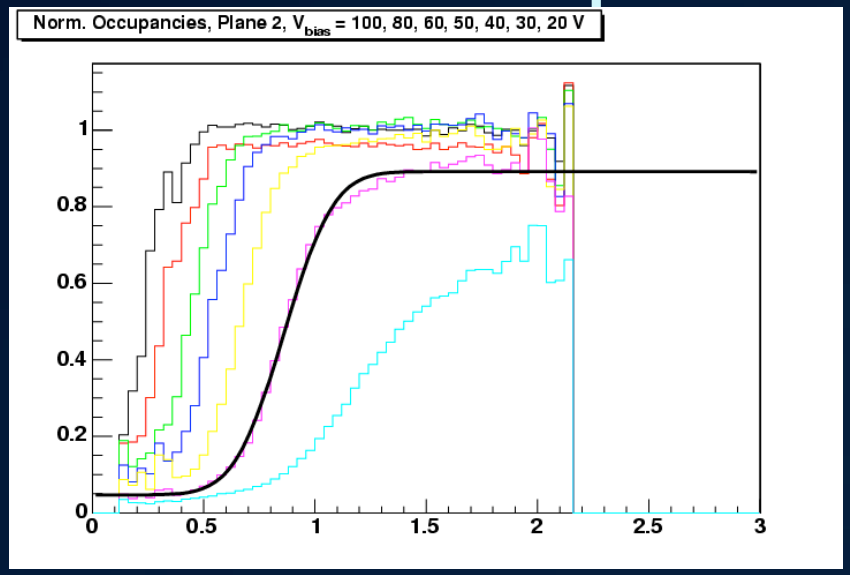


- with 20 and 70 V bias
- after 5 weeks running Indium beam

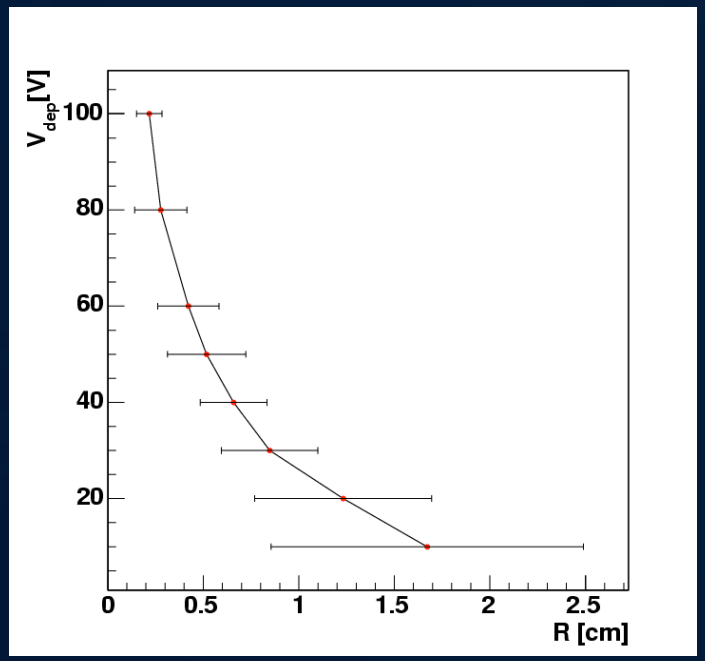
Online pixel hit maps



HV Scan – Depletion Voltage vs R



- Clear dependence of the working pixels on the depletion voltage
- Fit error function to get radius



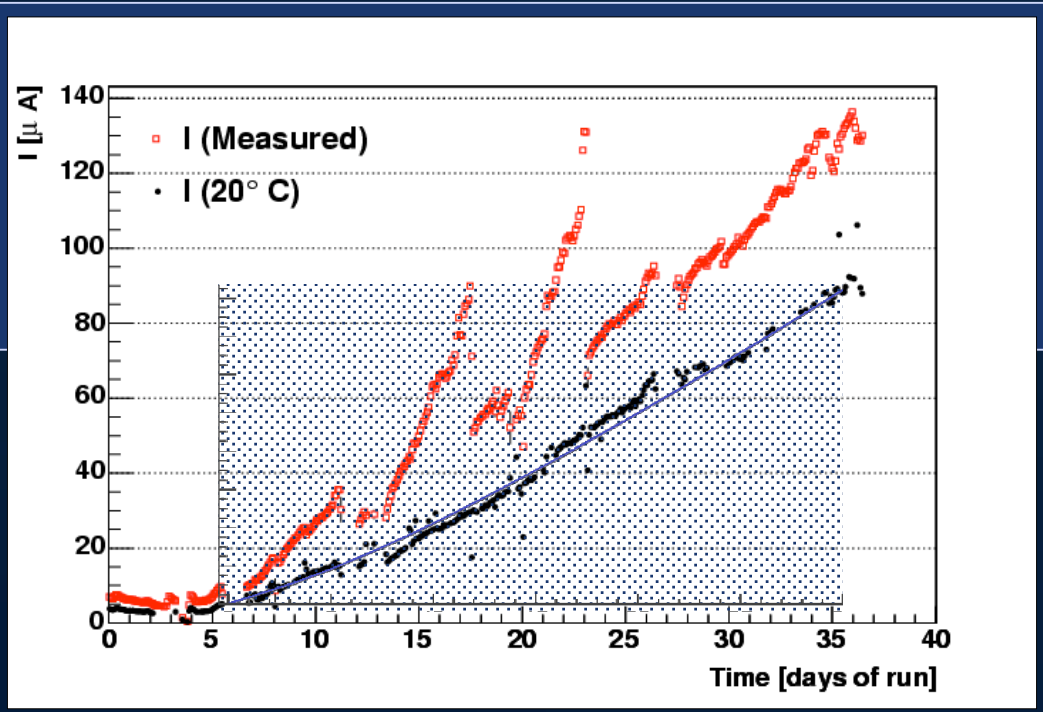
V_{dep} vs R

- Qualitative behaviour as expected!

  (error bars: sigma of the fit, more or less my undecisiveness of where to put the point)
- Quantitative analysis: understand annealing…

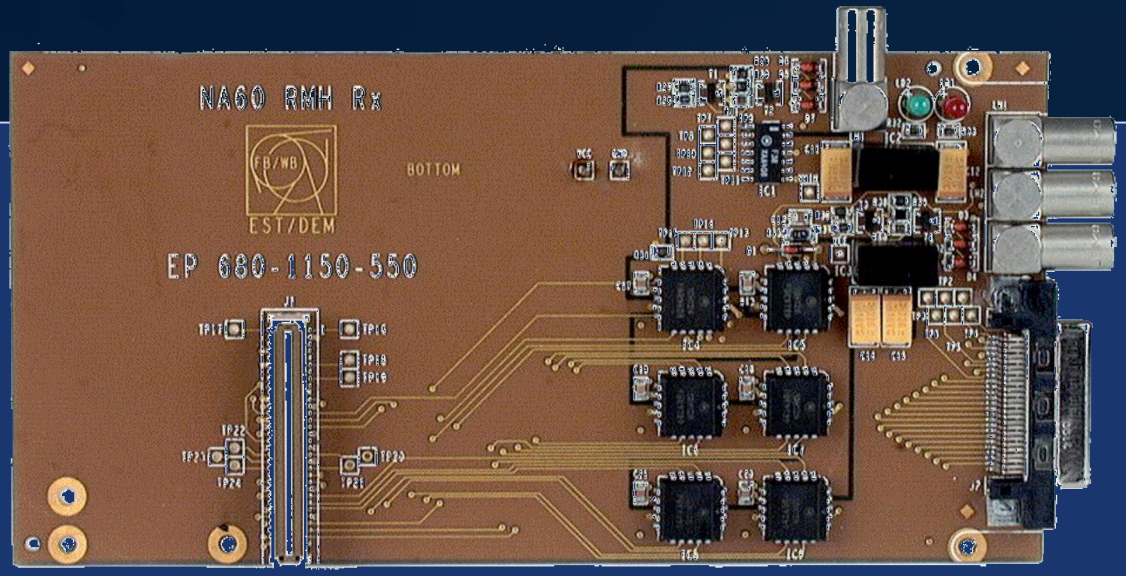
Radiation effects – leakage current

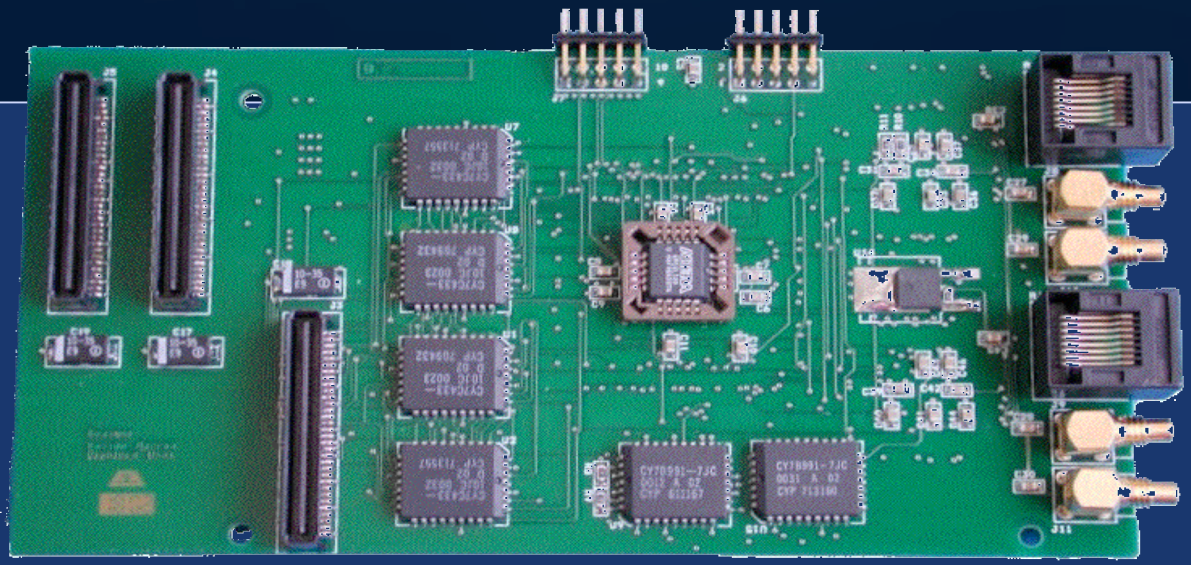
Temperature corrected current fits expected behaviour



Read-out mezzanines

ECL_TTL mezzanine

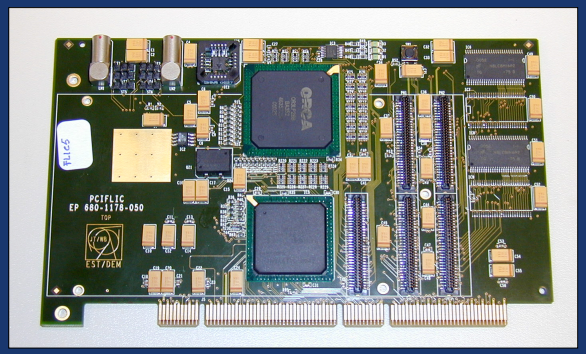




Pixel readout mezzanine

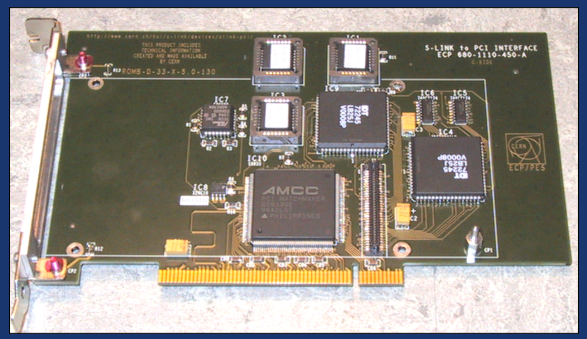
Other PCI cards

PCI-FLIC

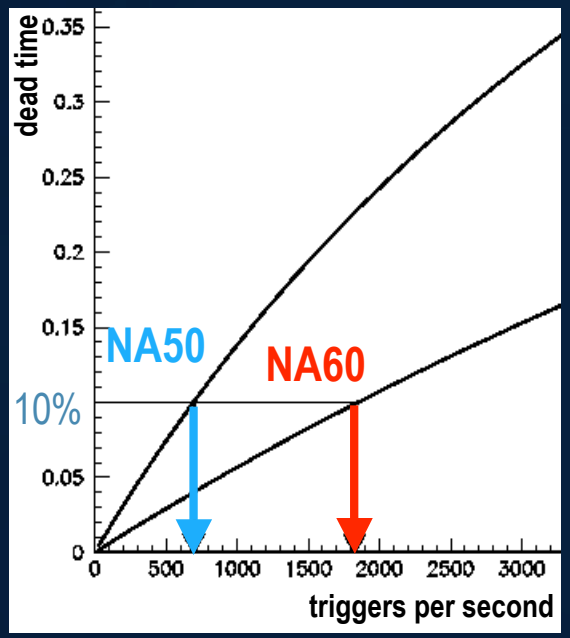


- PCI target
- ~ 10 MB/s rate
- 15 MHz logic
- 32 MB SDRAM
- CPU copies data
- Custom, PCI and SLINK mezzanines
- CERN-EP 2002
- No longer used

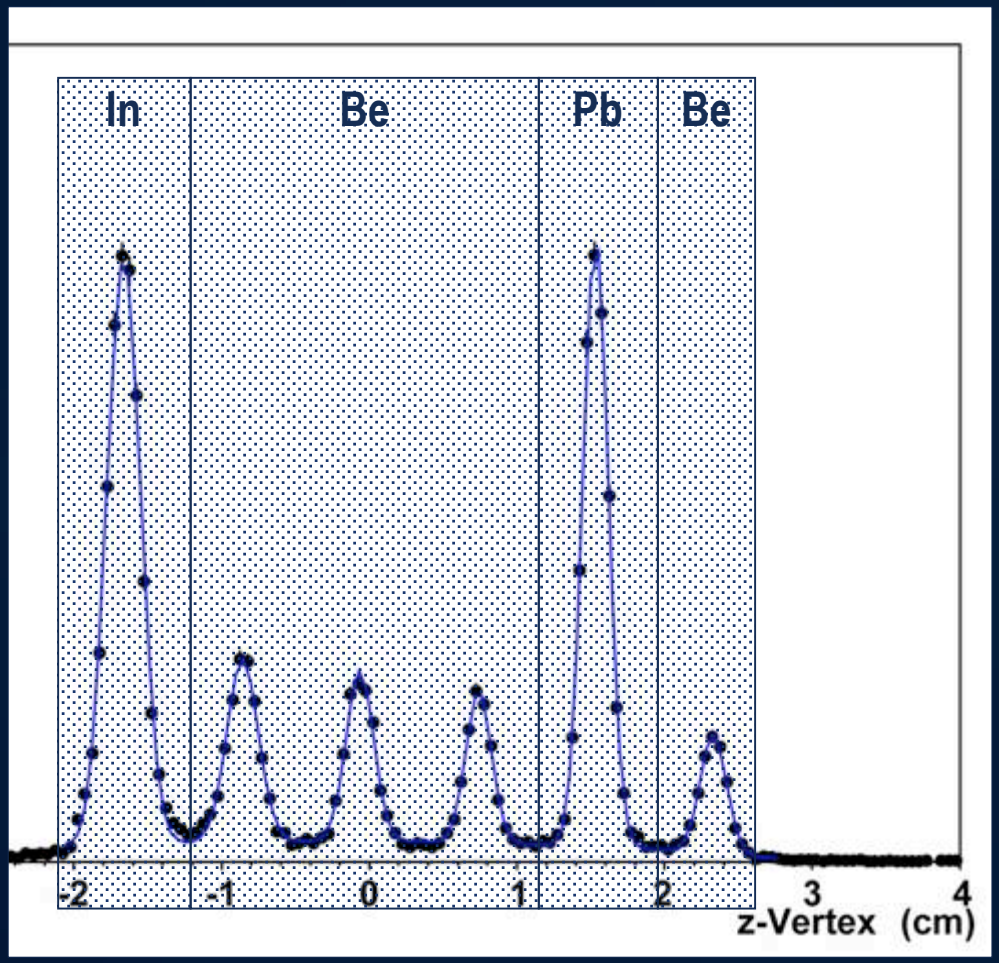
Custom SSPCI



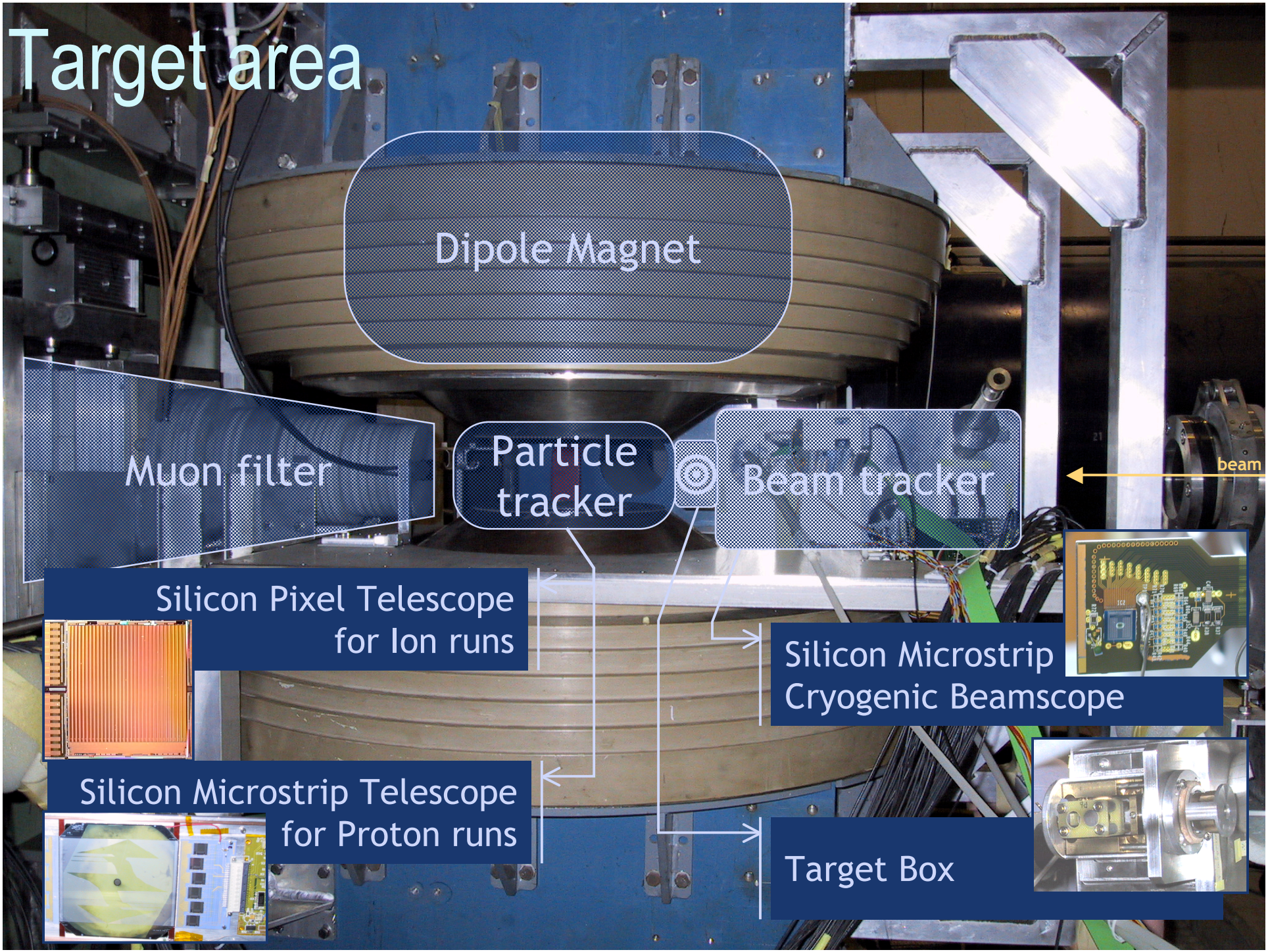
- PCI master
- ~ 120 MB/s rate
- 33 MHz logic
- 256 kB FIFOs
- DMA data to RAM
- SLINK mezzanines
- CERN-EST 1997
- Strip telescope read-out



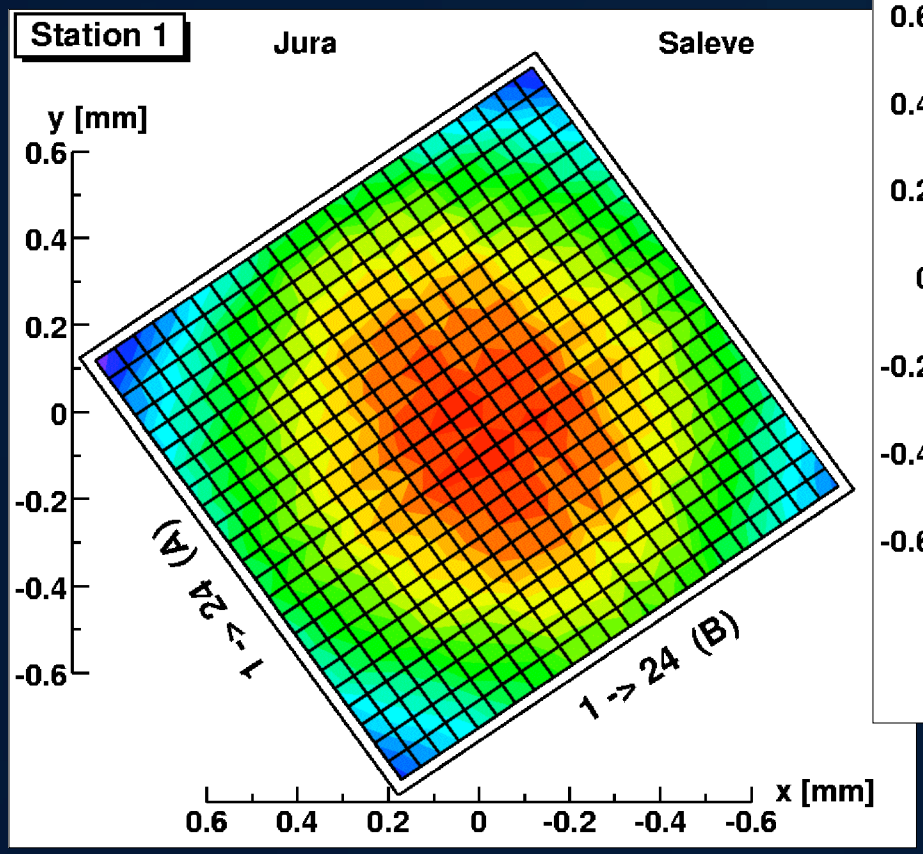
z-vertex in p-A

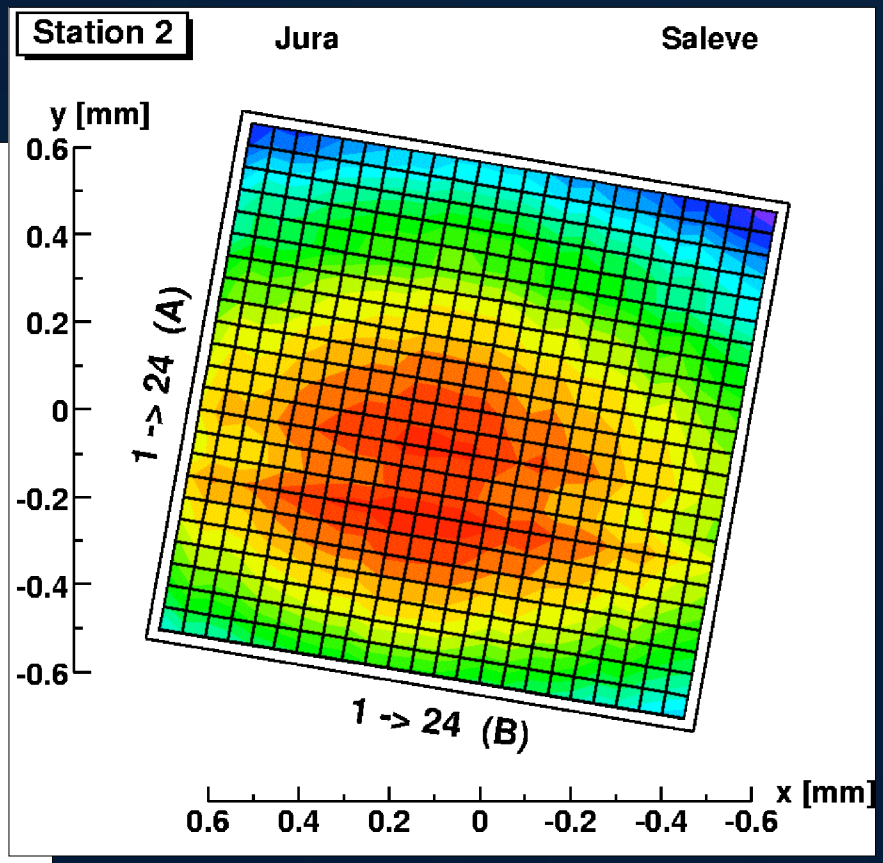


Target area

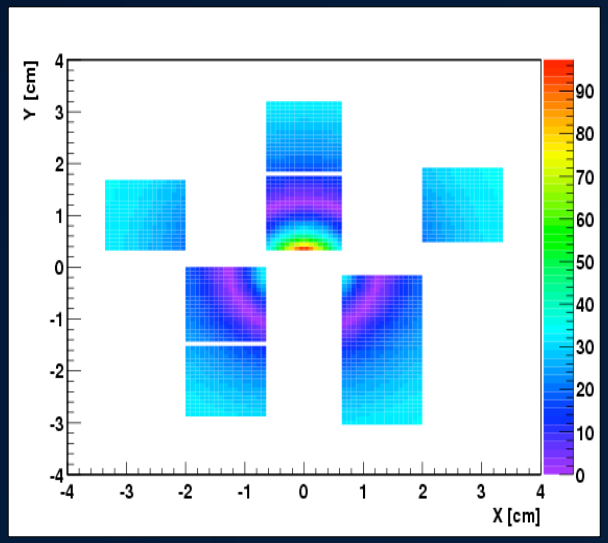

Dipole Magnet
Muon filter
Particle tracker
Beam tracker
beam
Silicon Pixel Telescope for Ion runs
Silicon Microstrip Cryogenic Beamscope
Silicon Microstrip Telescope for Proton runs
Target Box

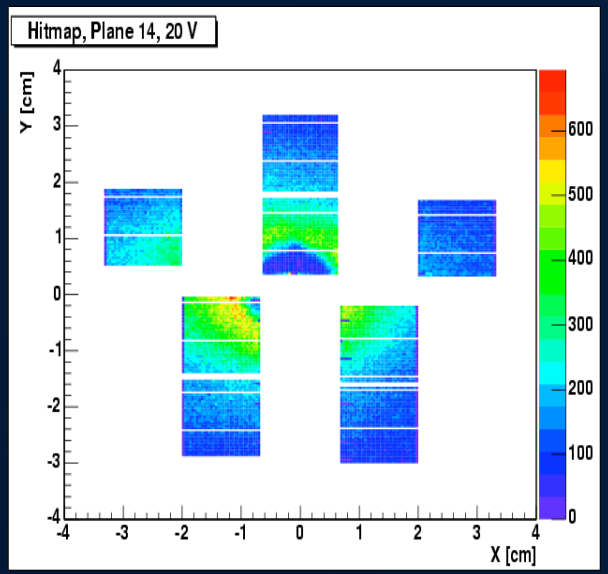
Beam tracker profiles with 20 GeV Pb beam

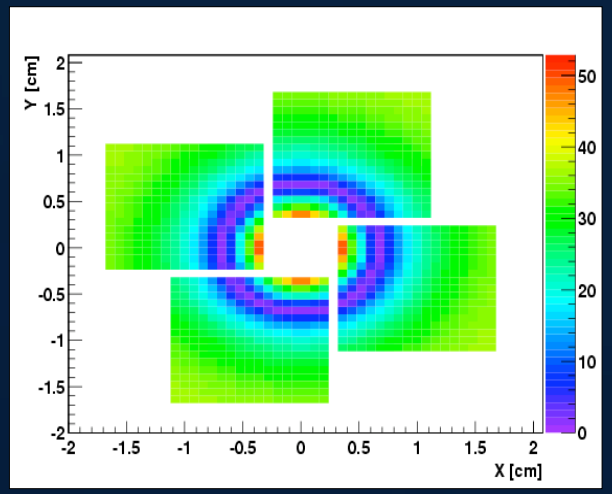


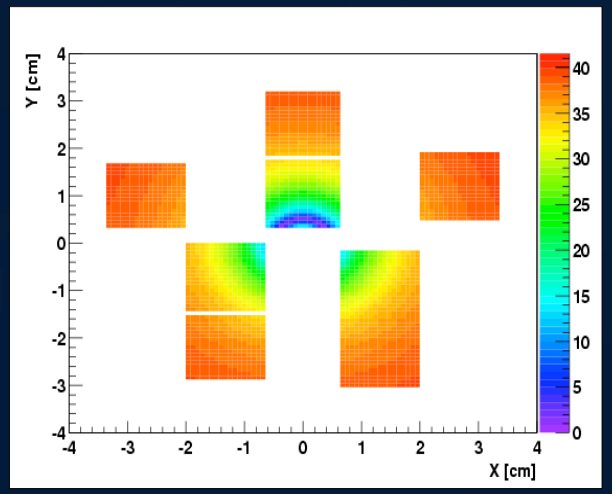


Radiation effects









Beam tracker profiles with 20 GeV Pb beam