
# Cryogenic Silicon Detectors to Measure High-Intensity Beams

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# Credits

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B. Pes
P. Rosinsky

All members of RD39 and NA60 Collaborations

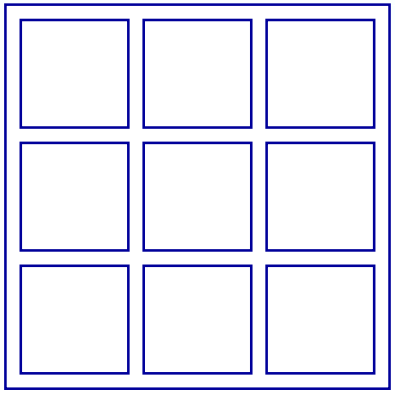
# Outline

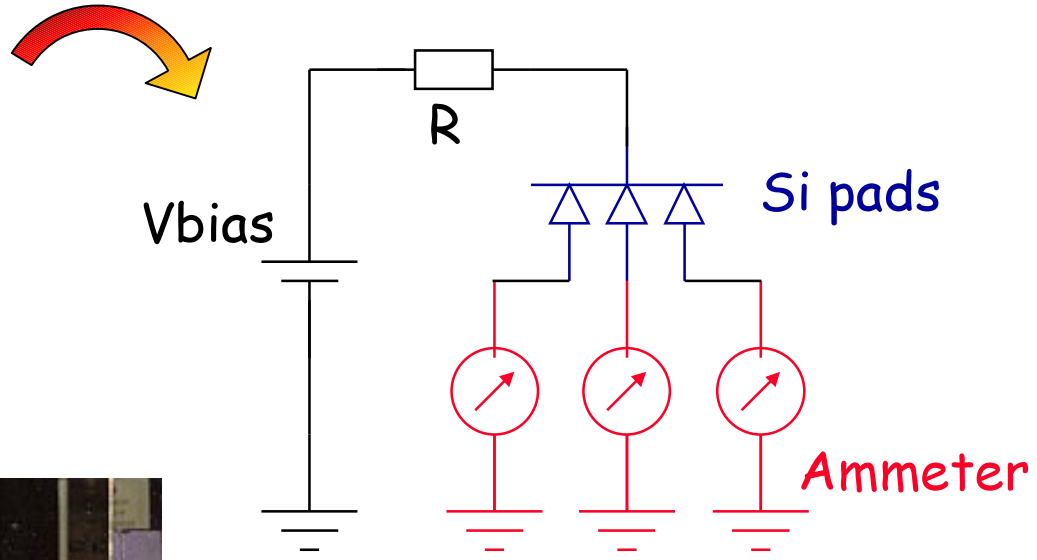
- **Beam Monitoring:**
  - ✓ proton beam
  - ✓ heavy ion beam
- **Beam Tracking:**
  - ✓ proton beam
  - ✓ heavy ion beam
- Conclusions

# Cryogenic Silicon as Ionization Counter

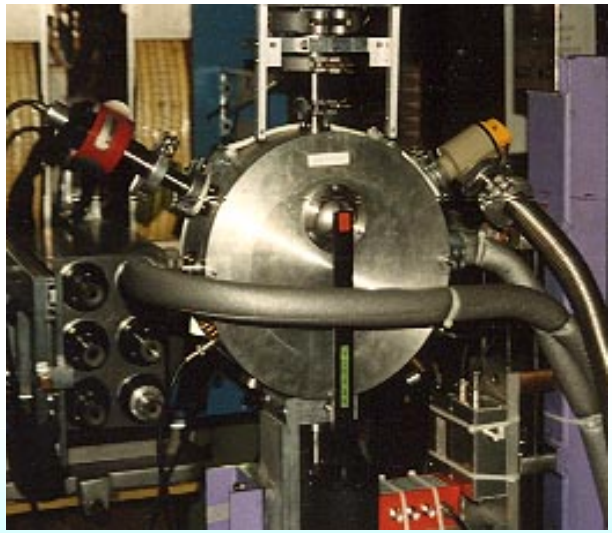
# Working Principle

Si Pads
(1.5 x 1.5 mm²)

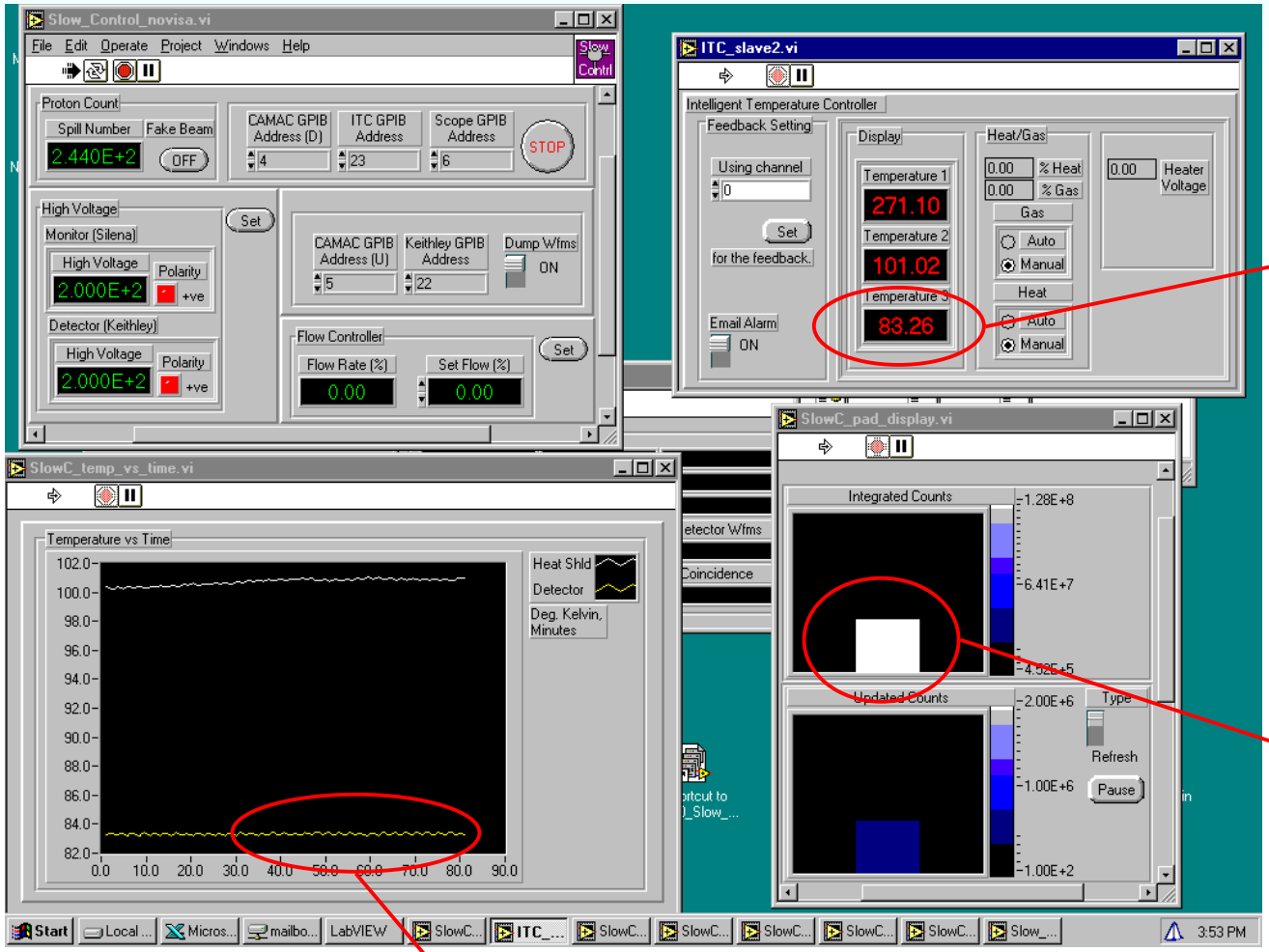





T = 80 K !



# The Experiment

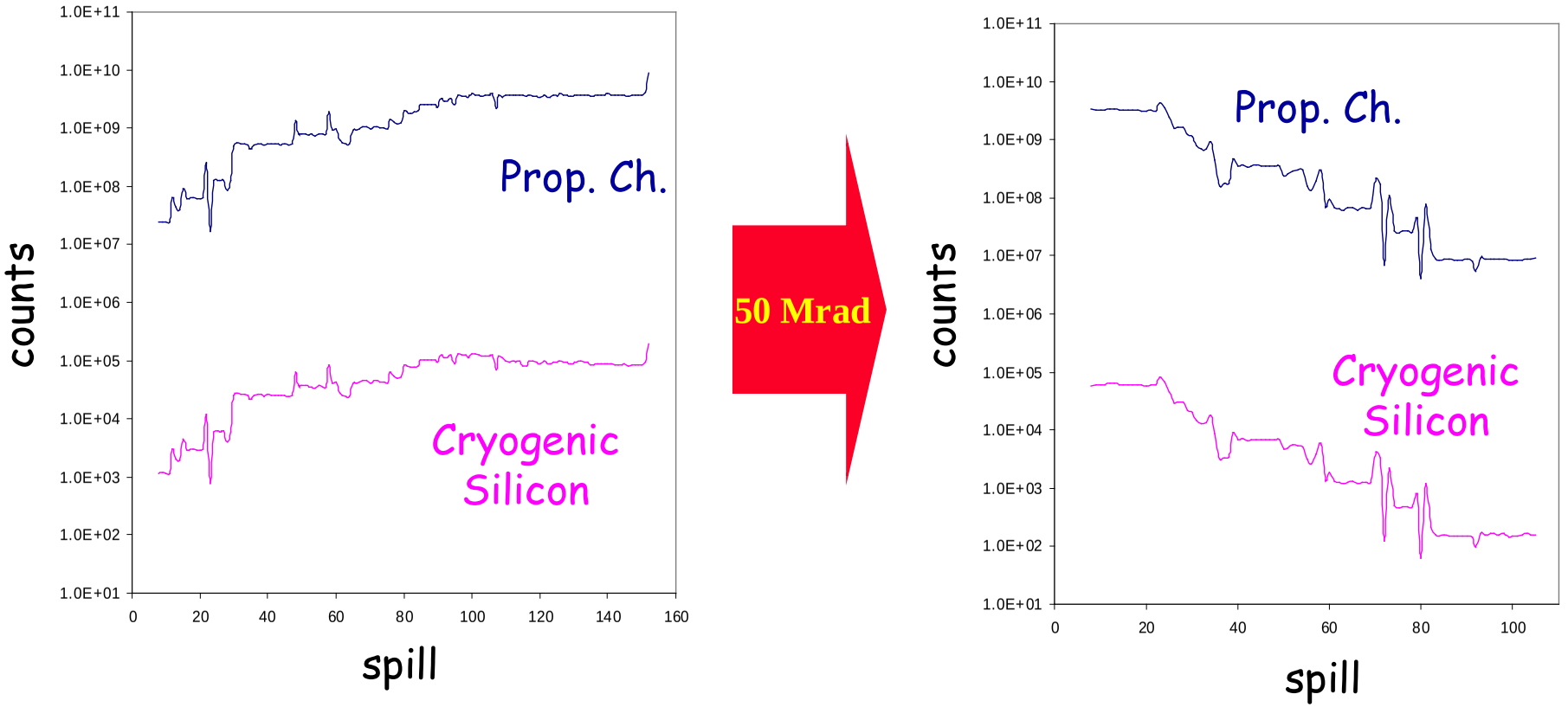



detector temperature

beam centered on bottom-middle pad

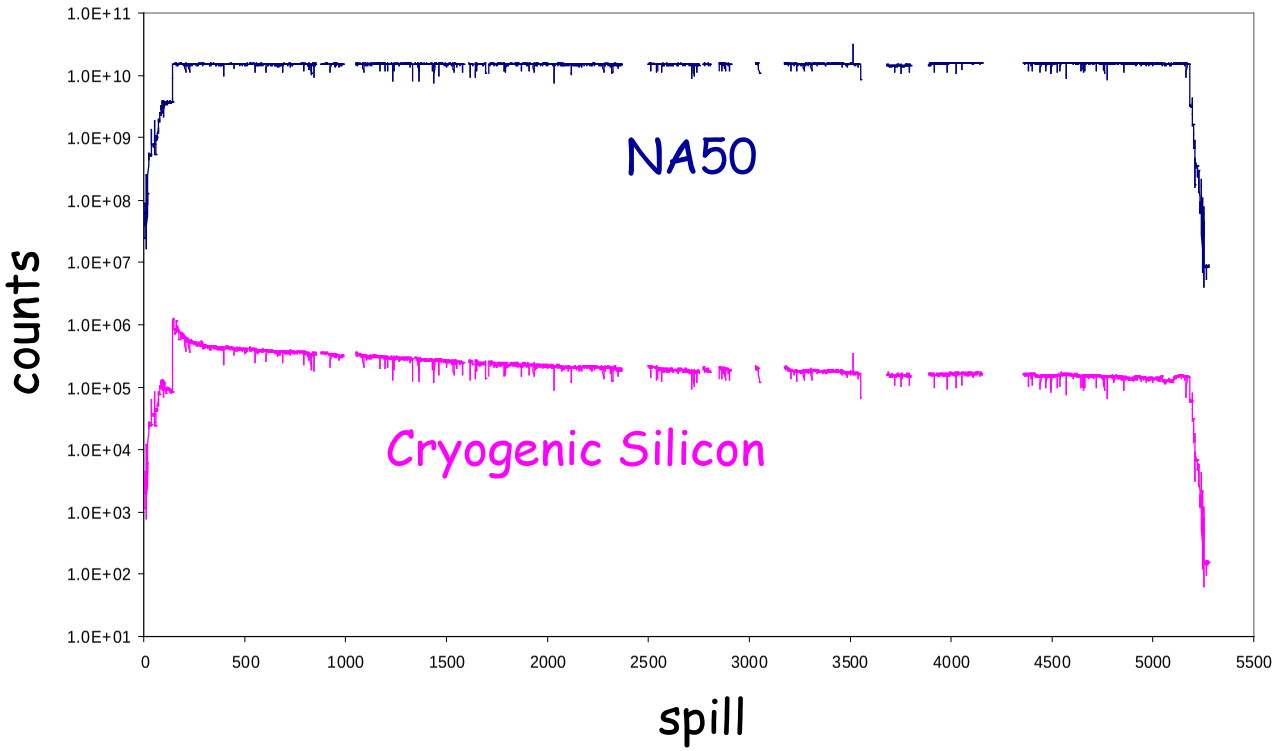
temperature evolution

# Cryogenic Si vs Proportional Chamber

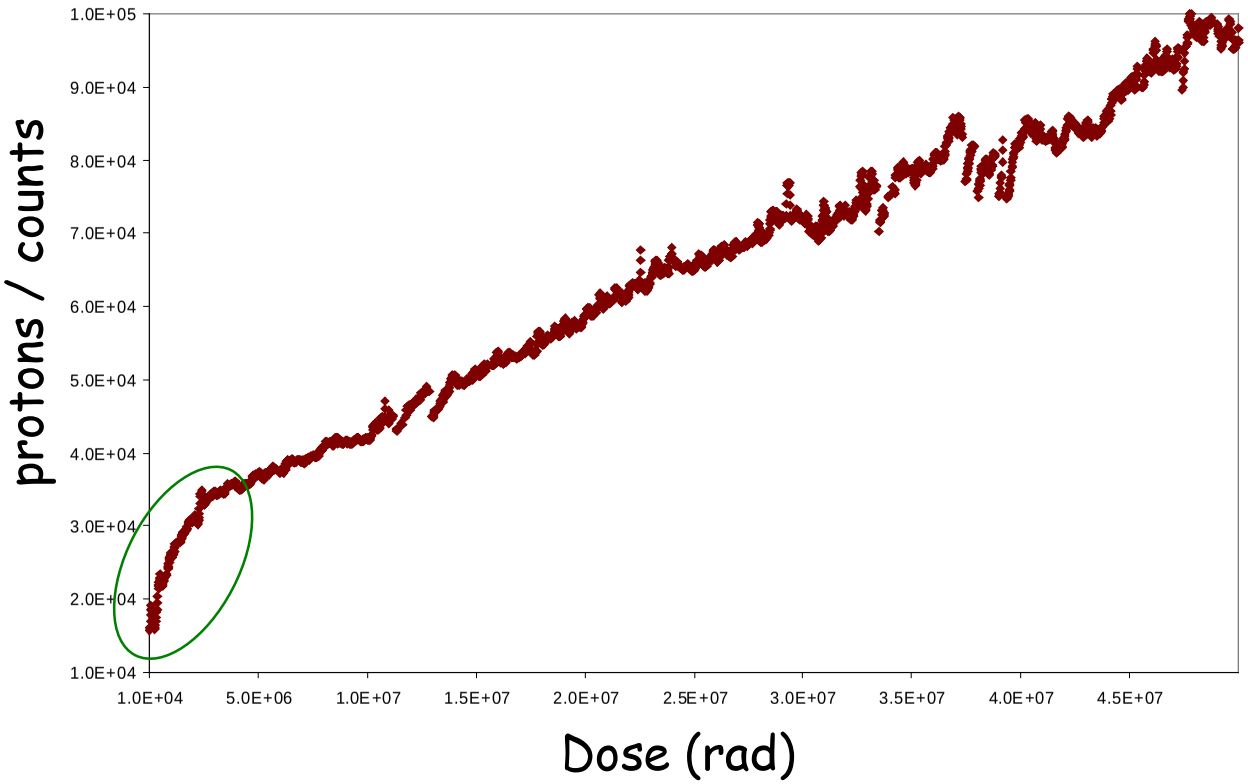



OK over 3 orders of magnitude !
($10^7 \div 10^{10}$ protons / burst)

# Calibration Evolution

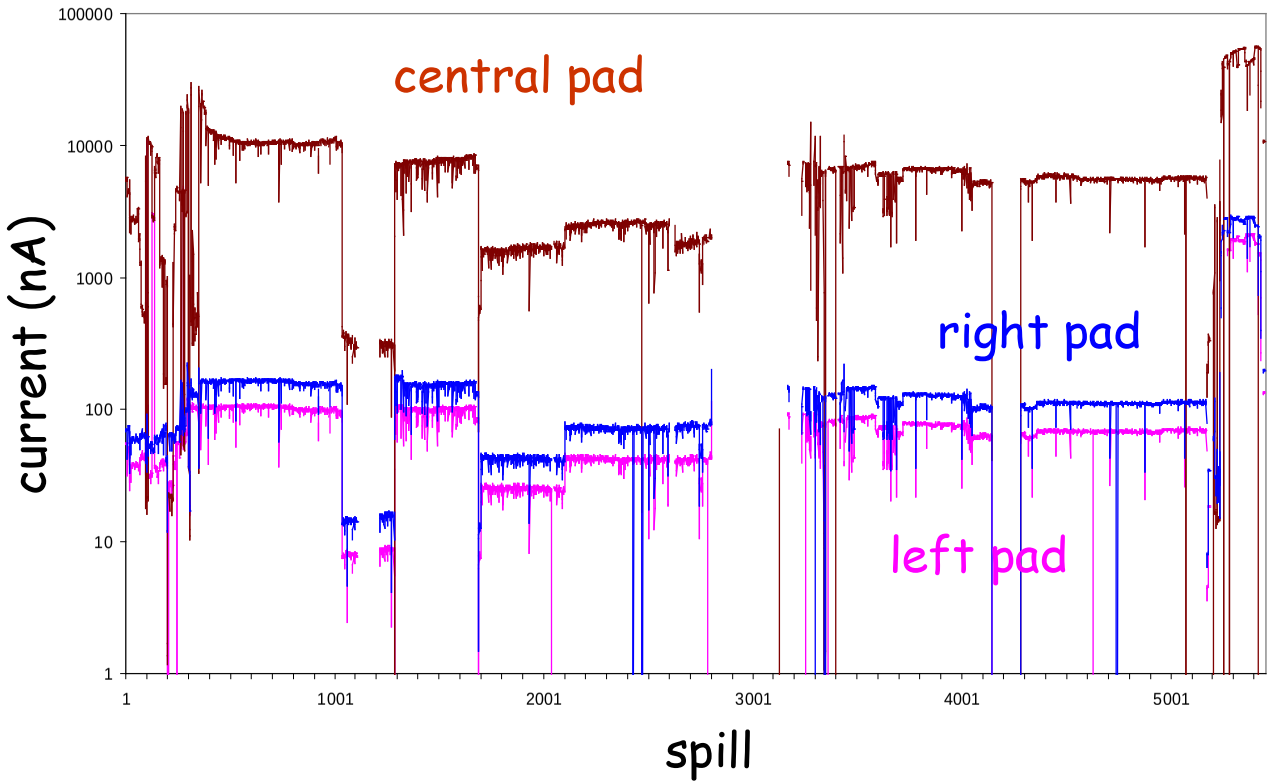


# Calibration Evolution



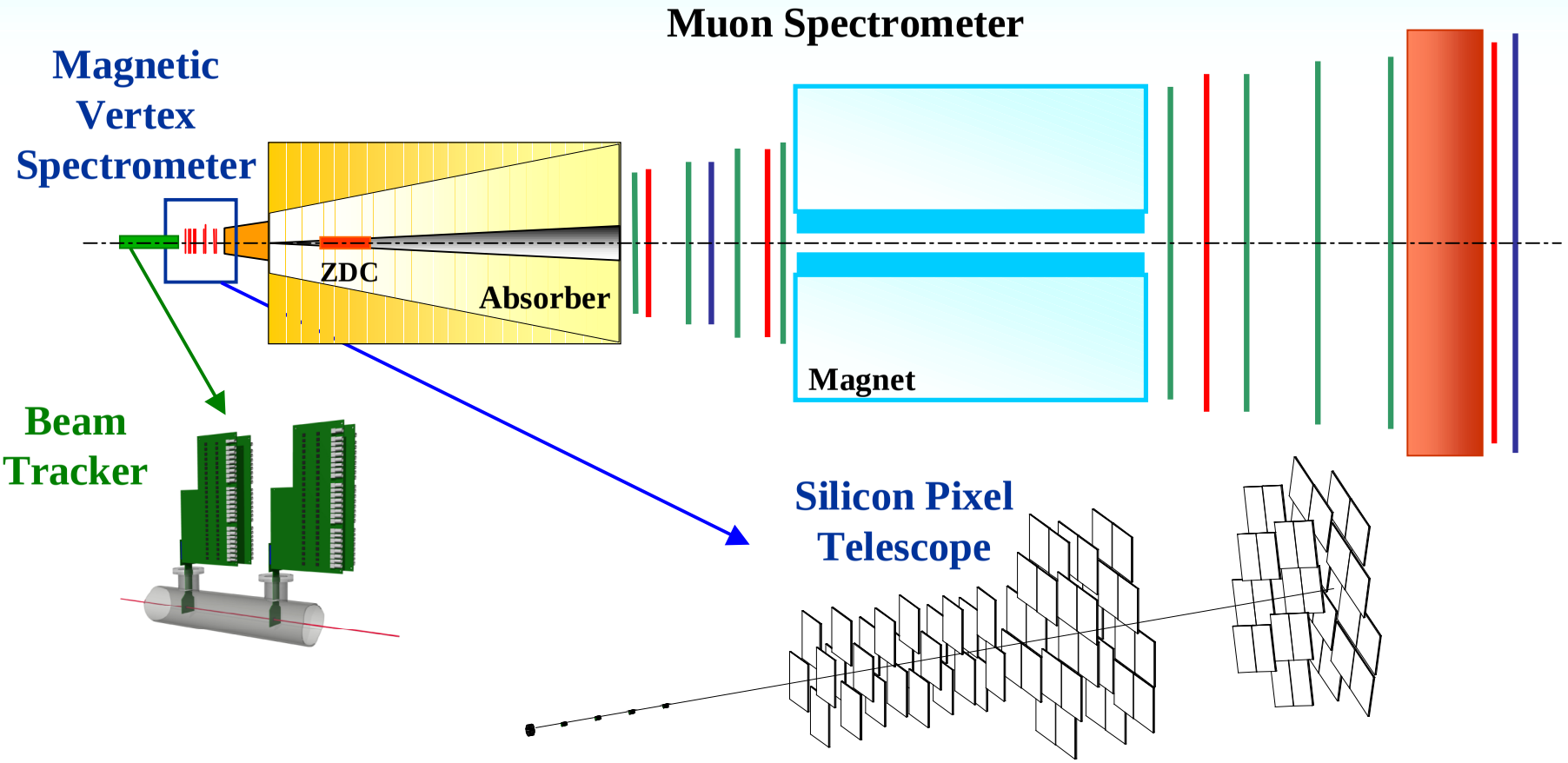

$$protons / counts = (32 + 1.4 \times Dose) \times 10^3$$

# Pb Beam Raw Data



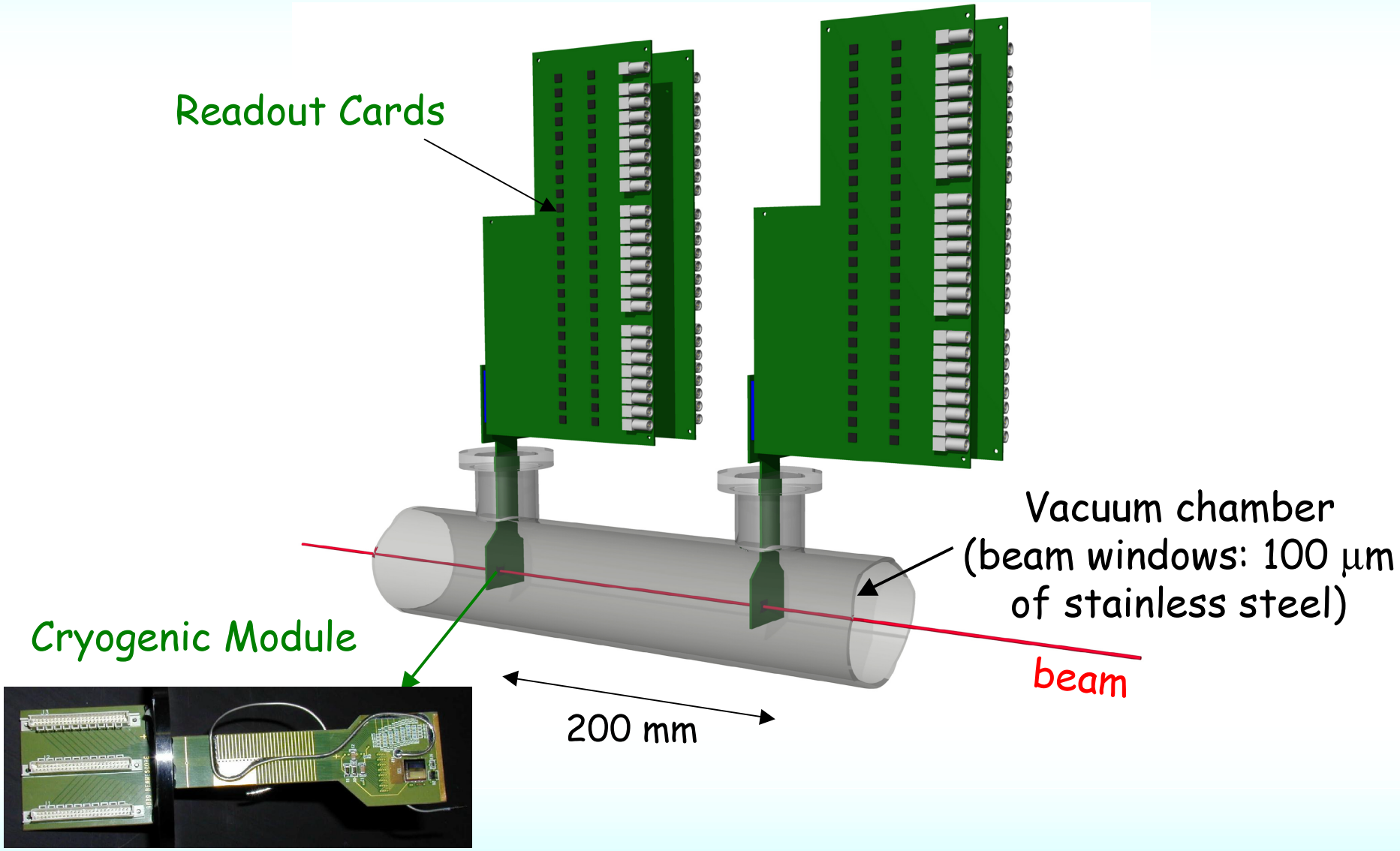
# Cryogenic Silicon as Beam "Tracker"

# The CERN NA60 Experiment



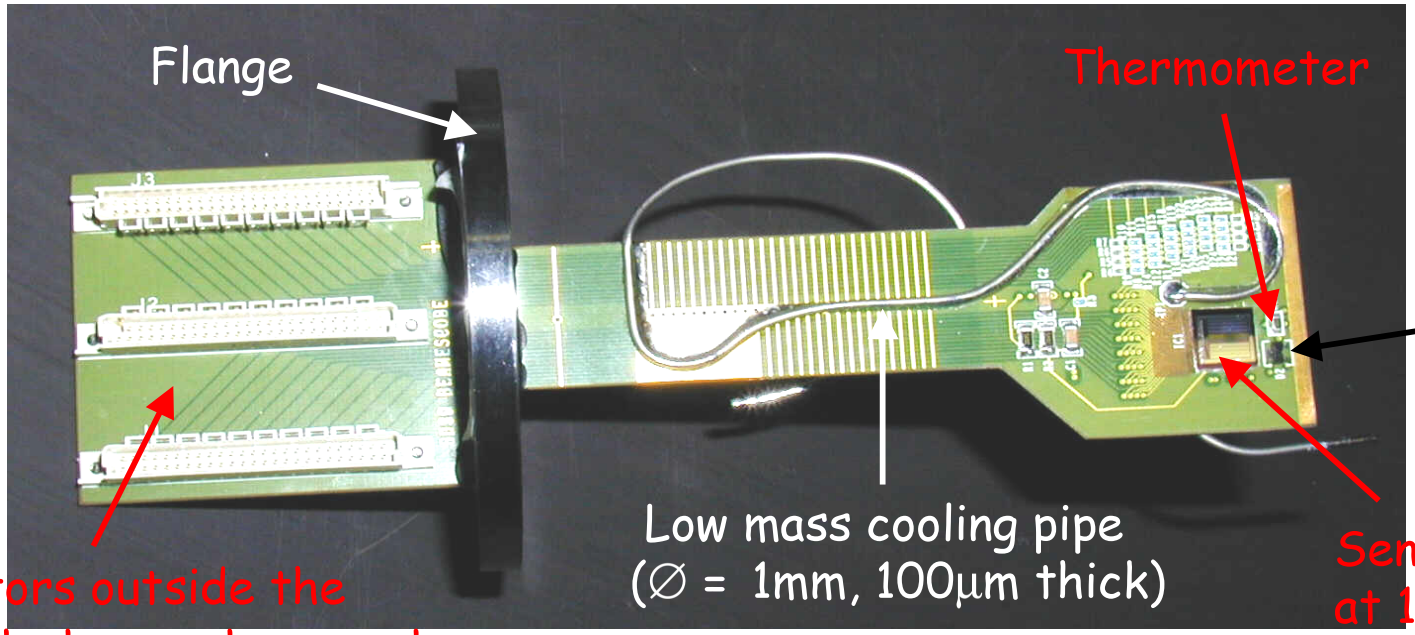

- Study $\mu^+\mu^-$ production in heavy ion collisions
- Signals related to phase transition from hadronic matter to Quark-Gluon Plasma
- First measurement of charm production in heavy ion collision

# The RD39/NA60 Ion Beamscope



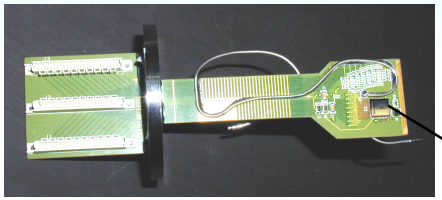
# The Cryogenic Module

Double-sided glass-epoxy PCB
with two detectors measuring x and y

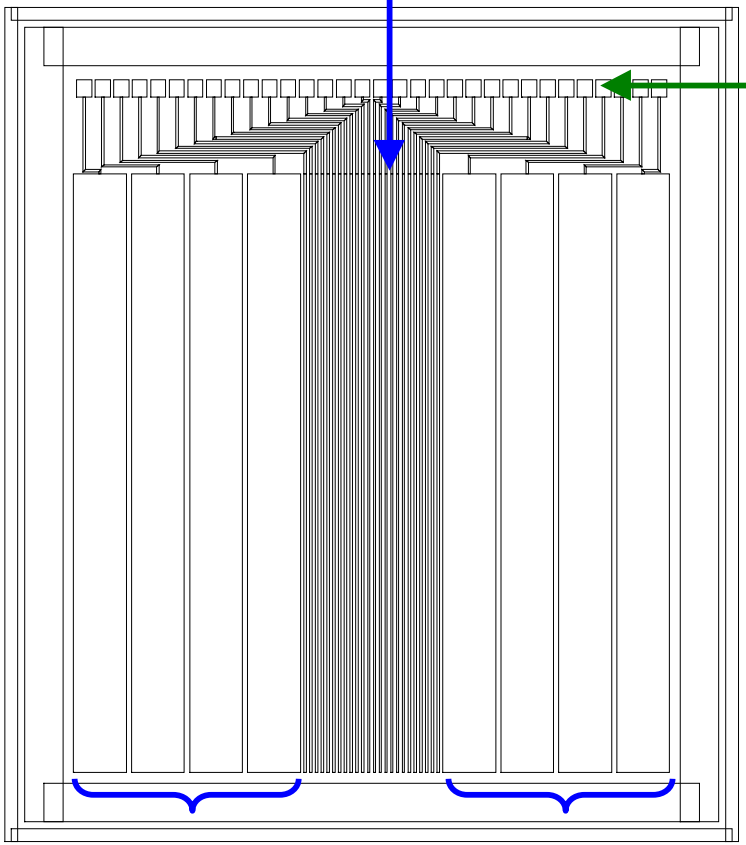



- Heat load from connectors: ~2W
- No power dissipation at the sensor
- Temperature adjusted between 80 K and 300 K by tuning the nitrogen flow and the power dissipated through the heater

# The Sensor



• 24 narrow strips (50 μm pitch)
to track the ions



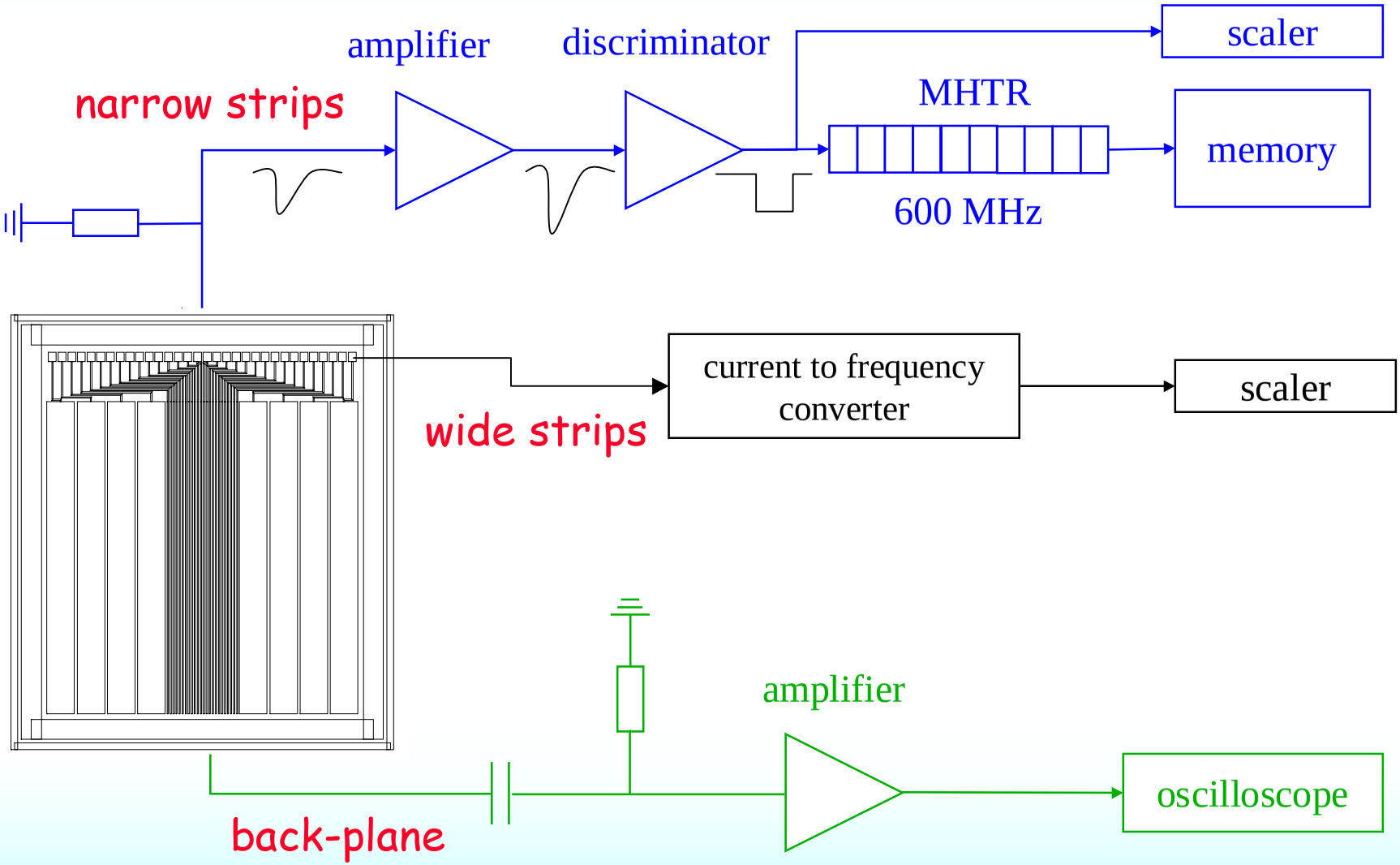
Integrated
fan out

Produced at BNL:
- Al/$p^+$/n/$n^+$/Al
- 30-40 KΩ/cm
- 400μm thick

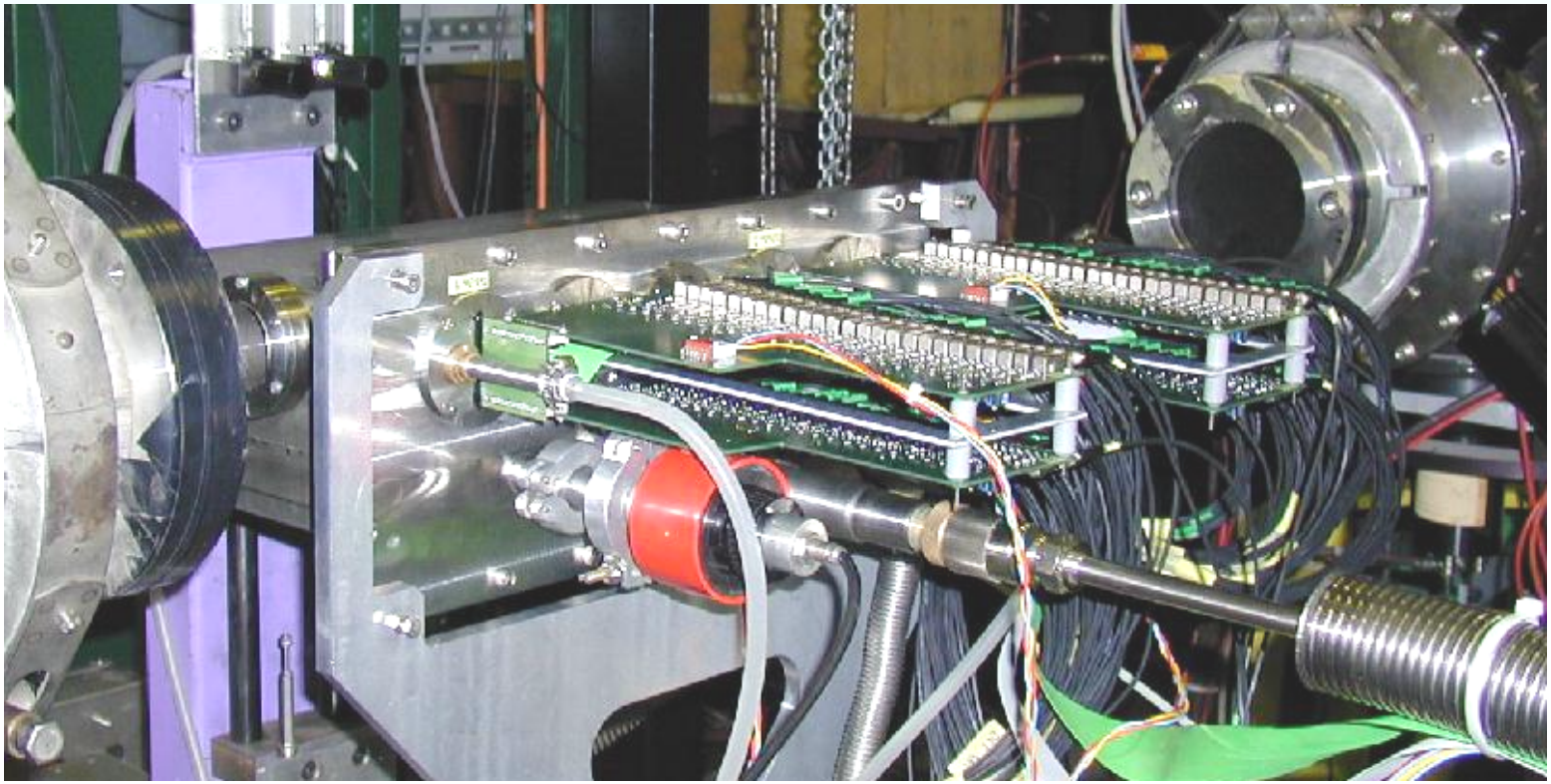
(4 planes: ~1% of interaction length)

• 2×4 wide strips (500 μm pitch)
for beam steering

# The Beamscope Readout



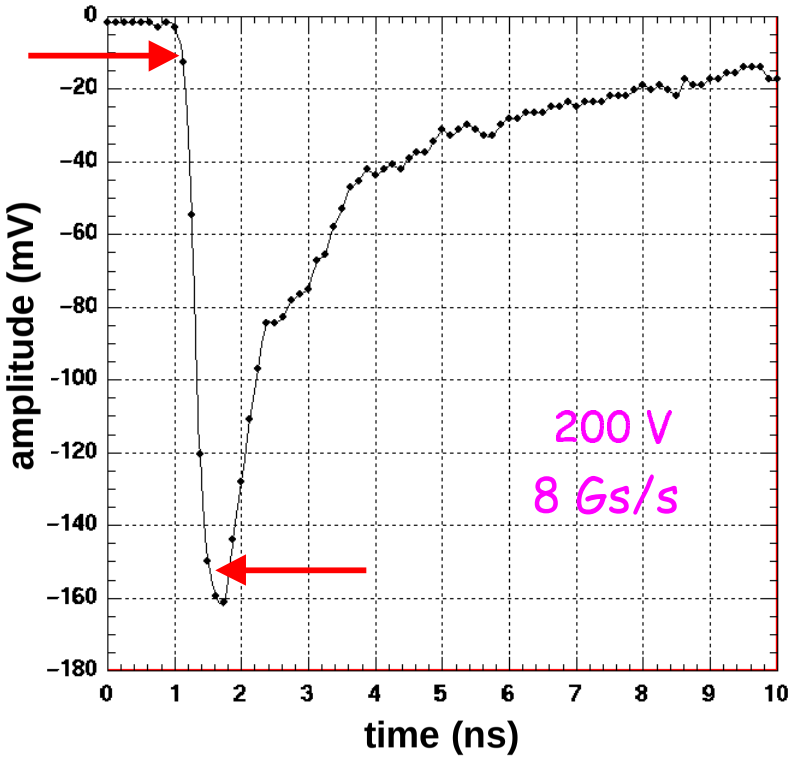
# High-Intensity Pb Beam



- *Exposed for 40 days to 158 A GeV Pb beam*
- *Average beam intensity: $7\times10^{7}$ ions / burst*
- *Total dose: $5\pm2\times10^{14}$ ions/cm$^2$ (90 ± 40 Grad)*

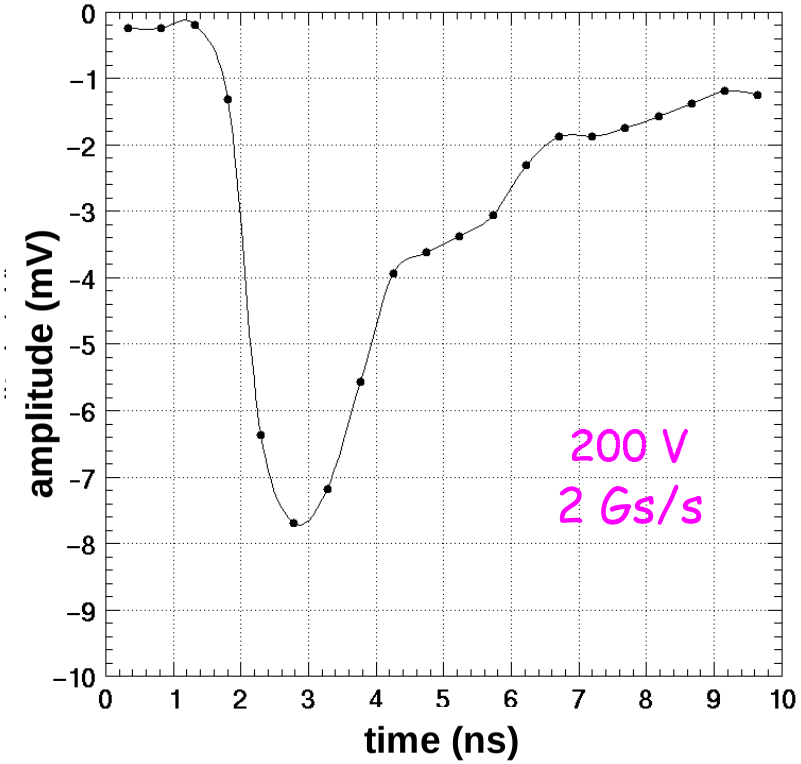
# True (unshaped) Pb Ion Signal

Non-irradiated




- Very fast rise time (< 500ps)
- Very long tail (~20ns)

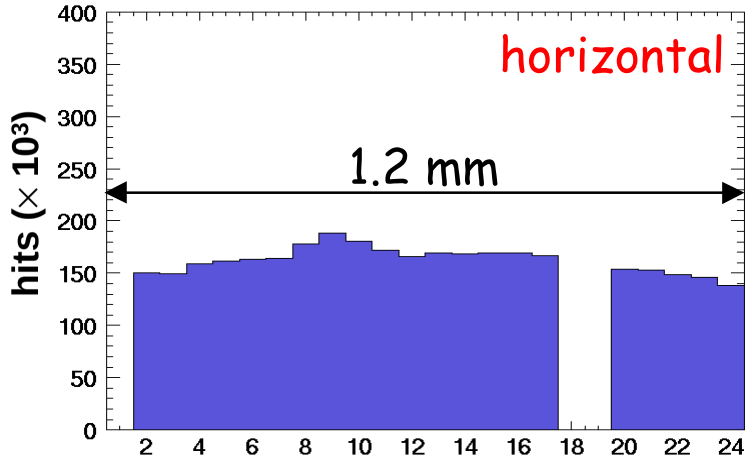
After 20 days (40 ± 20 Grad)

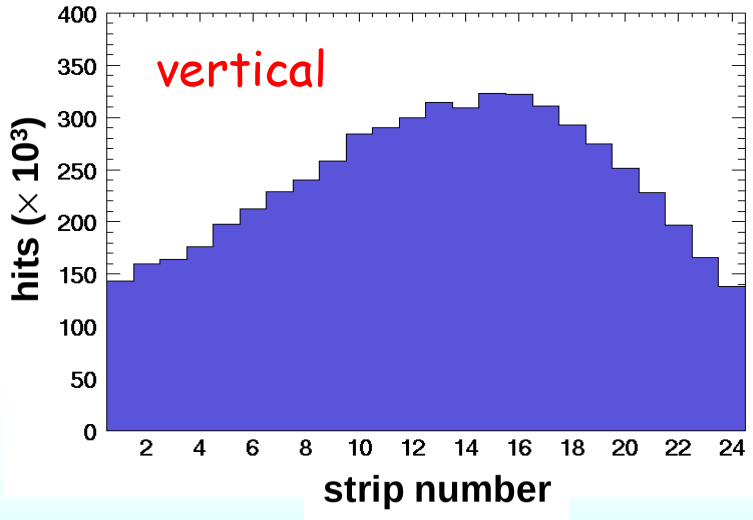



- Signal is broader
- Amplitude ~20 times lower…
  but we see it !

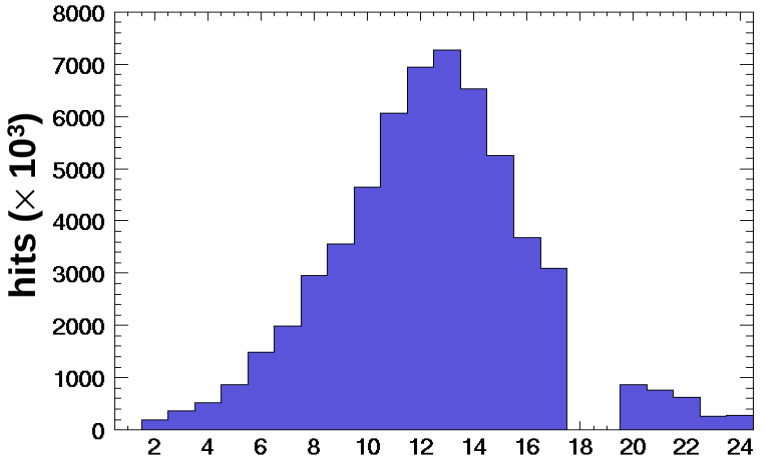
# Beam Profile

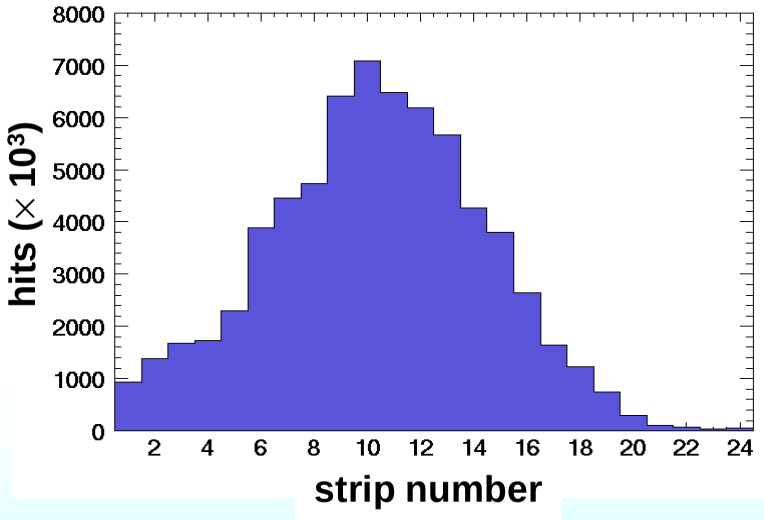
## Day 1



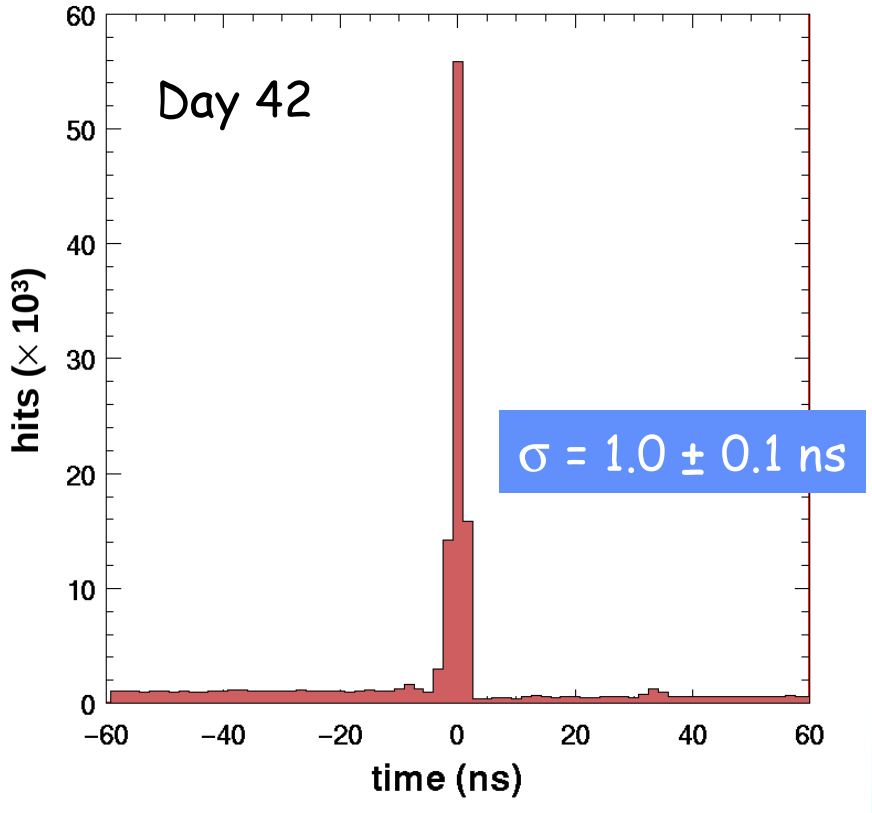

## Day 38 (~85 Grad)



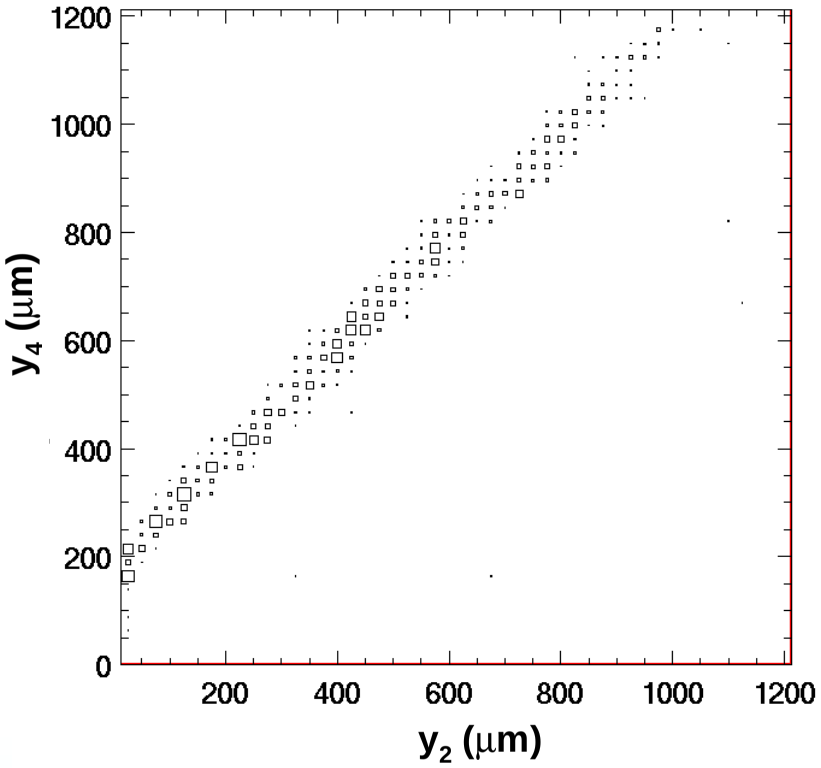



# MHTR Timing & Cluster Correlation

Time of arrival wrt the trigger of the hits in all strip integrated over several spills, normalizing to the same mean time.

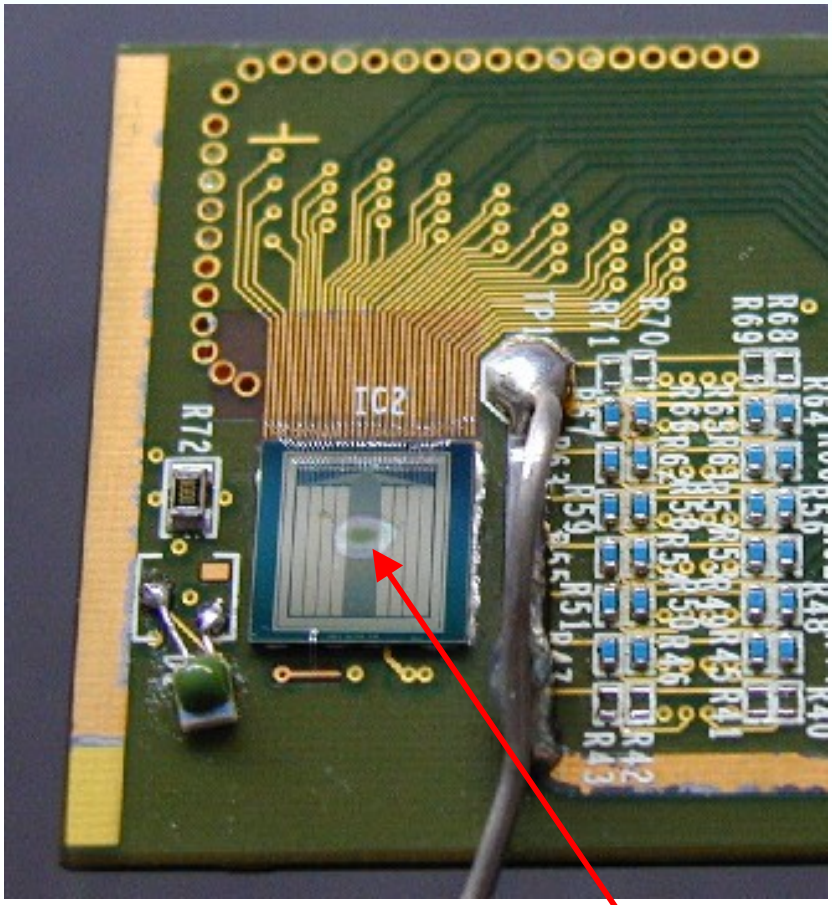


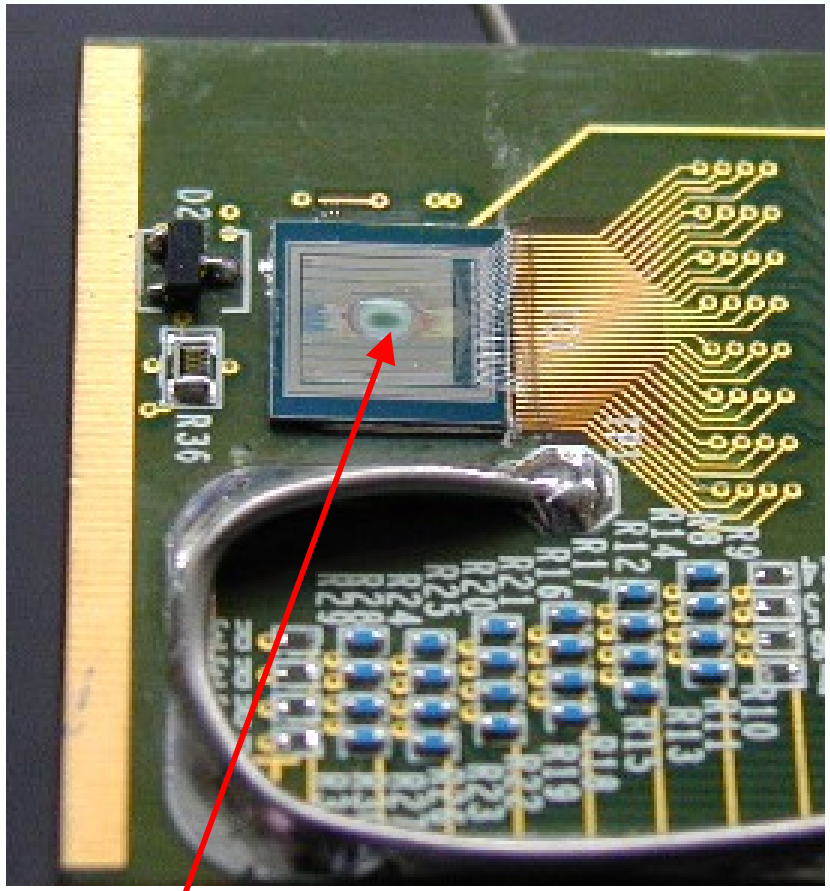

Correlation of clusters in plane 2 and 4 (only hits within 3 σ)




~200 μm misalignment

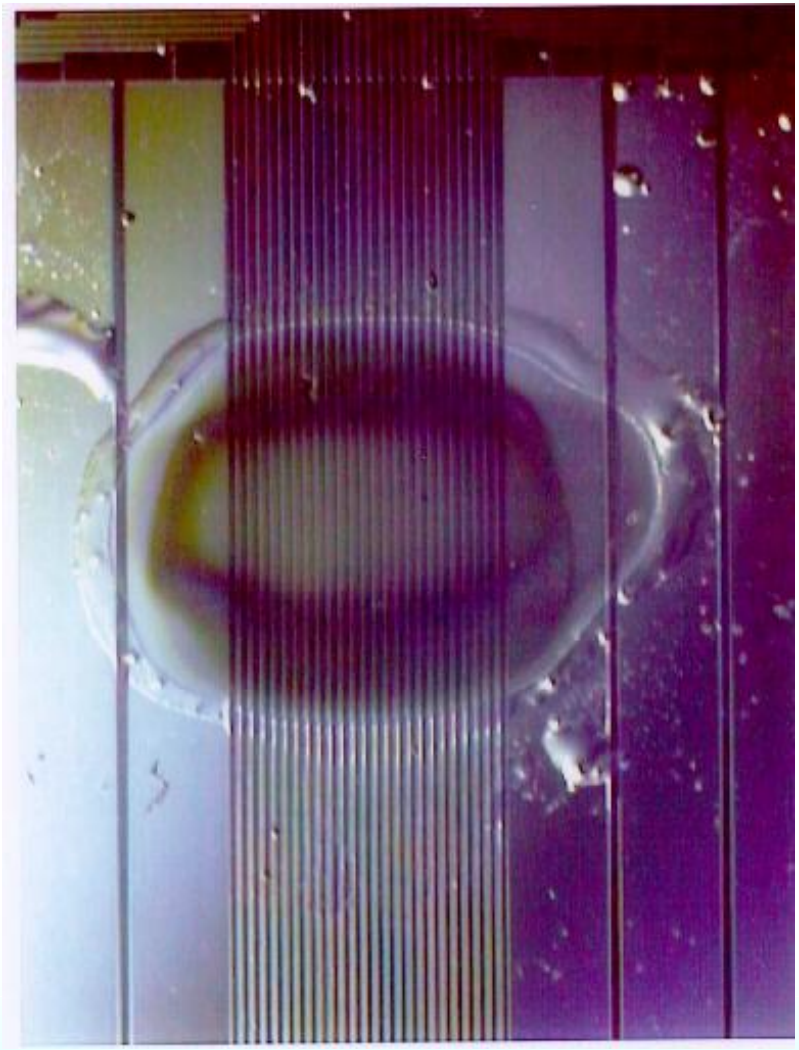
# The Beamscope After 90 Grad...




Pb beam's signature

# The Beamscope After 90 Grad...



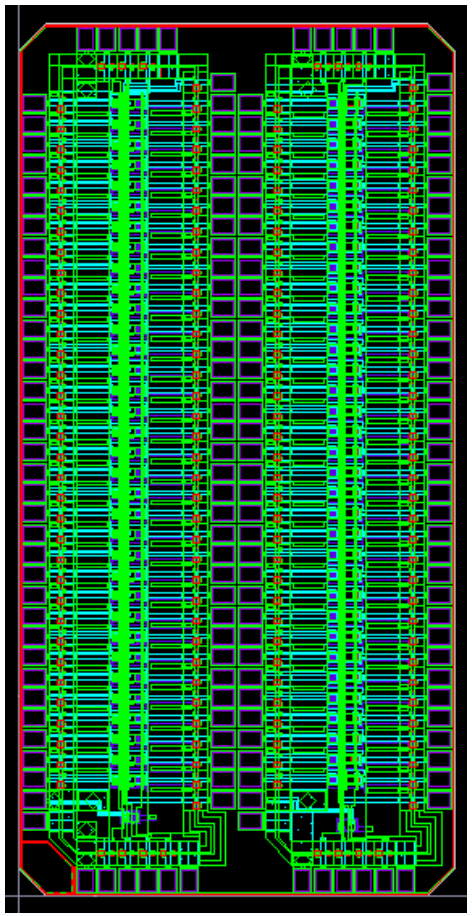

# The Proton Beamscope
## (beam test finished on Nov 3)

# The Proton Beamscope

## A new front-end chip by EP-MIC !

- manufactured in 0.25 µm CMOS
- 2 versions on the same chip
- 2 × 4 mm
- 32 channels

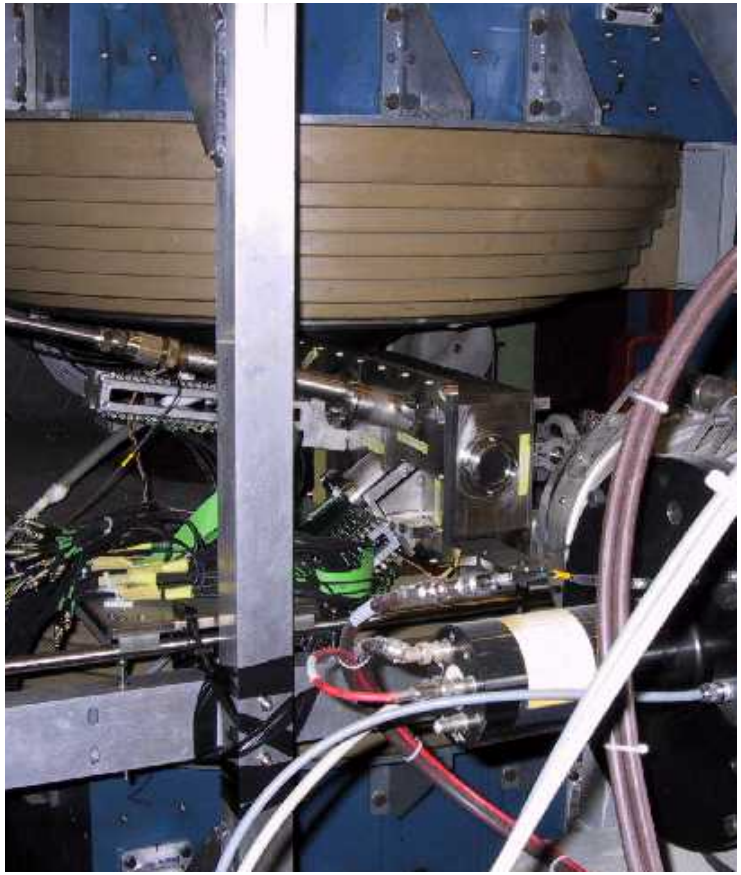
- Operated at 130 K
- Peaking time: ~3.6 ns at 130 K
- Good S/N down to 10% of a mip
- Power dissipation: ~300mW



Also:

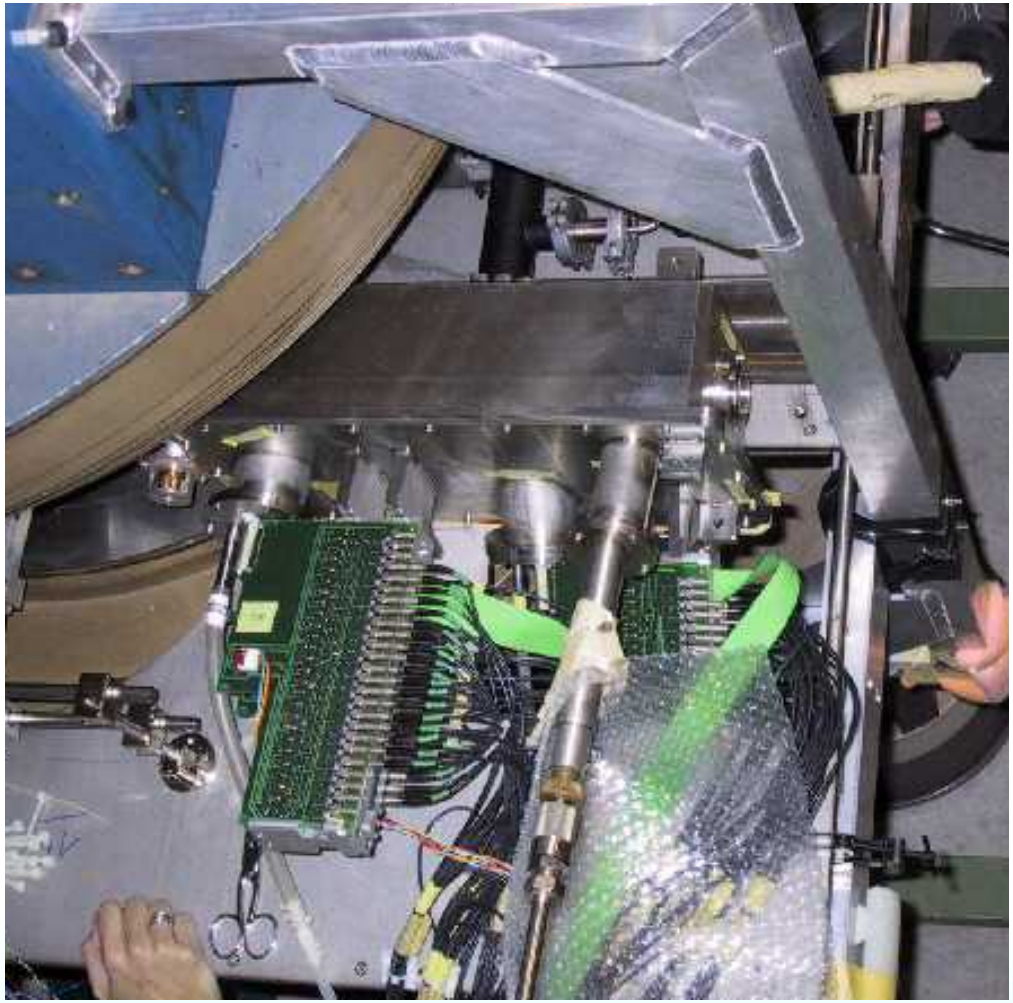
- New carrier design
- Cooling: 0.5 mm diameter pipes

# Test with Proton Beam



- 25 ns bunch structure beam
  → limited intensity
- Average intensity: $3 \times 10^{6}$ *protons/burst*
- *Irradiation @* $1 \times 10^{9}$ *protons/burst*
- *Total:* $\sim 2 \div 4 \times 10^{14}$ *protons / cm* $^{2}$
  → too low to notice any difference at 130 K...

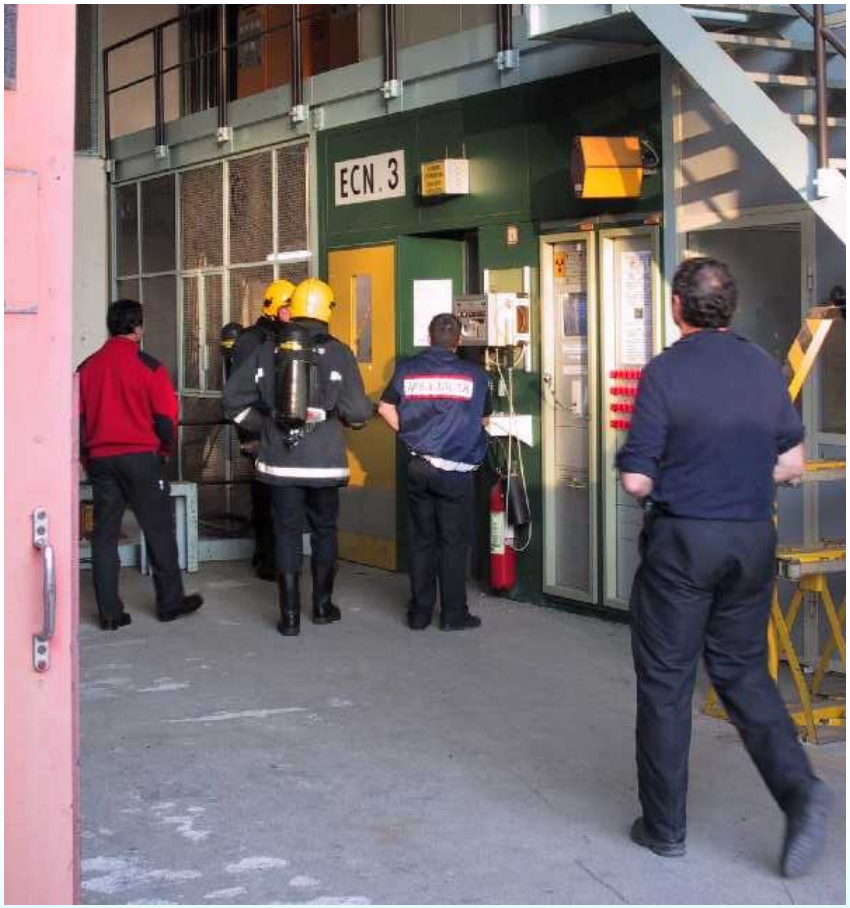
# The Proton Beamscope



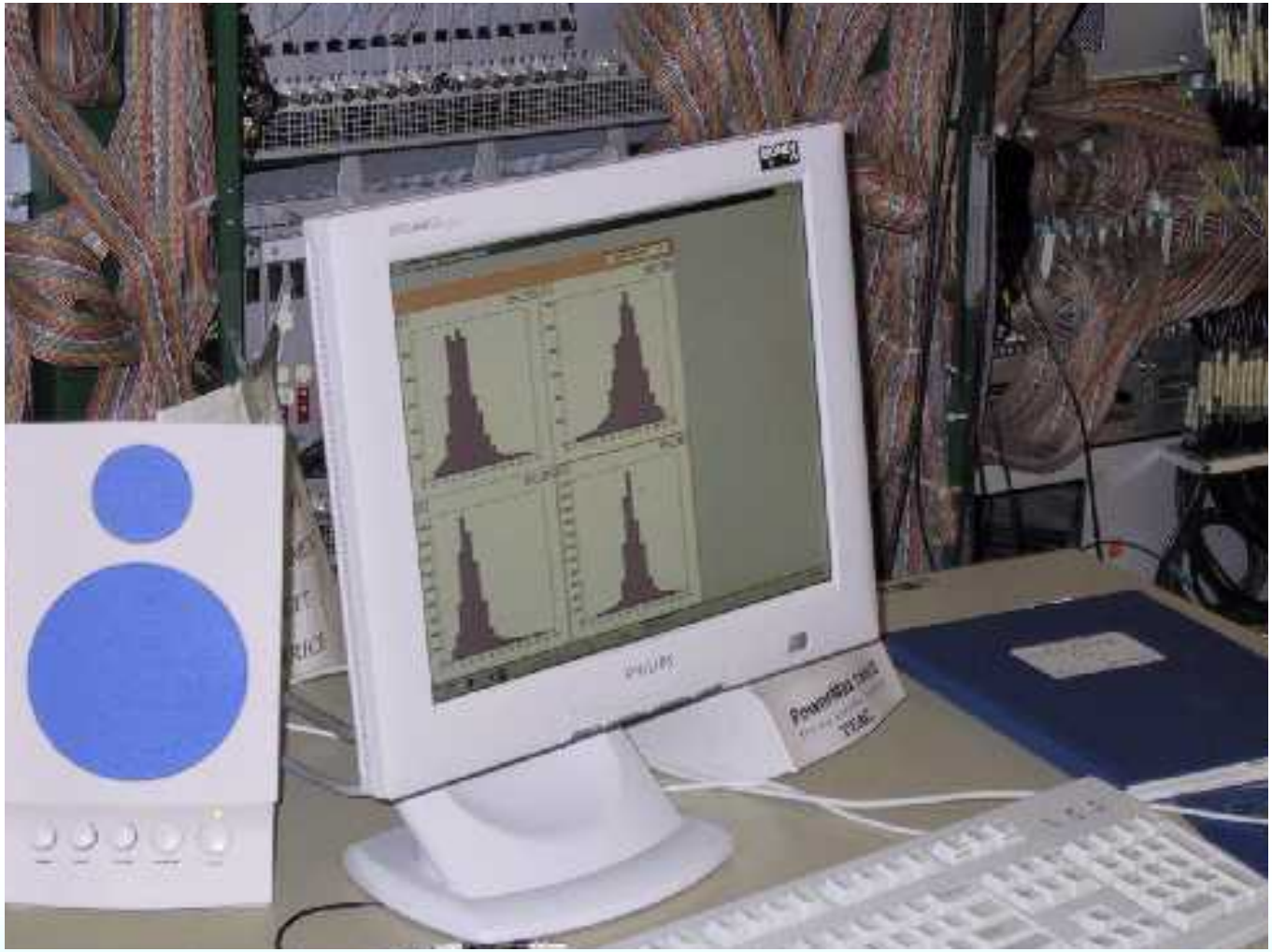
Very sophisticated alignment procedure...

# One Major Problem...

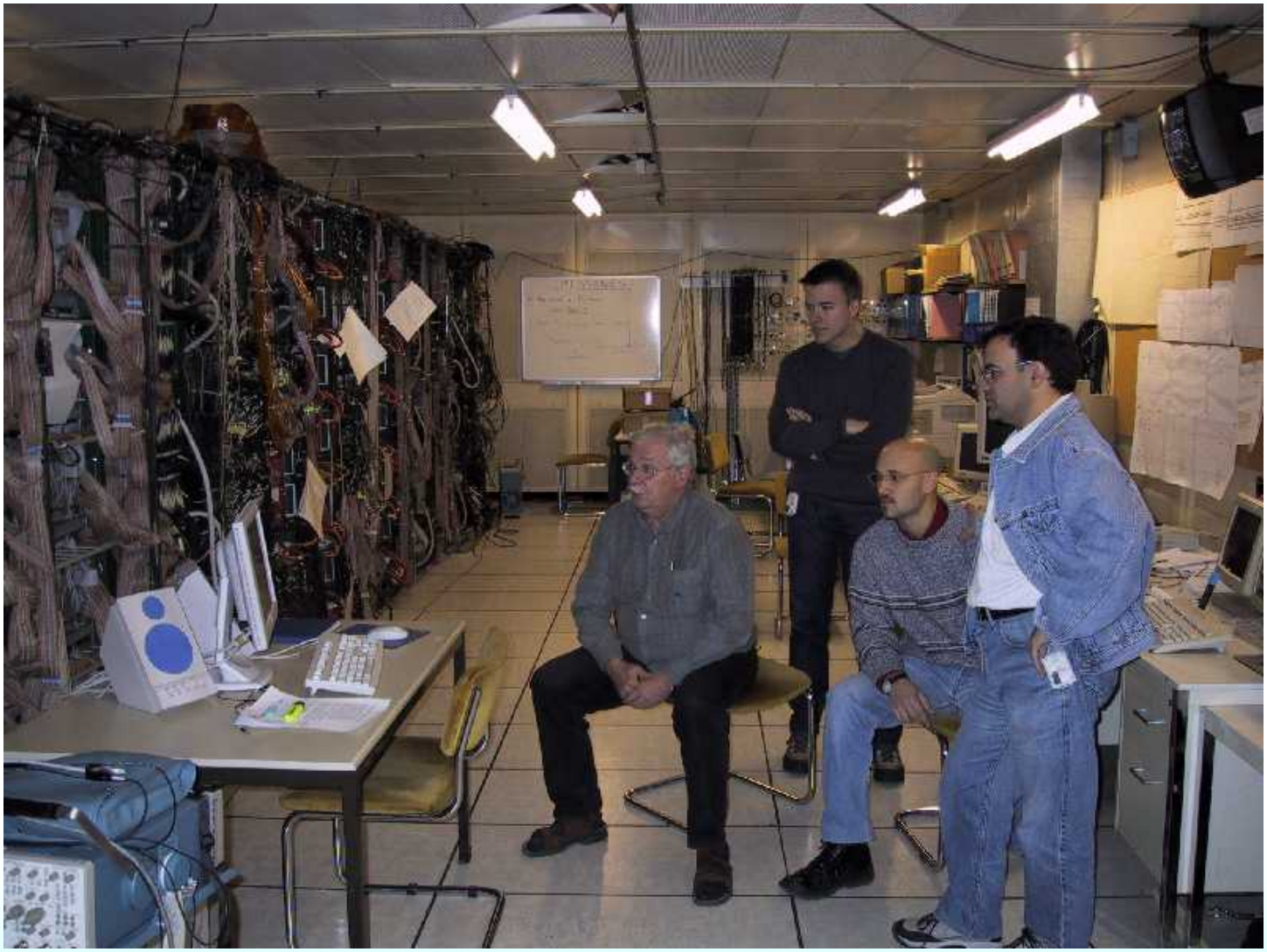
*... lack of oxygen in the beam hall !*



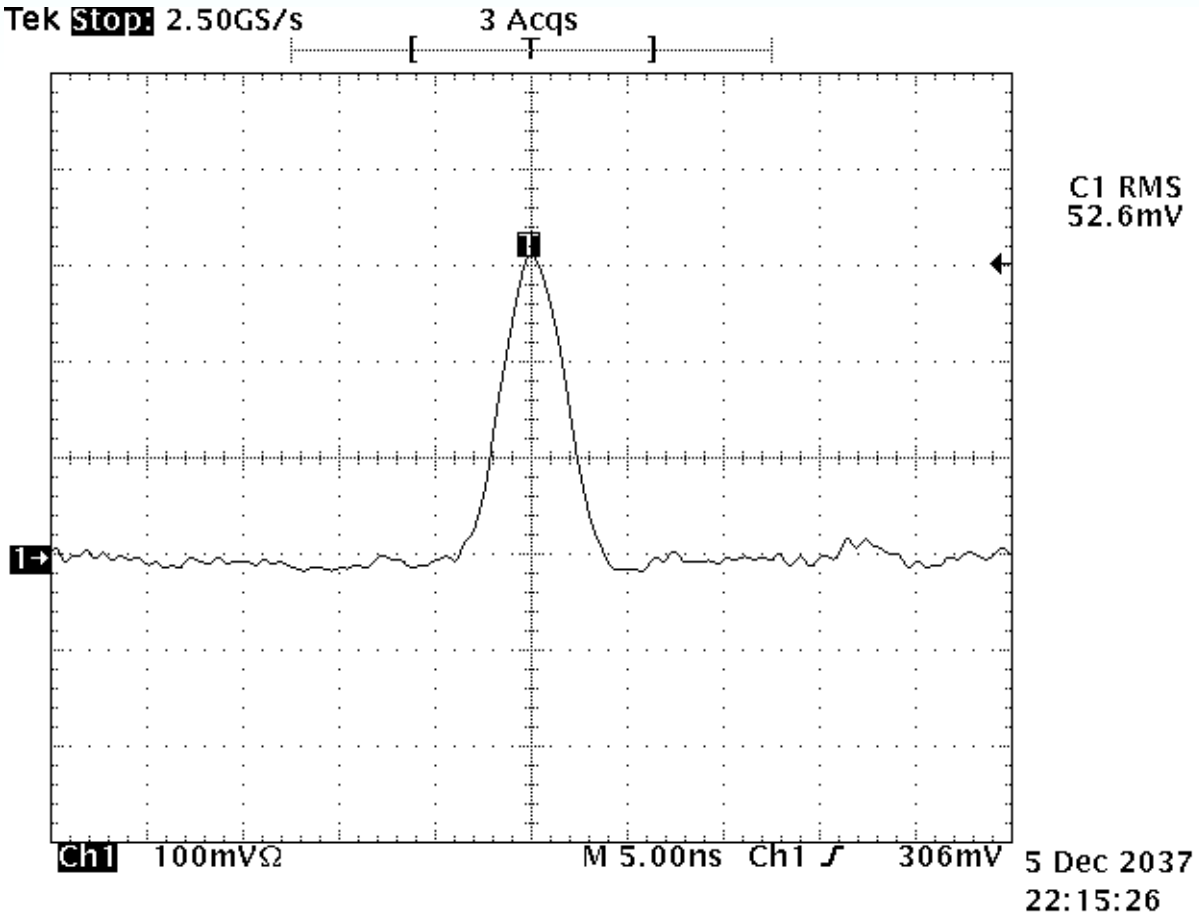
# Very Preliminary Results...



# … But Very Interesting !

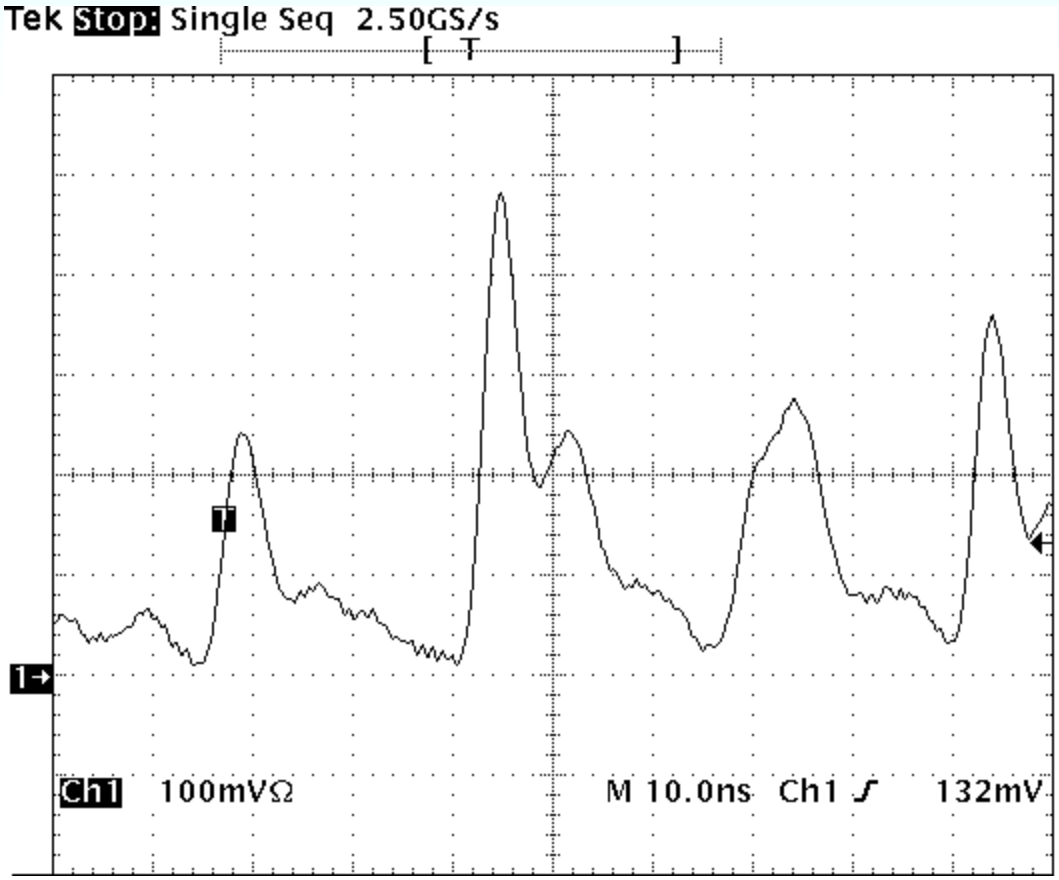


# How a Proton Looks Like...



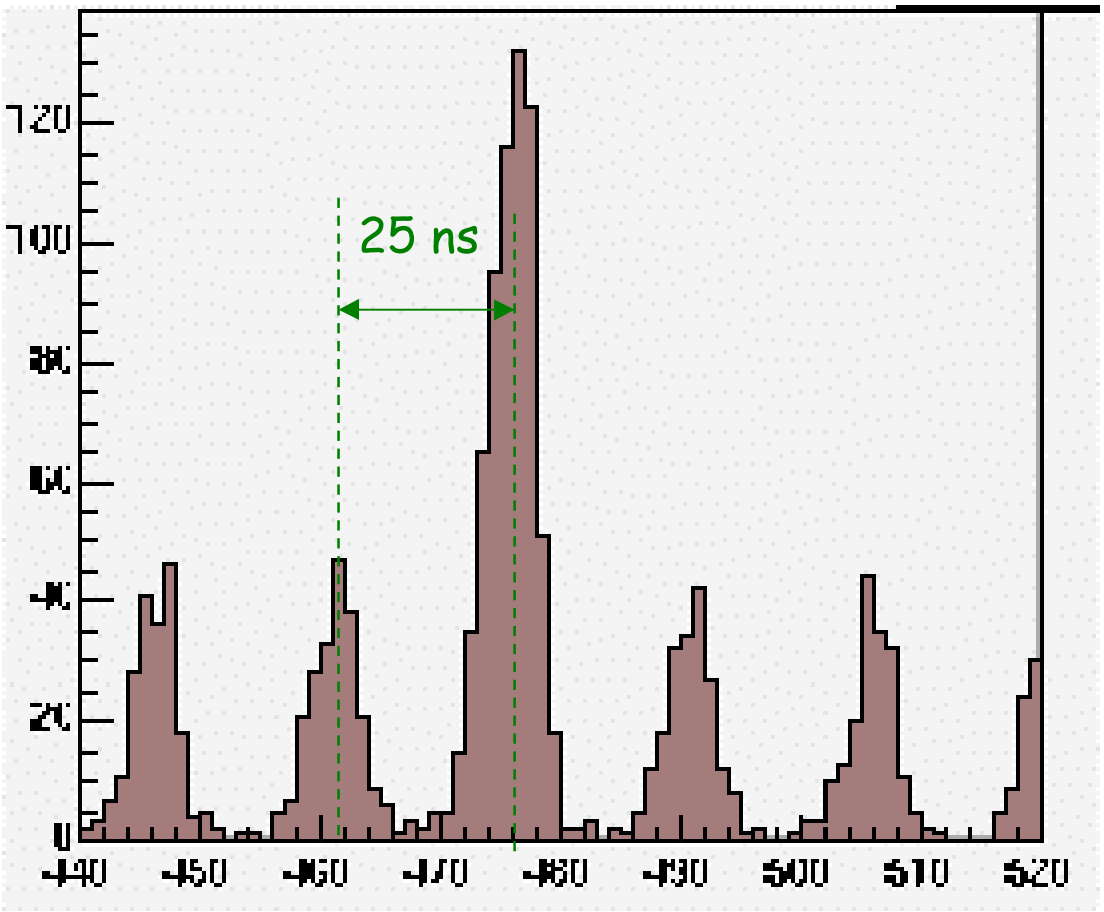

- Strip signal
- Looking with scope after front-end chip + shaping

# How Many Protons Look Like...




- Strip signal
- Looking with scope after front-end chip + shaping
- Beam intensity: $1 \times 10^9$ *protons/burst*

# MHTR for 1 Strip




Hit time wrt trigger

# Conclusions

- ✓ **Cryogenic Silicon**: a simple and cheap detector for monitoring high-intensity beams
- ✓ For heavy ions, where very large signals are obtained, **Cryogenic Silicon** can work up to several tens of Grad
- ✓ We have developed a **Cryogenic Silicon** Detector which is able to track high-intensity proton and heavy ion beams
- ✓ The only limit to its application is your fantasy...