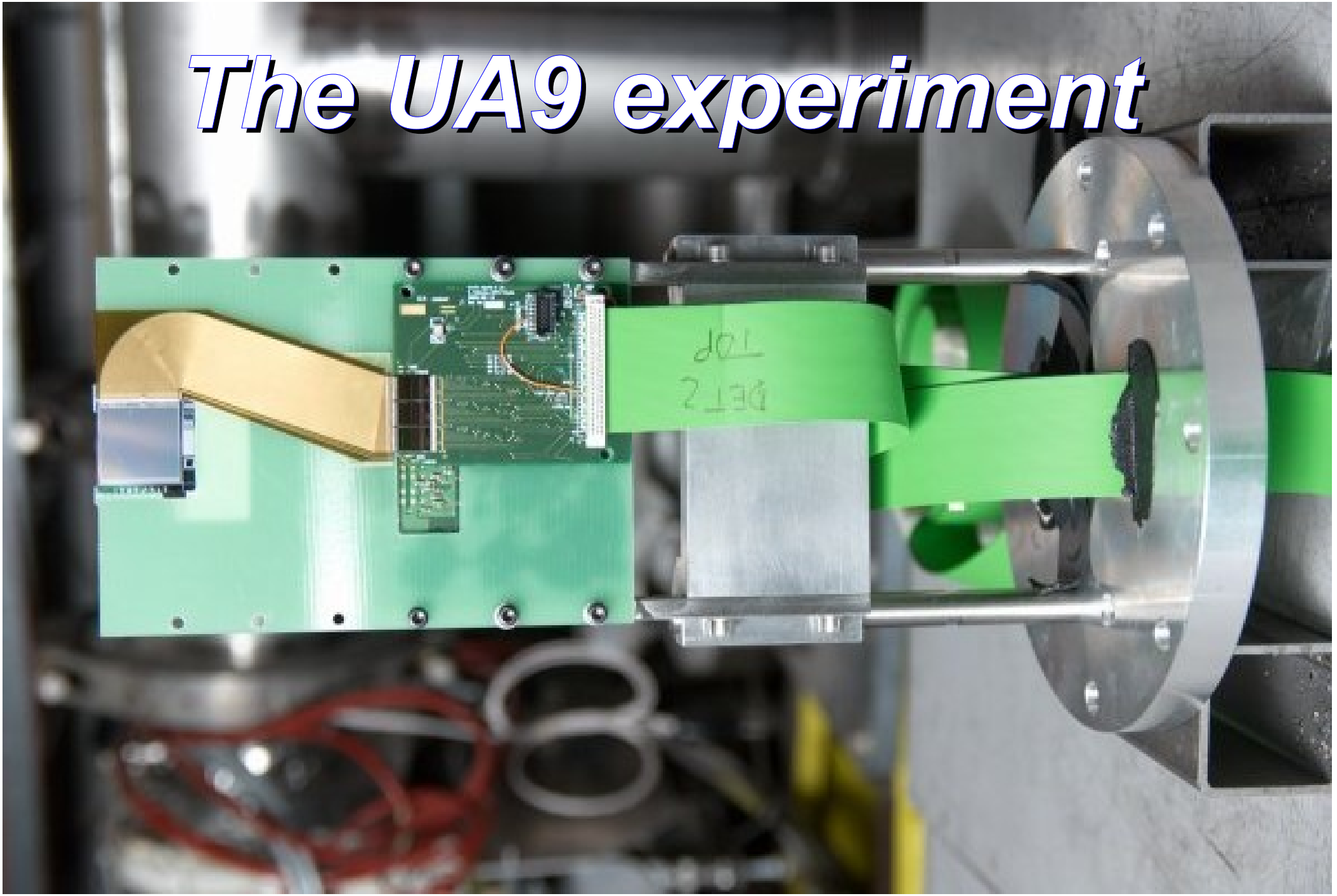
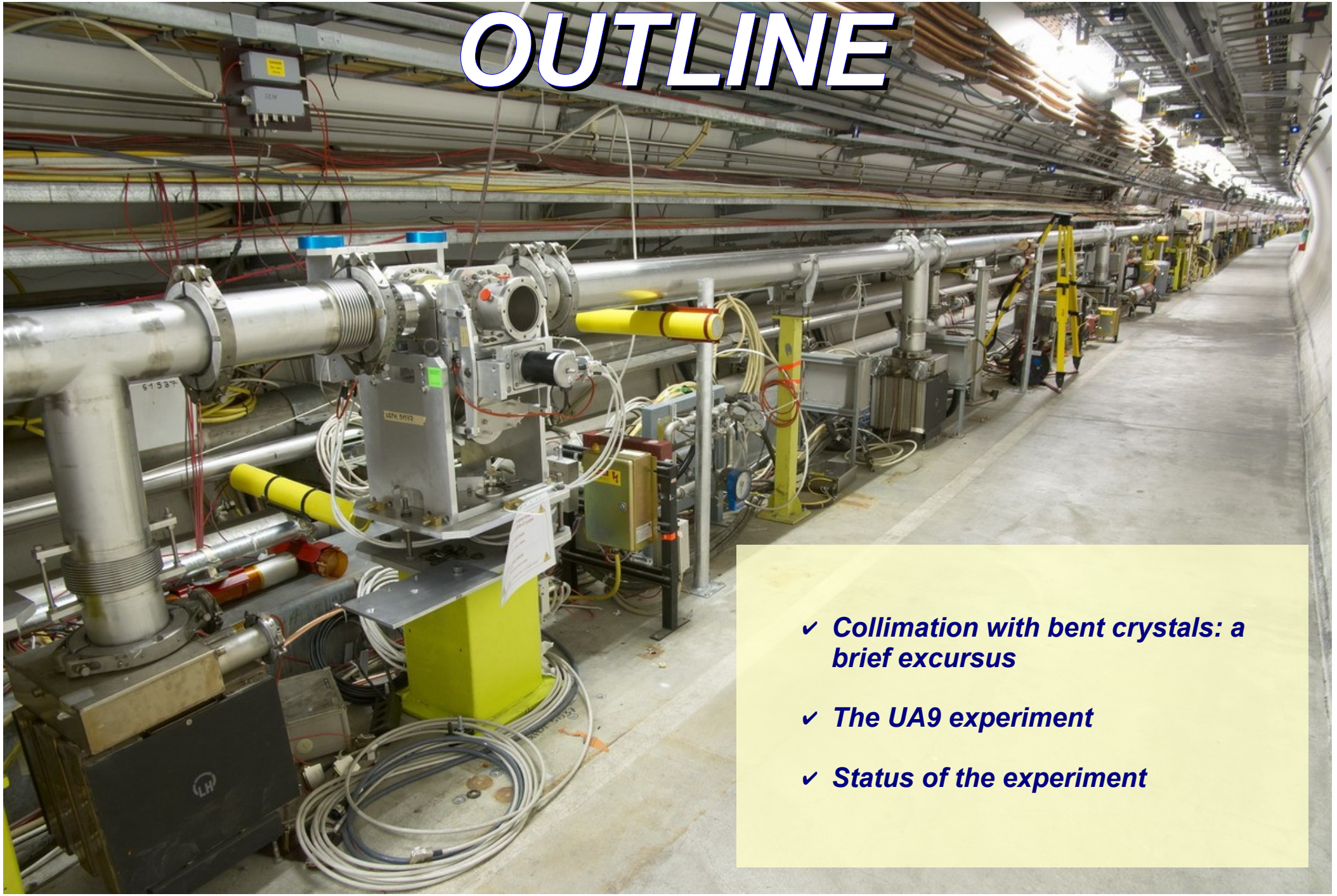
The UA9 experiment



OUTLINE



- ✔ *Collimation with bent crystals: a brief excursus*
- ✔ *The UA9 experiment*
- ✔ *Status of the experiment*

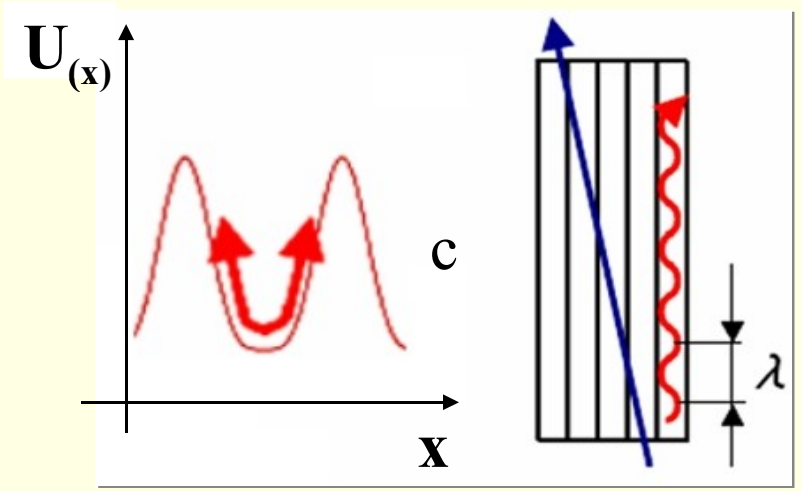
In 1976, the IDEA on crystals

E. N. Tsyganov: channeling in bent crystals

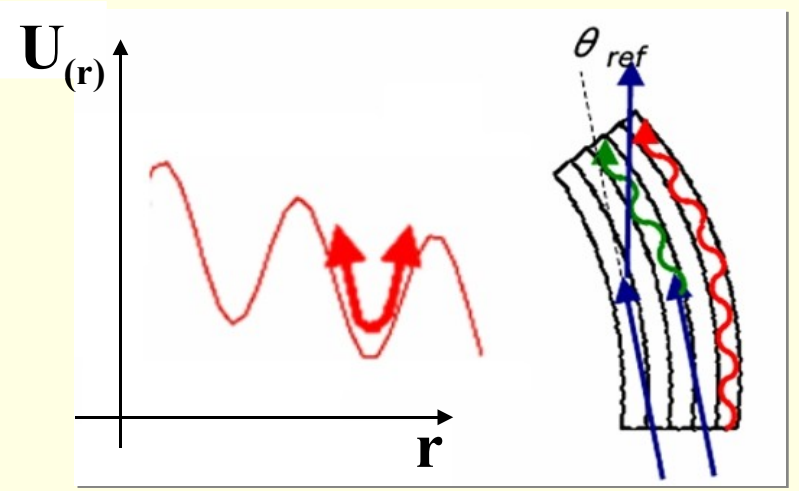
➔ *CRYSTALS can be used to deviate particles*

➔ *First experimental evidence: FNAL 1979*

Interplanar potential



Effective potential

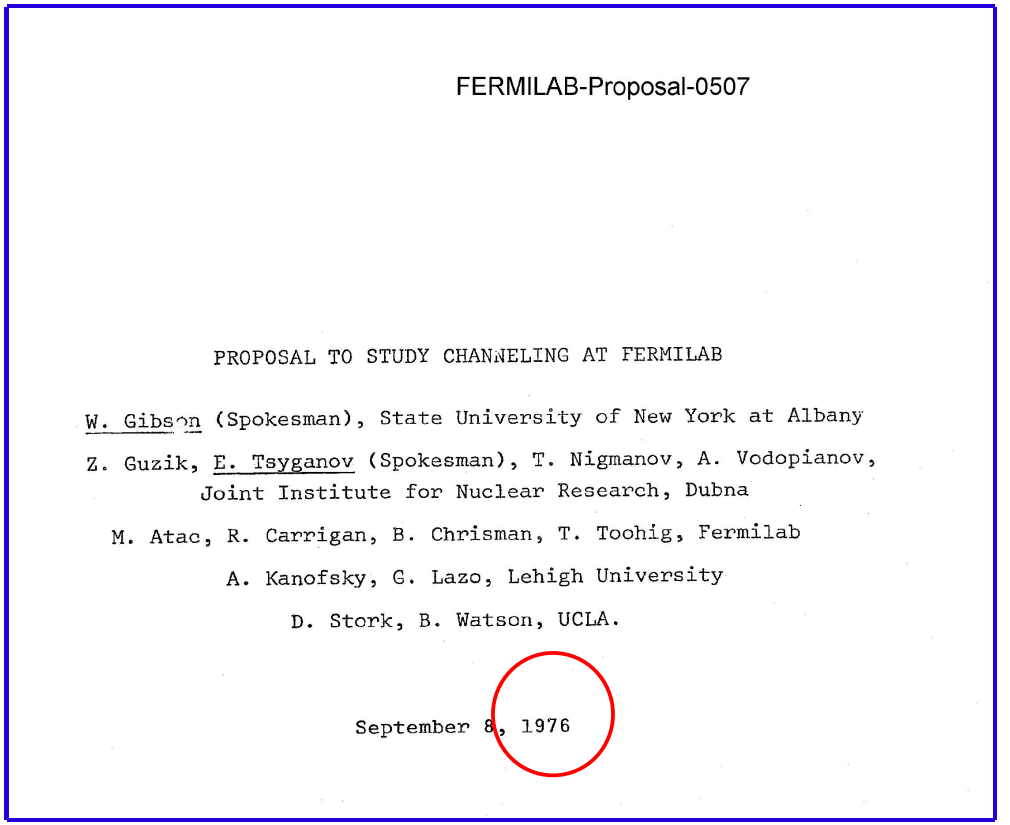


$$\Theta_C = \frac{L}{R}$$

Limit curvature = Tsyganov's radius
~ 5cm x P (GeV/c)

But can bent crystals be useful ?

- **EXTRACTION for SECONDARY BEAMS**
- **COLLIMATION**
- **BEAM SPLITTING**
- **MICROBEAM**



FERMILAB-Proposal-0507

PROPOSAL TO STUDY CHANNELING AT FERMILAB

W. Gibson (Spokesman), State University of New York at Albany

Z. Guzik, E. Tsyganov (Spokesman), T. Nigmanov, A. Vodopianov,
Joint Institute for Nuclear Research, Dubna

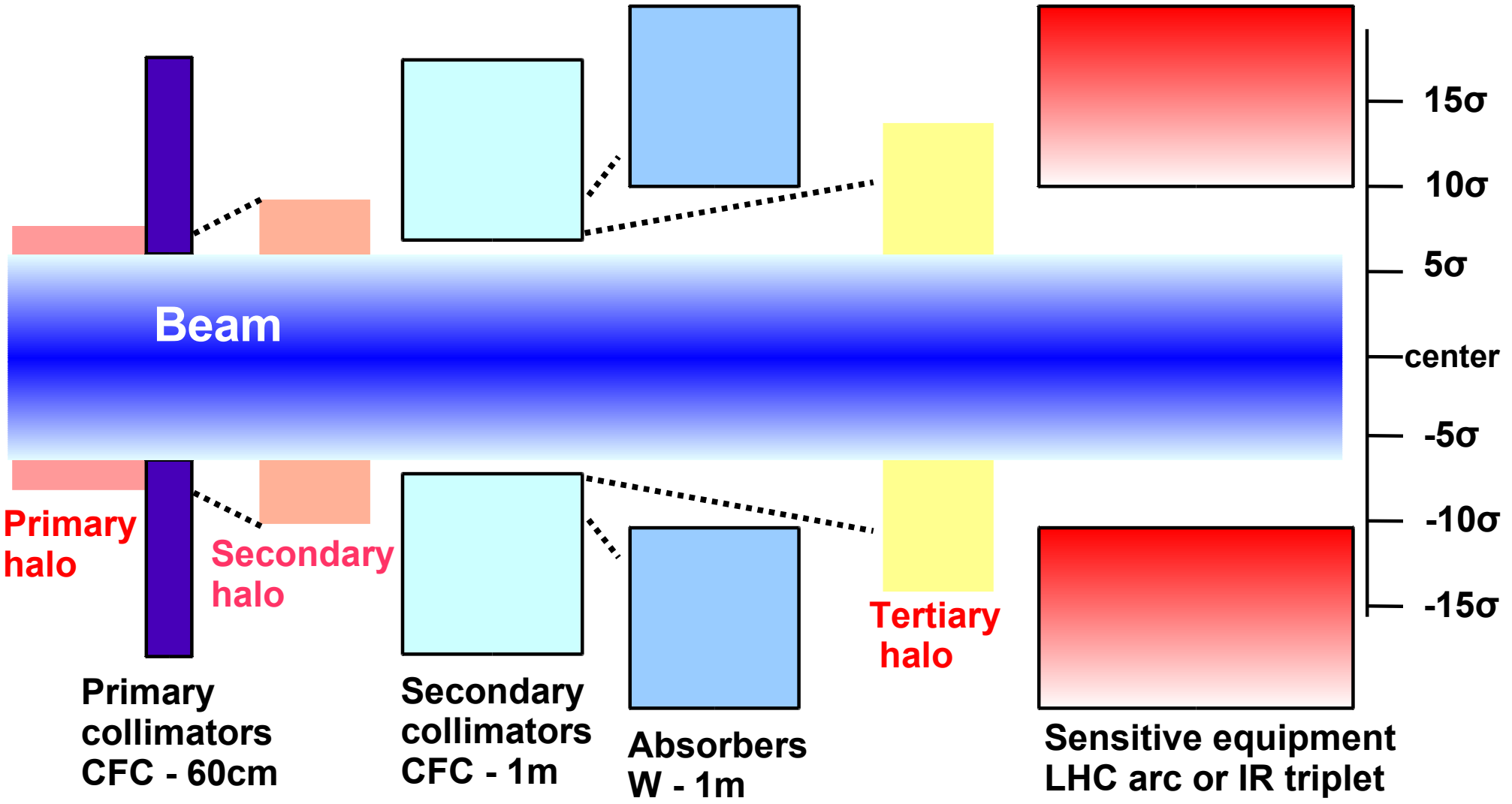
M. Atac, R. Carrigan, B. Chrisman, T. Toohig, Fermilab

A. Kanofsky, G. Lazo, Lehigh University

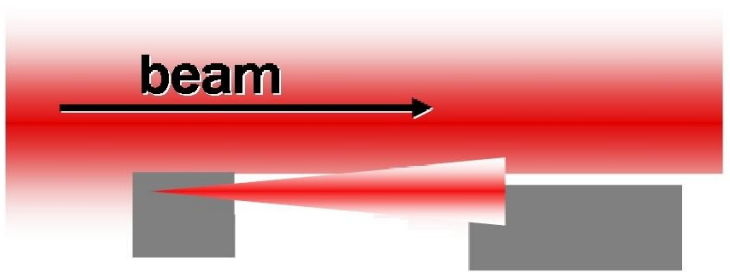
D. Stork, B. Watson, UCLA.

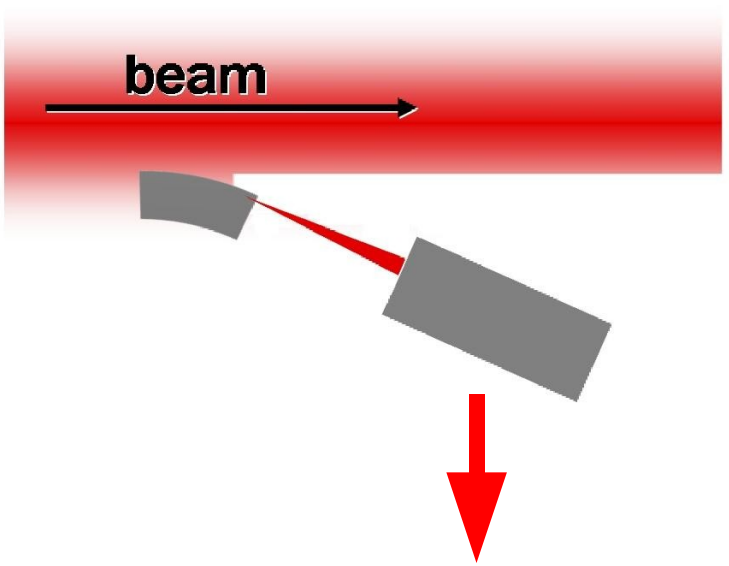
September 8, 1976

LHC collimators: the PRESENT



That's it: CRYSTALS are CLEVER!





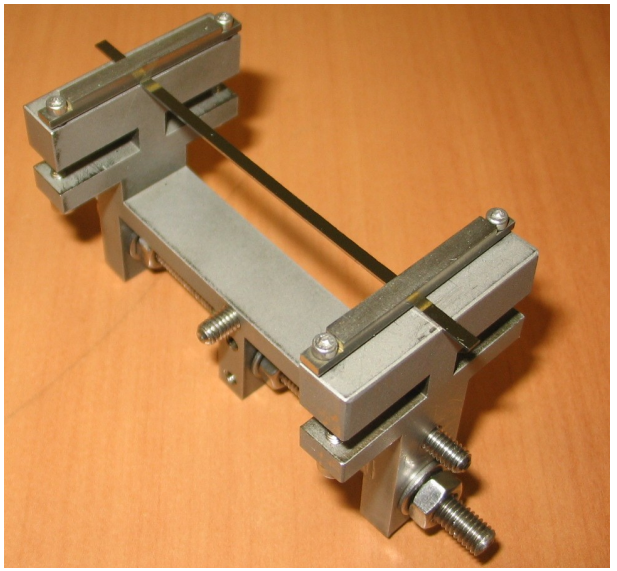
The halo is scattered over the whole angular range

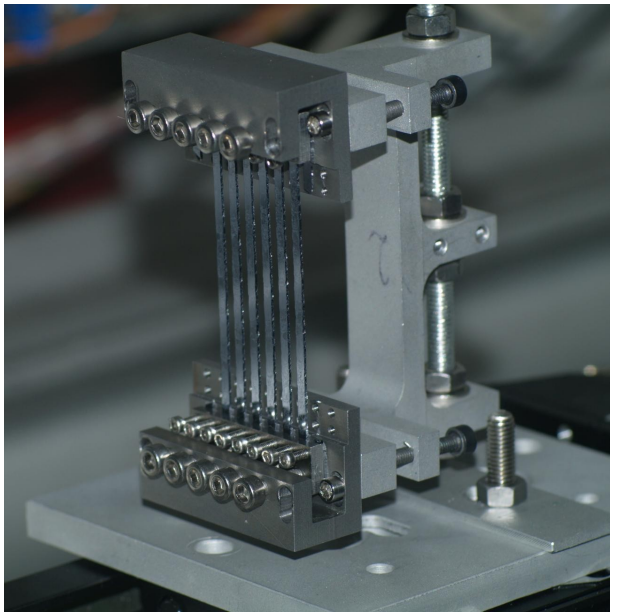
- ➔ *The impact parameter of the particles on the secondary collimator has to be maximized*
- ➔ *The requirement on the alignment of the secondary collimator is stringent*

The halo is steered in a precise direction

- ➔ *The cleaning efficiency increases*
- ➔ *The constraints on the alignment of the secondary collimator are released*
- ➔ *The secondary collimator can be farther from the core → impedance decreases*

... and small and compact and easy to use and reliable and ...

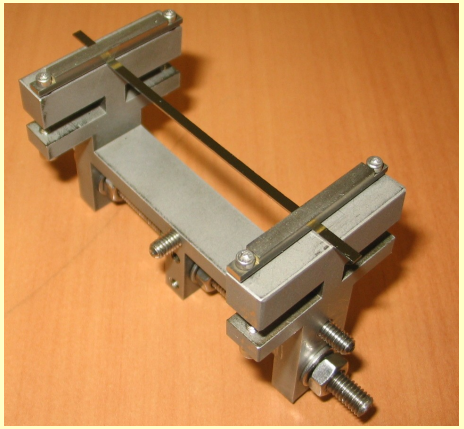


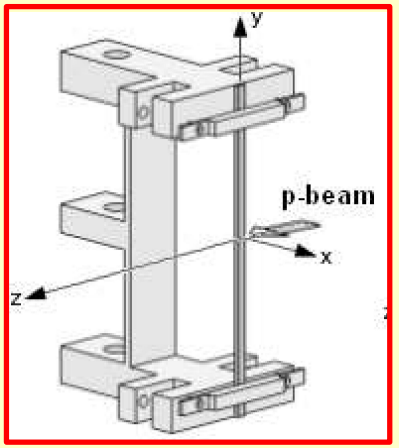


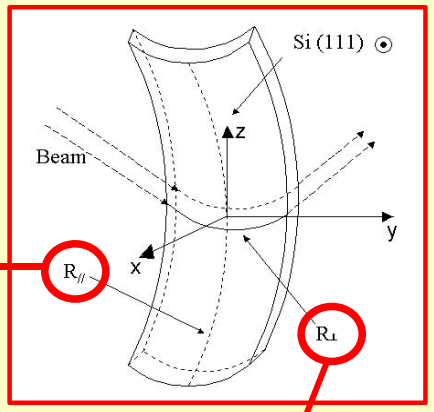
A 3 x 0.9 x 70 mm^3 bent silicon crystal → equivalent magnetic field > 100T !!!!

Ready? No you have to bend it!

STRIP CRYSTALS





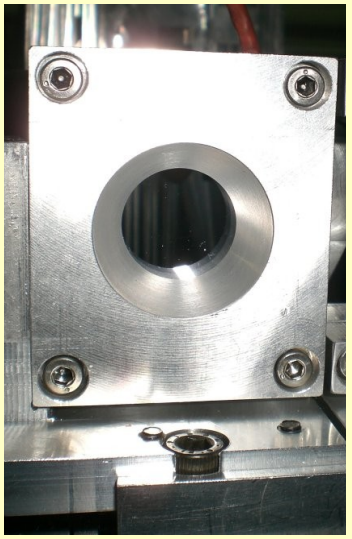


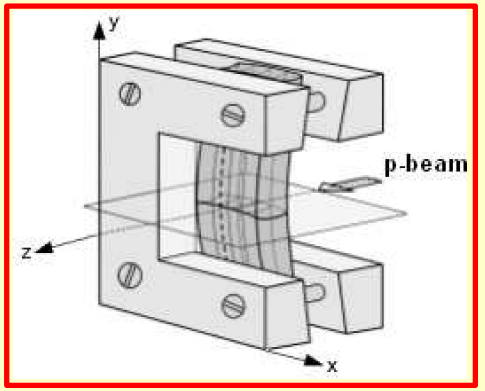
primary curvature

secondary curvature generated by the anticlastic forces

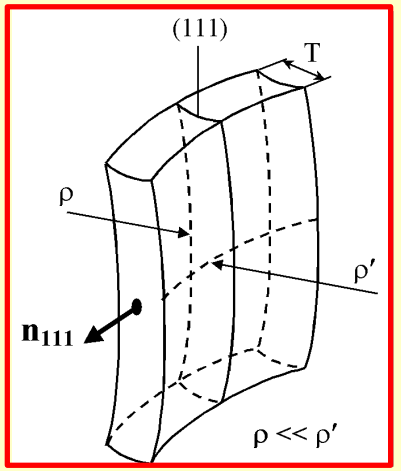
INFN Ferrara and IHEP

QUASIMOSAIC CRYSTALS





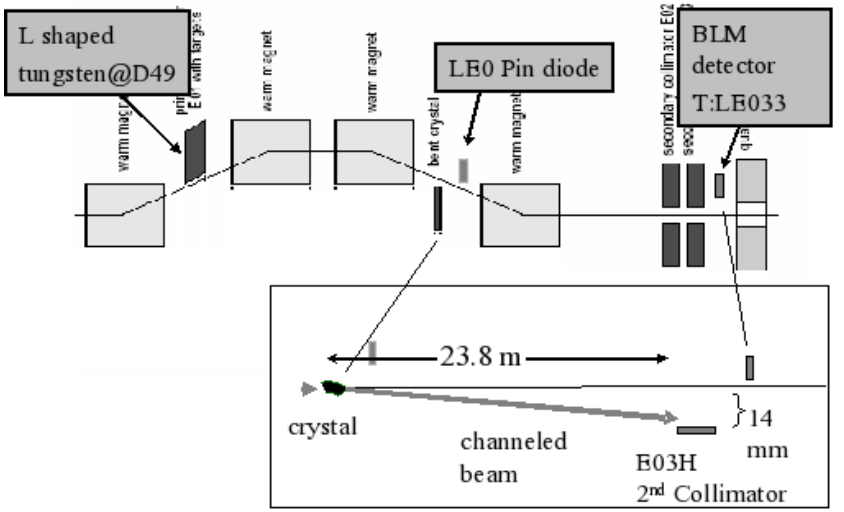
- The (111) crystalline planes are normal to the large face and parallel to the edges
- The crystal is bent in the yz plane → ρ = principal curvature
- The anticlastic forces produce the secondary curvature (ρ') in xz (quasimosaic curvature)



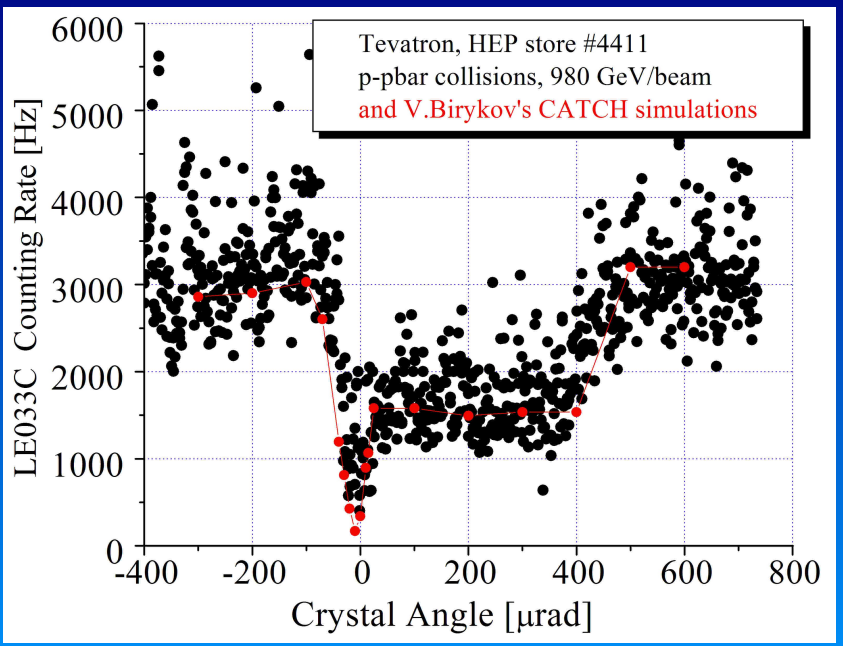
PNPI

One of the first collimation trials: FNAL (2005)

- ➔ same O-shaped crystal (PNPI) of RHIC
- ➔ detectors = PIN diodes, ionization beam monitors
- ➔ PIN diode used to measure the large angular scattering (*that is a scattering rate proportional to the nuclear interactions inside the crystal*)



- ➔ dip = channeling; it is due to the suppressed rate of nuclear interactions + the particle steered towards the secondary collimator where it is absorbed
- ➔ channeling efficiency ~78%
- ➔ evidence of volume reflection?



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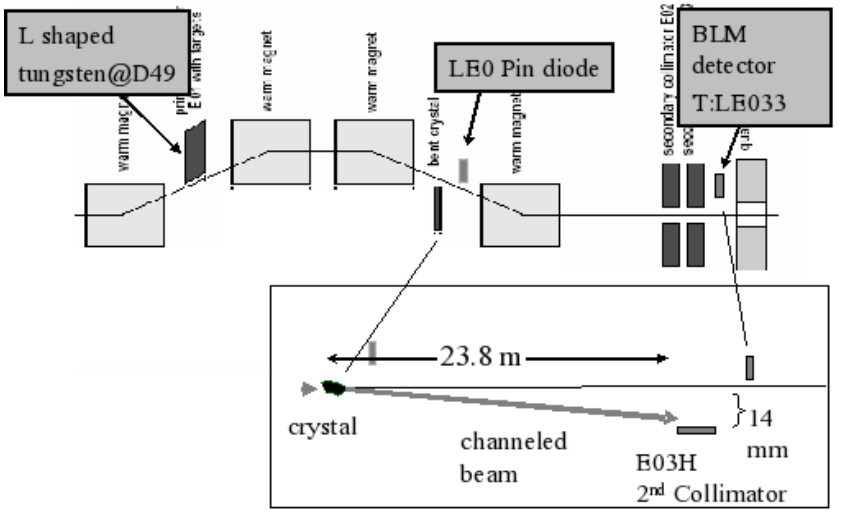
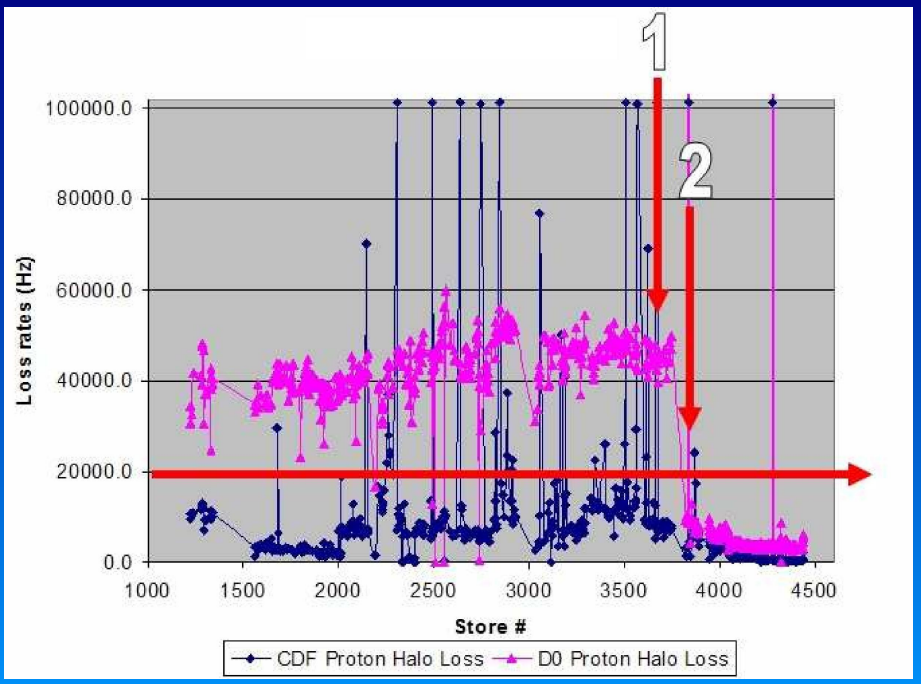


FIRST TIME !!!!

- *effective reduction of the background*
- *horizontal line = proton halo loss limit*
- *vertical ones = machine developments to reduce background:*
  - *1 = installation of a double scraper*
  - *2 = improvement of the vacuum system + alignment + installation of the crystal*



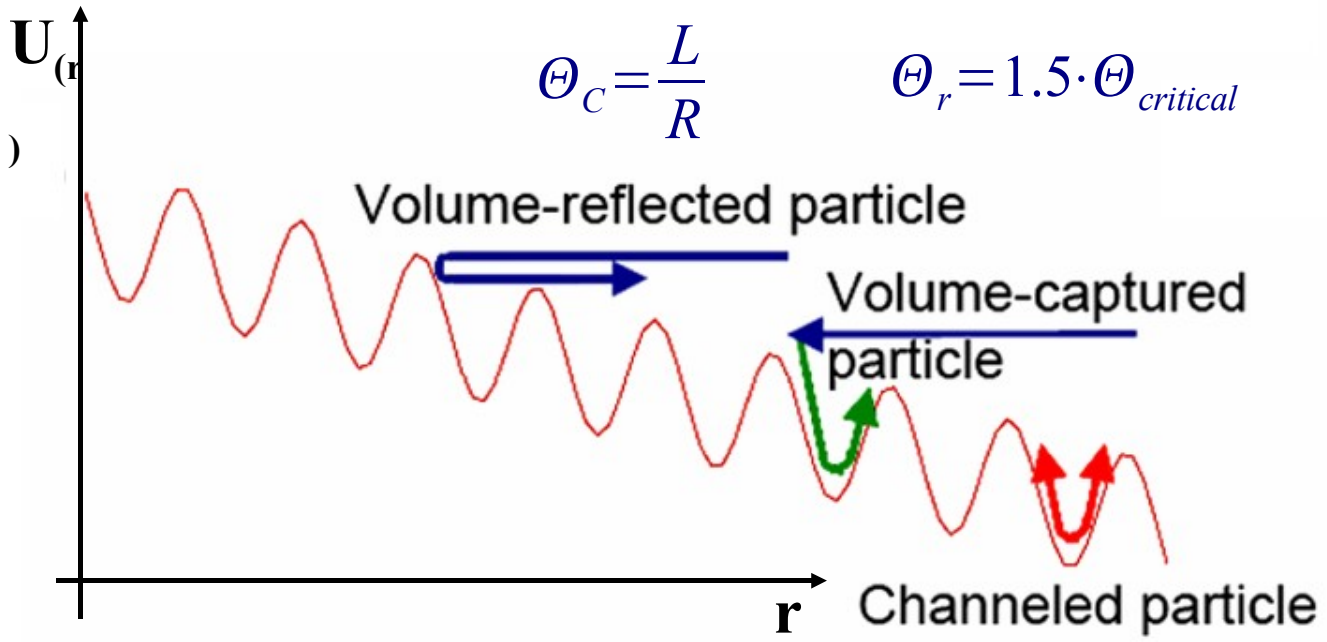
The legacy of Tsyganov: volume reflection

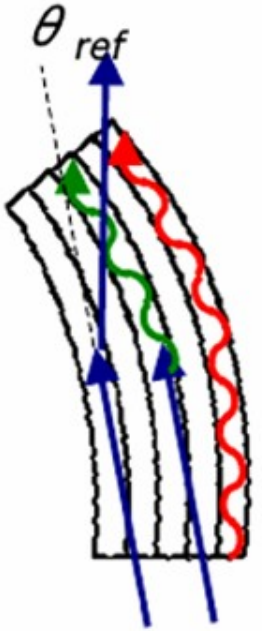
New phenomena → an initially misaligned particle becomes *tangent* with a channel →

- ➔ *volume capture* if the particle enters in channeling losing energy
- ➔ *volume reflection* if the effective potential reflects it

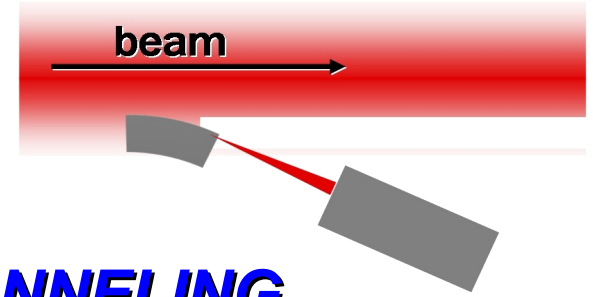
- ➔ *large (and adjustable) angular acceptance*
- ➔ *favourable scaling properties with energy ($\theta \propto 1/\sqrt{E}$ instead of $1/E$ as in multiple scattering)*
- ➔ *high efficiency*

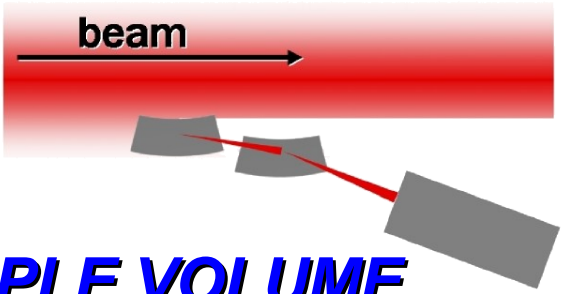
$$\Theta_C = \frac{L}{R} \qquad \Theta_r = 1.5 \cdot \Theta_{critical}$$





New century → new possibility: two effects can be exploited for collimation





CHANNELING

- Angular acceptance limited by the Lindhard critical angle (~10μrad @400 GeV/c)
- Efficiency of the order of 50% @400 GeV/c
- Large deflection angle (~130μrad @400 GeV/c)

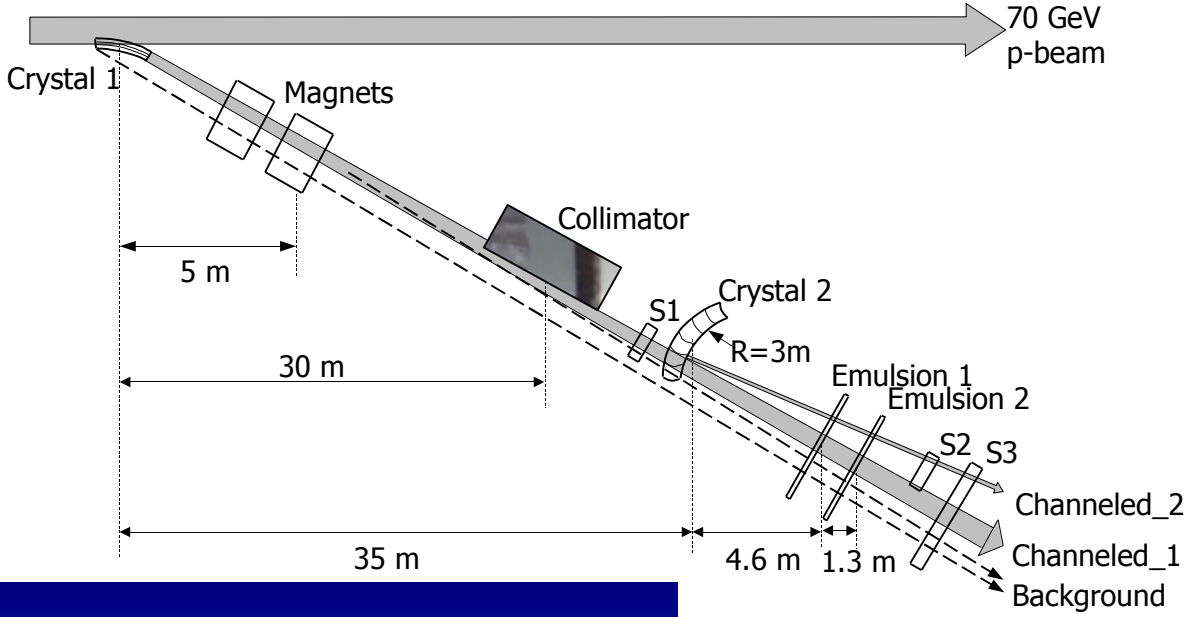
MULTIPLE VOLUME REFLECTION

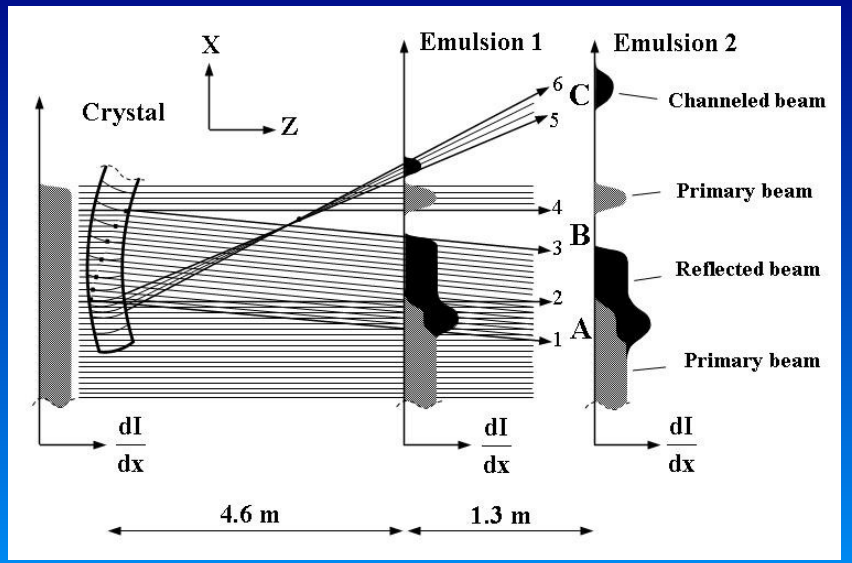
- Large angular acceptance (~roughly the channeling deflection angle)
- Efficiency of the order of 100% @400 GeV/c
- Small deflection angle (~14μrad @400 GeV/c)
- Possibility of using many aligned crystals to increase the deflection angle maintaining the efficiency > 90%

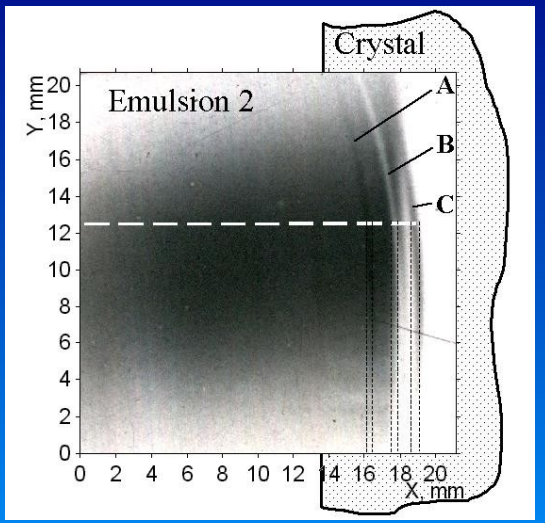
And many other effects under test (see V. Guidi's and A. Mazzolari's talks at the 4th crystal workshop (2009, CERN)

IHEP (2002): breakthrough on VR

- ✔ U-70 accelerator
- ✔ 70 GeV/c protons
- ✔ quasimosaic crystal:
  - ✗ 0.72 mm (along the beam)
  - ✗ area of 20x60 mm^2
  - ✗ bending angle of 423 μrad

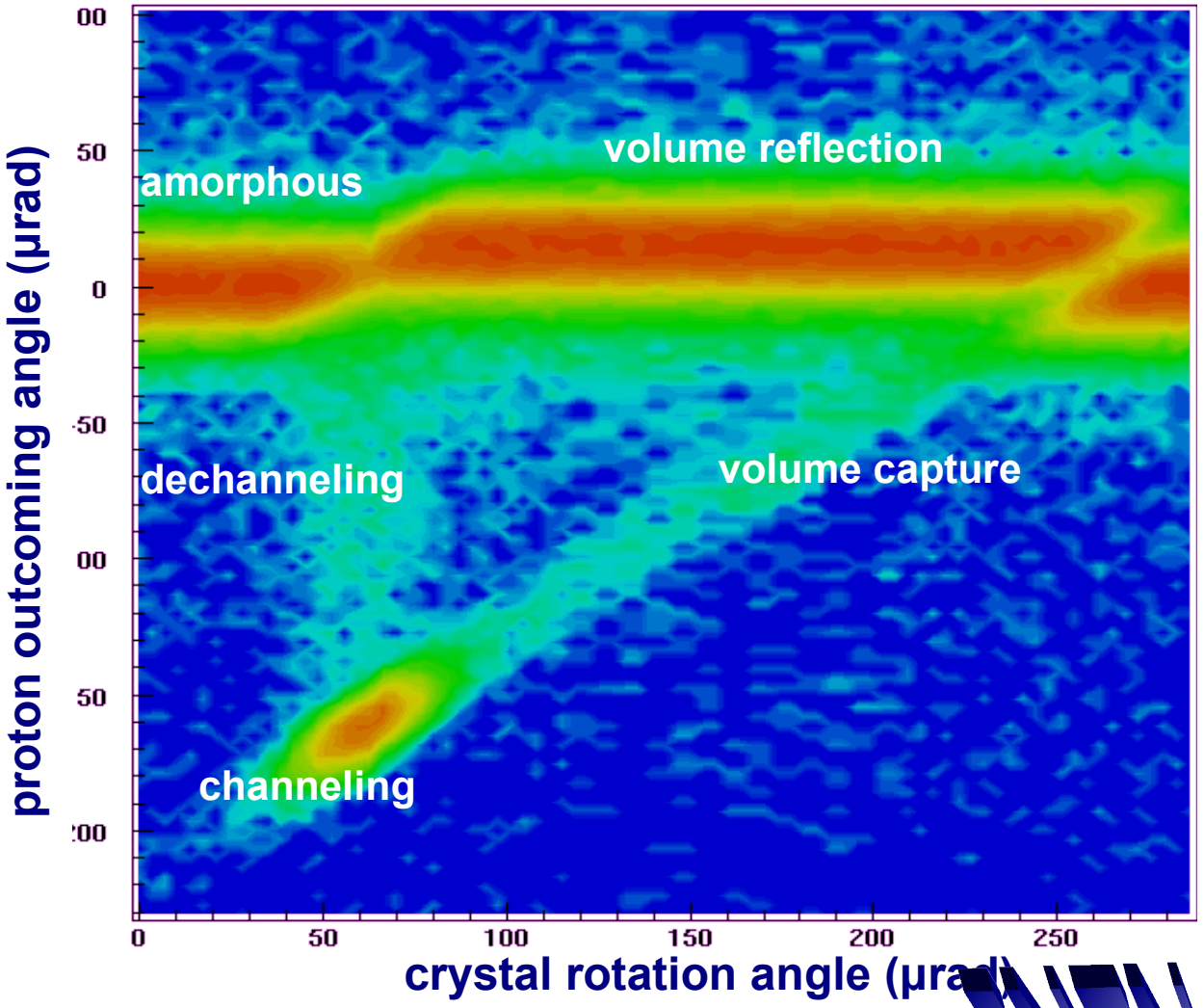




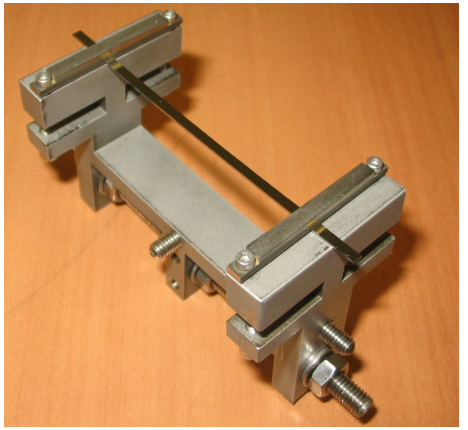


and the CLOU ....

First observation @400GeV/c: CERN (2006)



Single strip crystal



- *First measurement* of the volume reflection effect with a proton beam of 400 GeV/c

EFFICIENCY	VALUE
VOLUME REFLECTION	98.2 ± 0.1%
CHANNELING	51.2 ± 0.7%
VOLUME CAPTURE	1.3 ± 0.1%
DECHANNELING	5.0 ± 0.4%

Crystal collimation story

For the first time:
- → channeling
- → single VR
- → multi VR

LHC?

SPS: 2009

FNAL: 2008 -2009

SPS-H8:2006-2007

FNAL: 2005 -2007

RHIC: 2003

IHEP: 1997-2000

FNAL: 1979

Channeling only

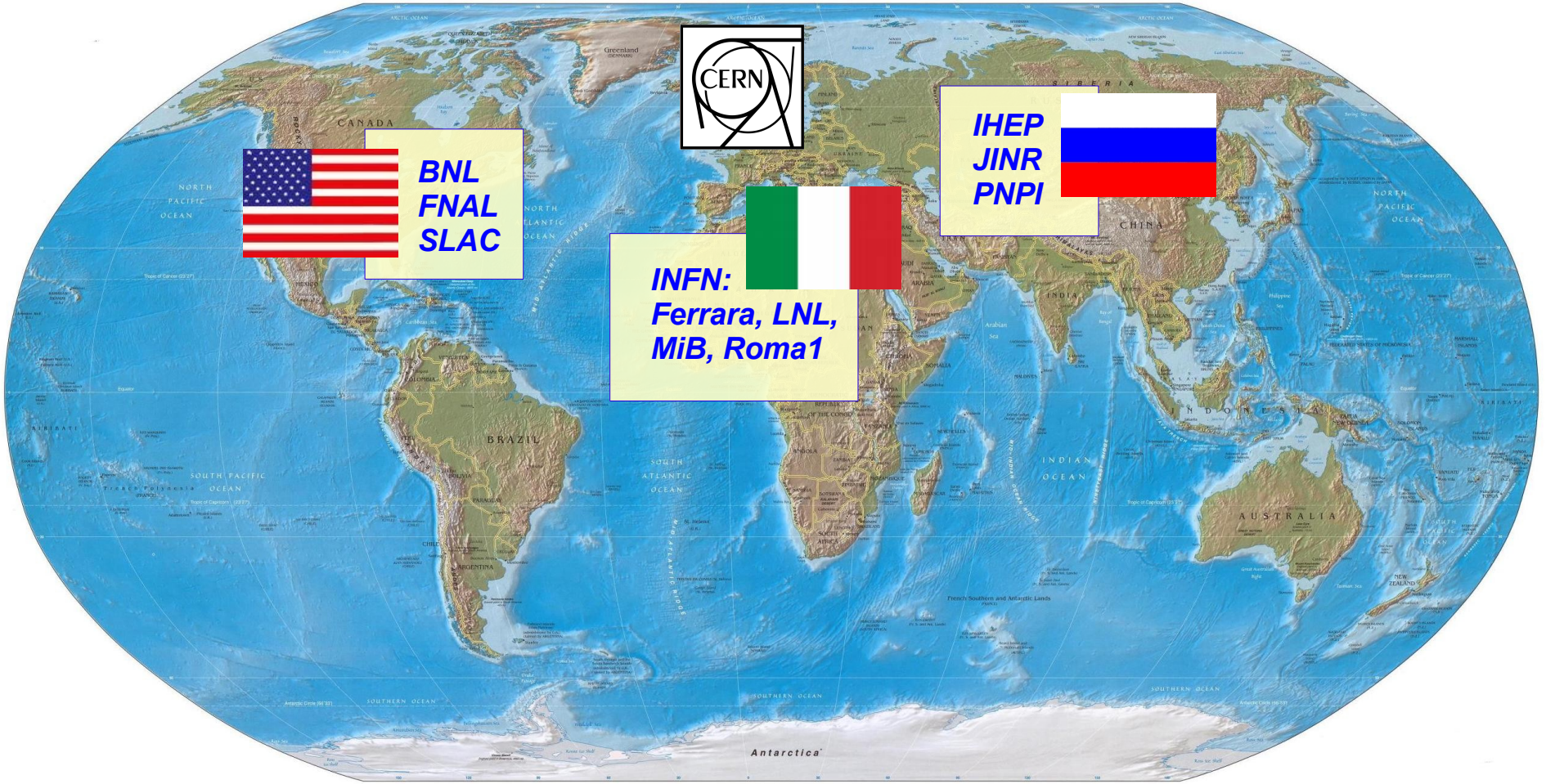
Collimation with crystals: UA9

- ➔ *LSS5 straight section of the SPS ring*
- ➔ *Crystals on goniometers in vacuum tanks*
- ➔ *GEMs, scintillators and BLMs for the crystal alignment*
- ➔ *Silicon strip detectors in roman pots for the tracking of the steered particles*
- ➔ *Halo generation with a proton beam of 120GeV/c during the SPS MD*
- ➔ *Commissioning and tests under way*

- ➔ *COLLIMATION EFFICIENCY*
- ➔ *MEASUREMENT OF THE PHASE SPACE*
- ➔ *MEASUREMENT OF THE LOSSES ALONG THE RING (with beam loss monitors)*

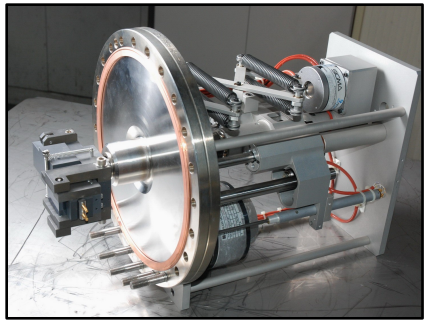
(approved by CERN Research Board on the 3rd of September and by NTA as NTA-CRYSTAL)

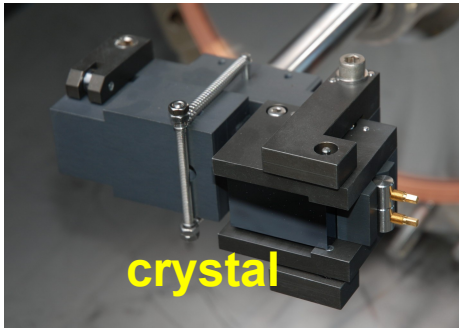
UA9: the COLLABORATION

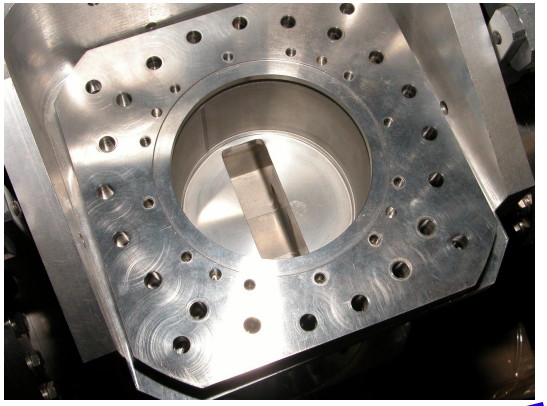


For a total of ~60 participants

The basic idea: collimate and track

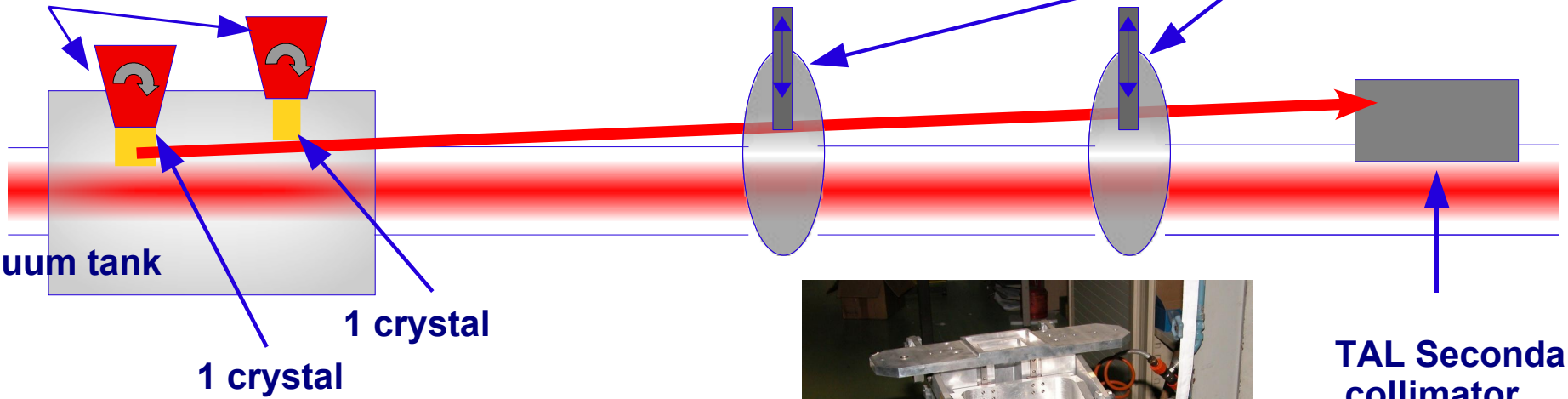


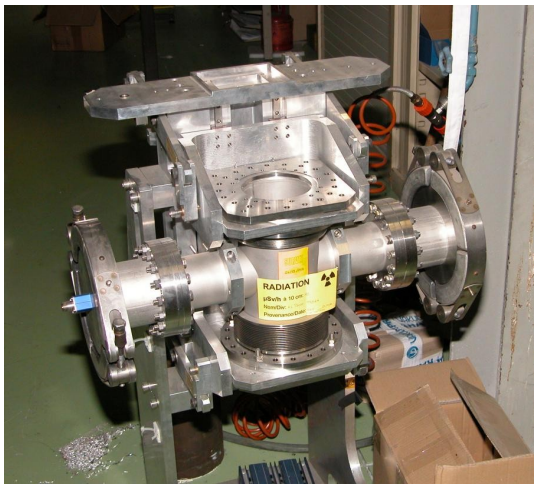




goniometers

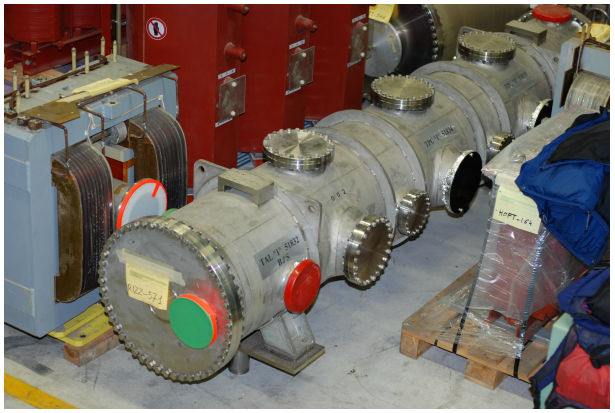
roman pots



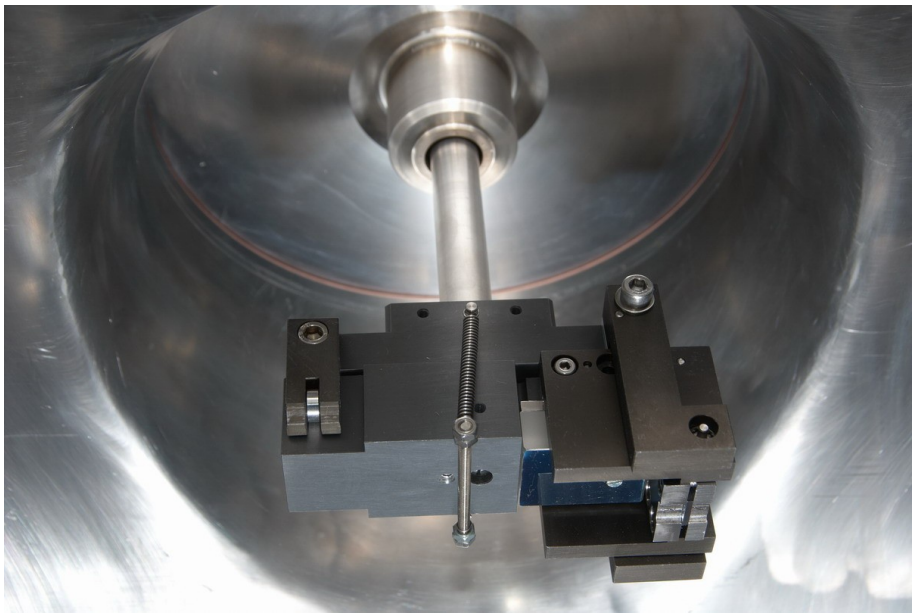


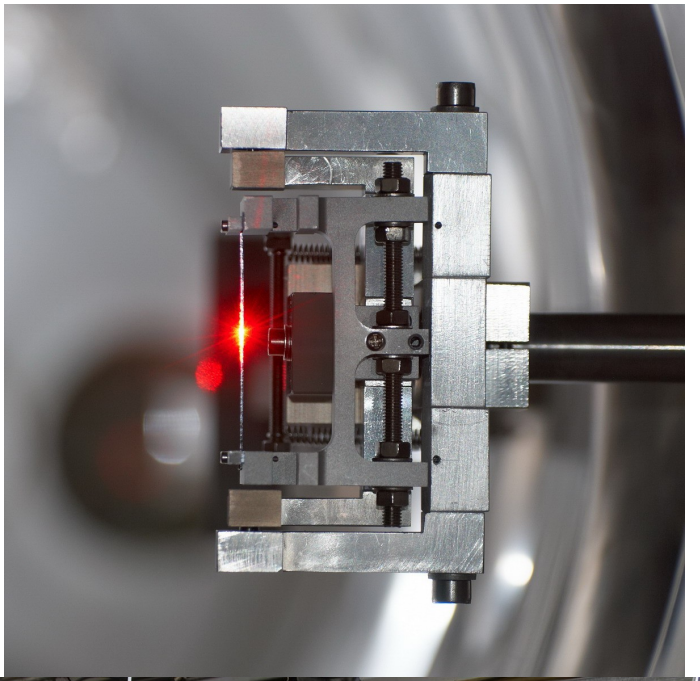
TAL Secondary collimator

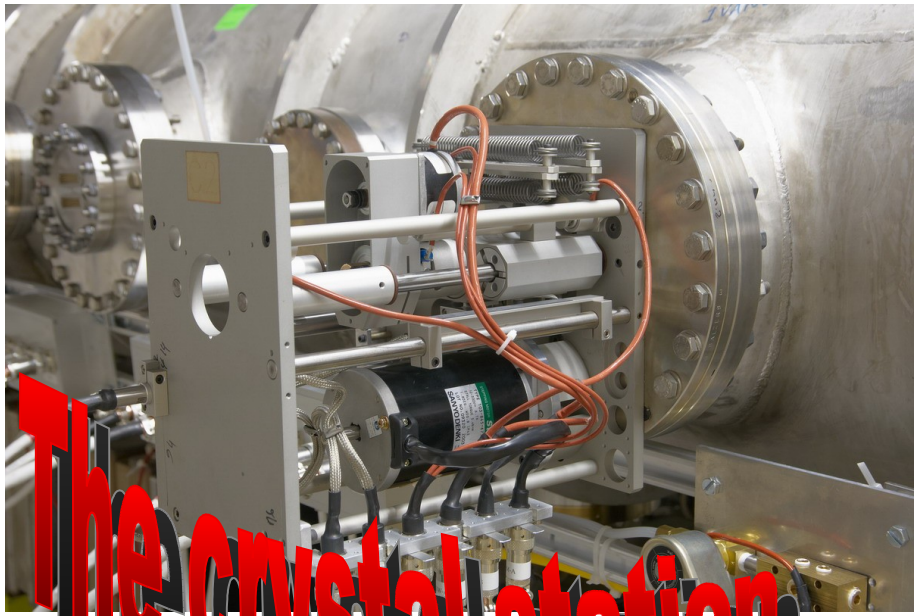
(maximize phase difference to exploit the maximum distance of the steered beam from the core)



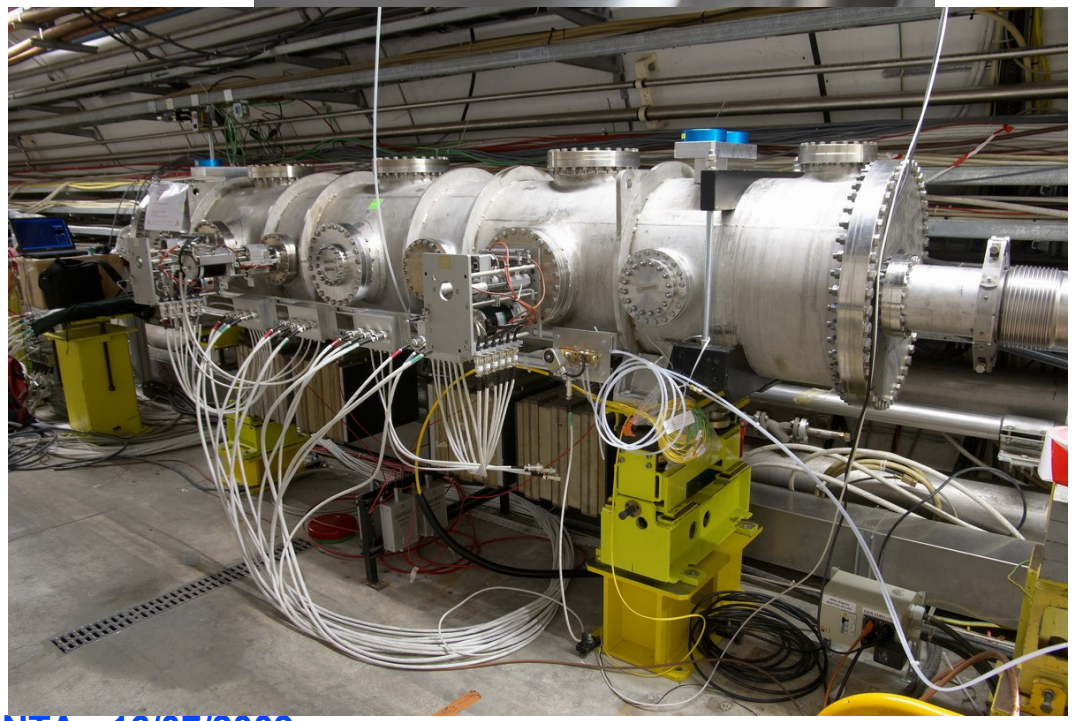
From idea to reality

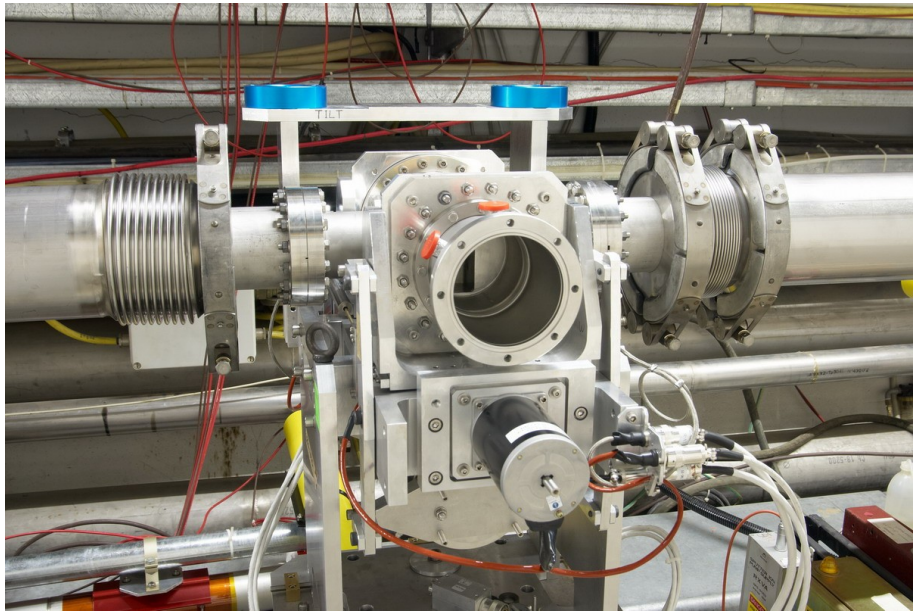


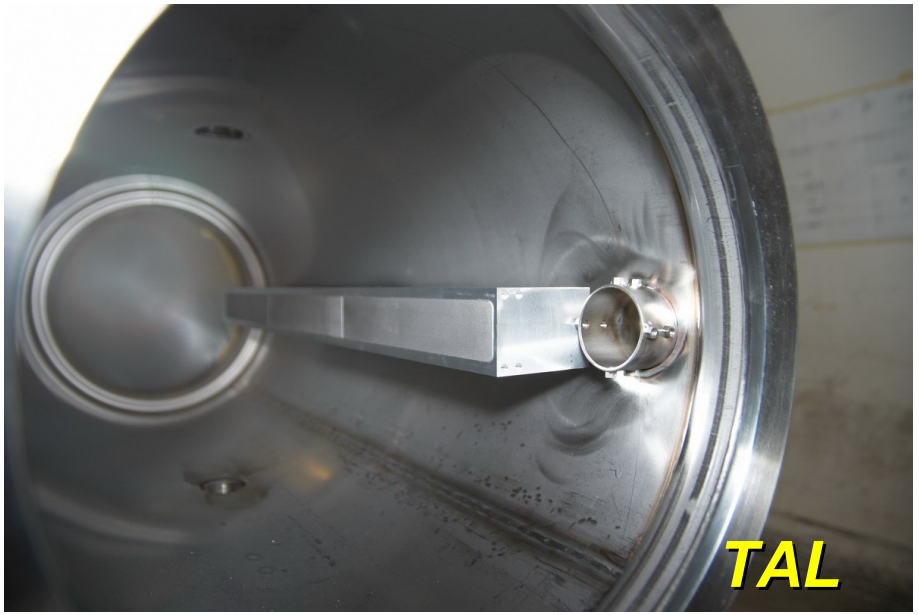


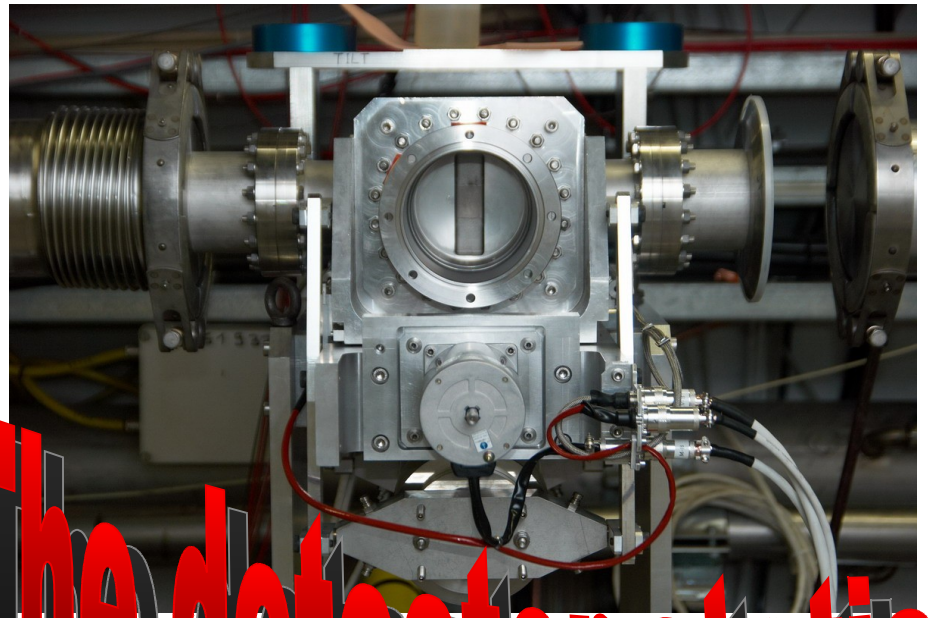


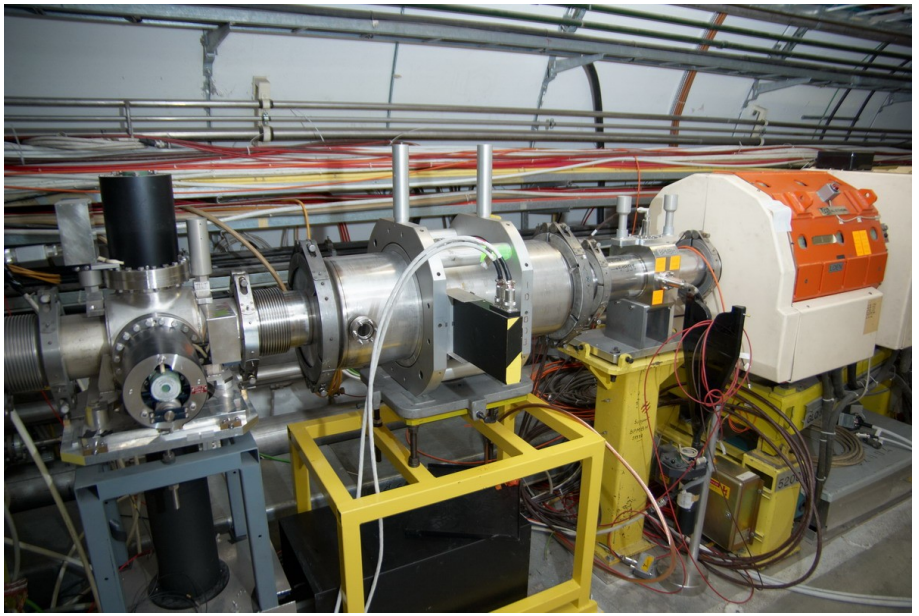
The crystal station











The detector station

Addendum to the initial experiment:

- *GEM detectors and scintillators (2 pairs) near the crystal tank (Roma 1)*
  - *To align the crystal measuring the rate of nuclear interactions (minimum once the crystal is aligned → a la FNAL)*
  - *Counting system*
- *Quartz counter in front of the TAL collimator (PNPI)*
  - *To count particles entering the secondary collimator*
  - *In a second phase, it will be put in coincidence with an identical detector in the crystal tank*
- *Scintillators (2 pairs) downstream of the TAL collimator (Roma 1)*
  - *Measurement of beam interaction products*
- *Fiber detector (Roma 1)*
  - *To be installed in one of the pots of the 2nd roman pot as a backup and for tests with ions*

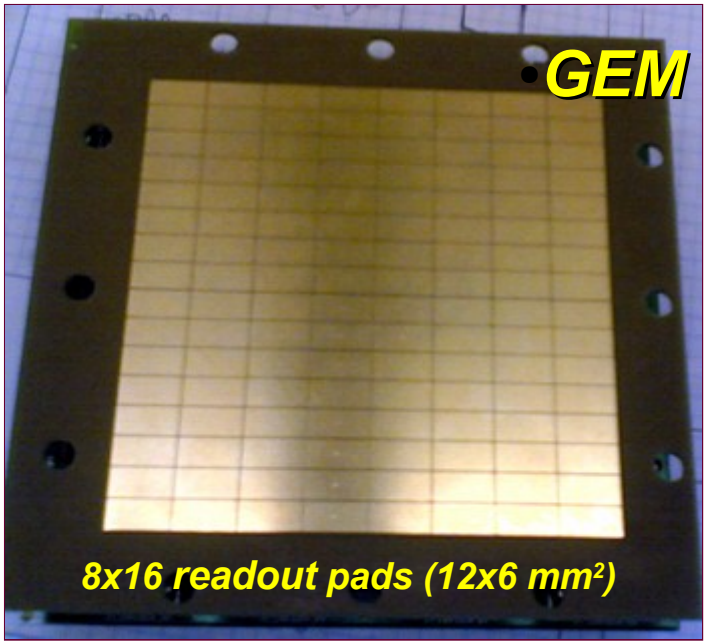
Roma 1 and Frascati contribution:

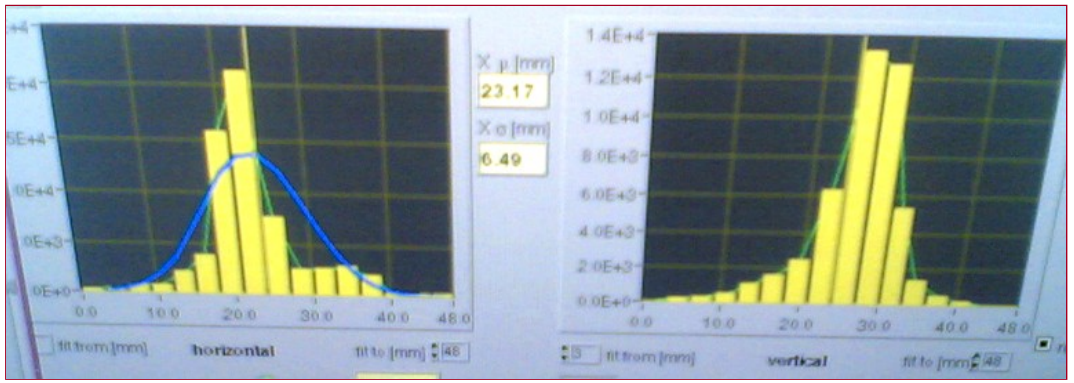
ITEMS

- 2 GEM detectors, 1 fiber detector, 8 scintillator pairs
- Simulation on halo generatio
- Analysis

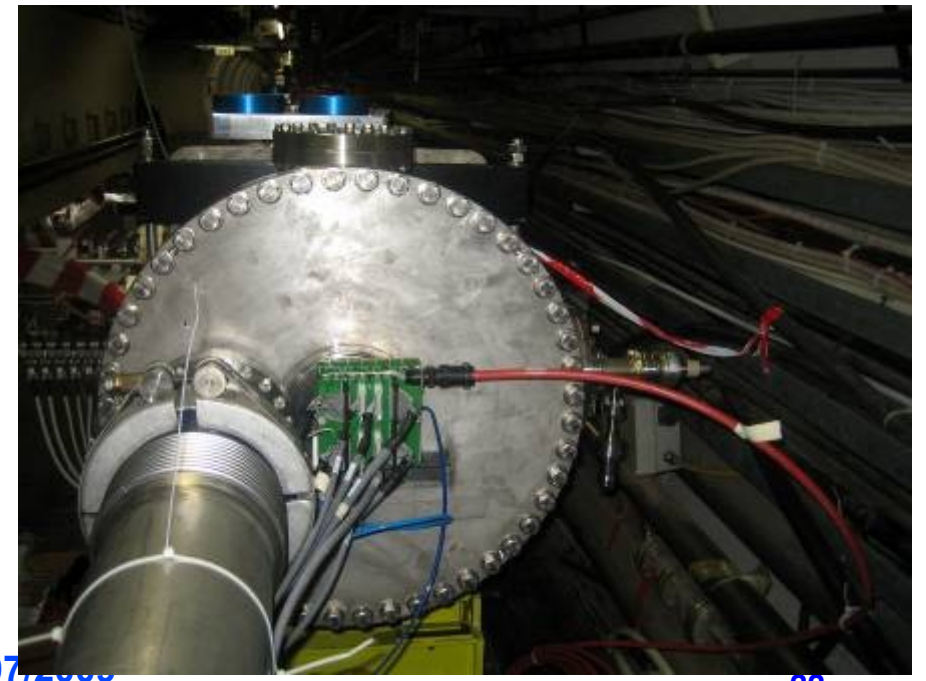
PEOPLE

- G. Cavoto, S. Rahatlou, R. Santacesaria, P. Valente (RM1)
- F. Murtas (LNF)

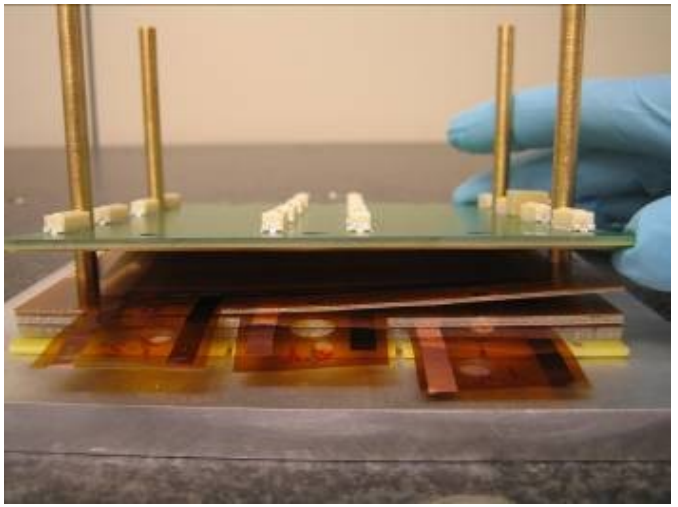




BTF (LNF) beam

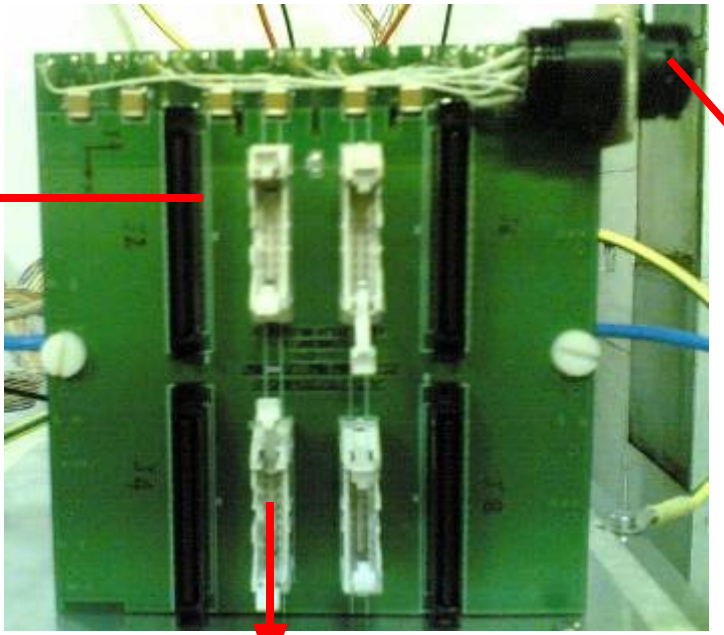


Triple – GEM features



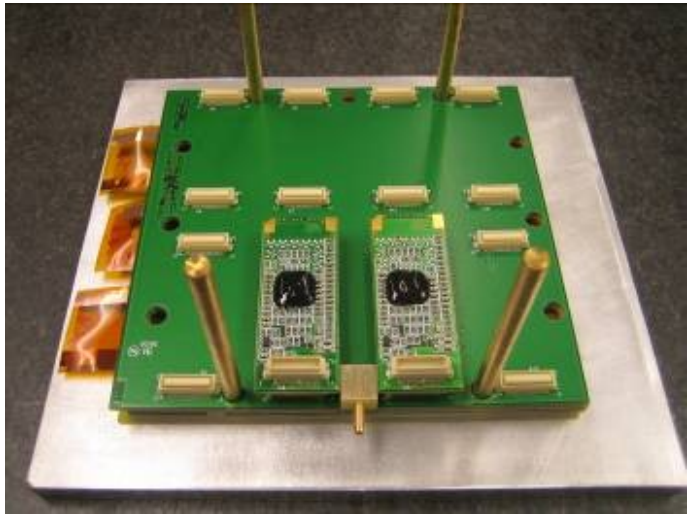
CARIOCA readout electronics(LHCb)

4x32 LVDS signals out



HV in

Threshold & LV in



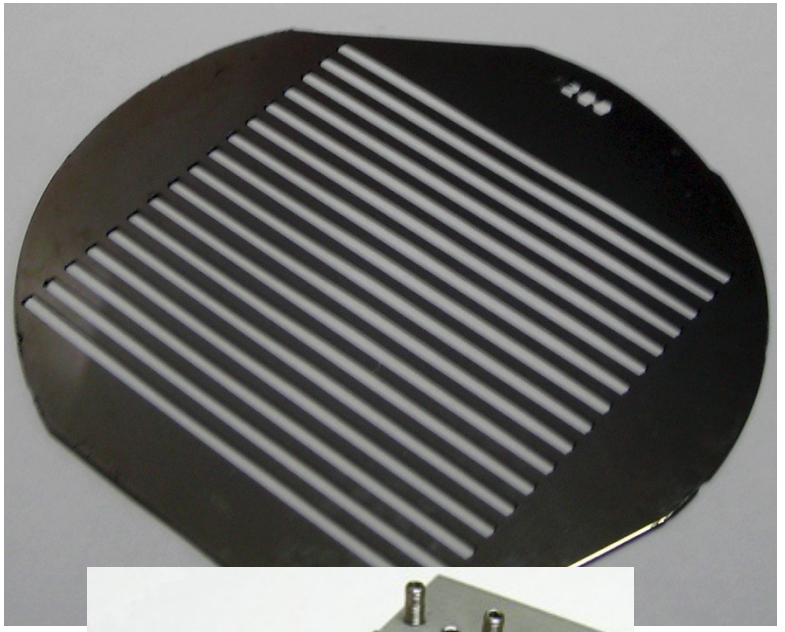
Ferrara contribution

ITEMS

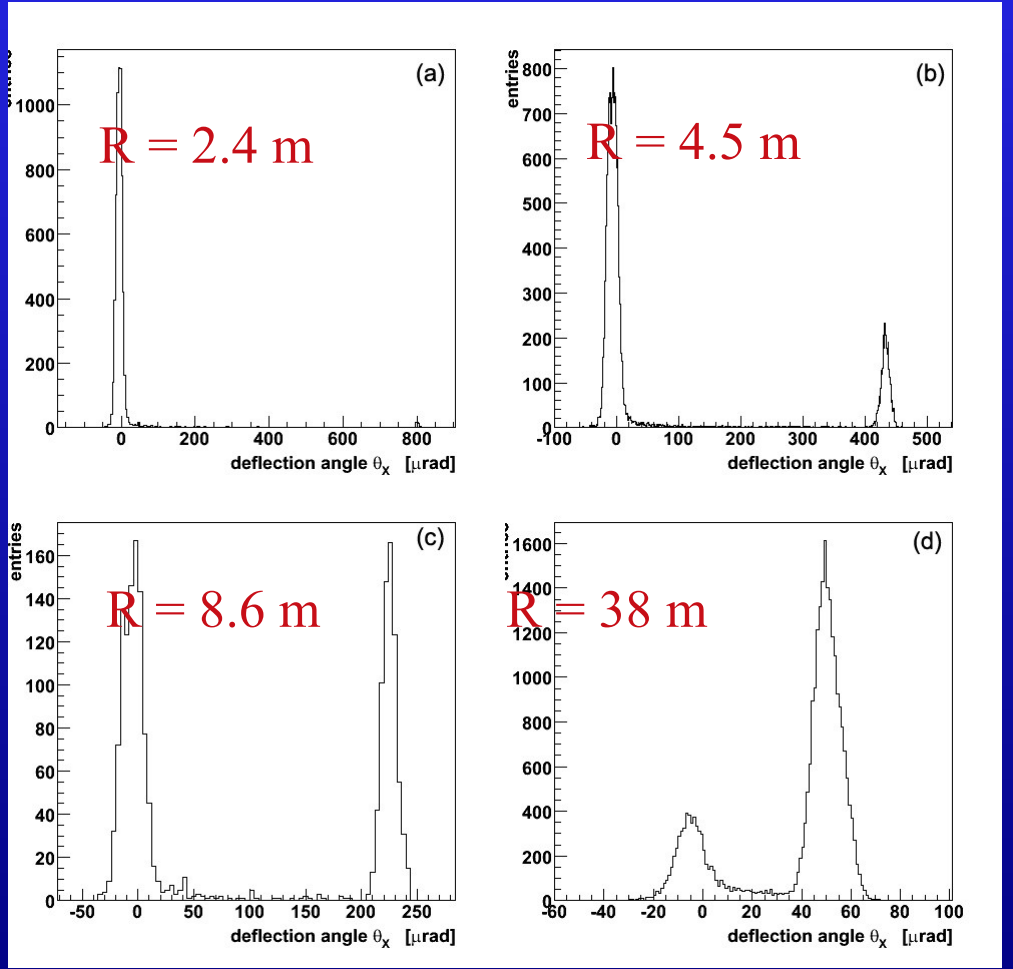
- Crystal (single and multistrip) development and structural characterization
- Mechanics for the crystals (from holders to goniometers)
- Simulations

PEOPLE

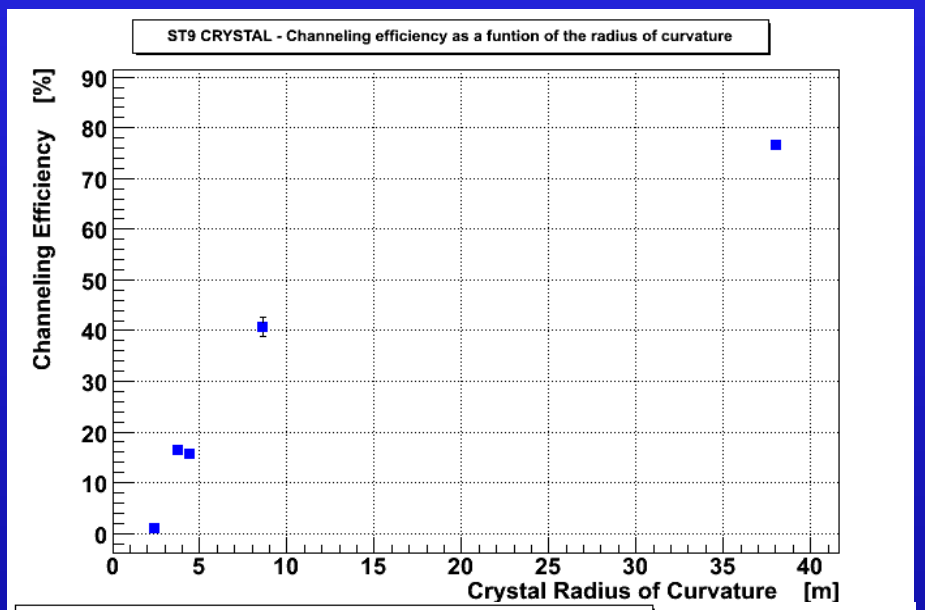
- V. Guidi, P. Dalpiaz, A. Mazzolari, E. Bagli, S. Baricordi, D. Vincenzi

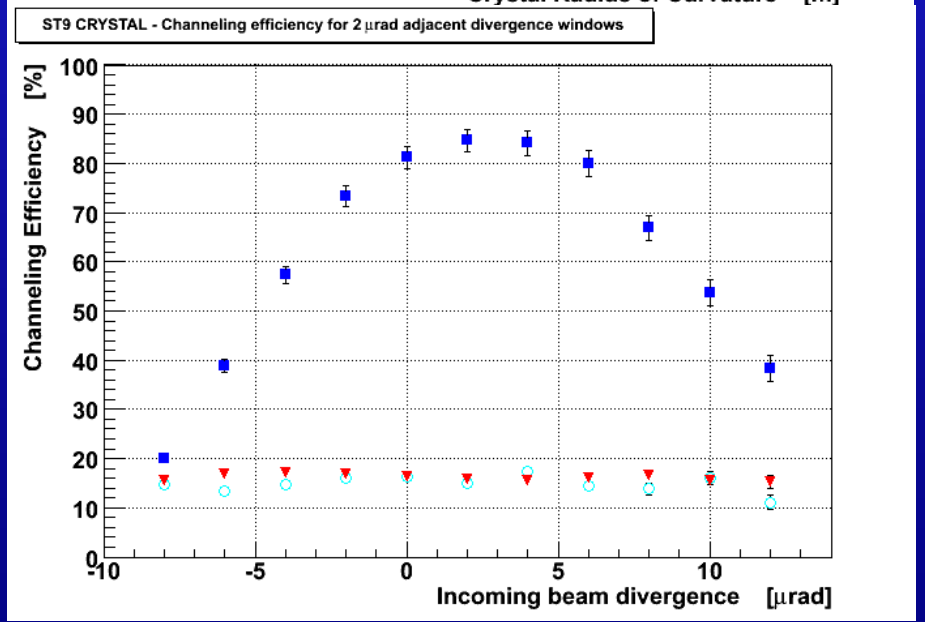


ST9: single strip in SPS



- *ST9 crystal tested with 400GeV/c protons on the H8 beamline (North Area)*
- *Very high planar channeling efficiency*

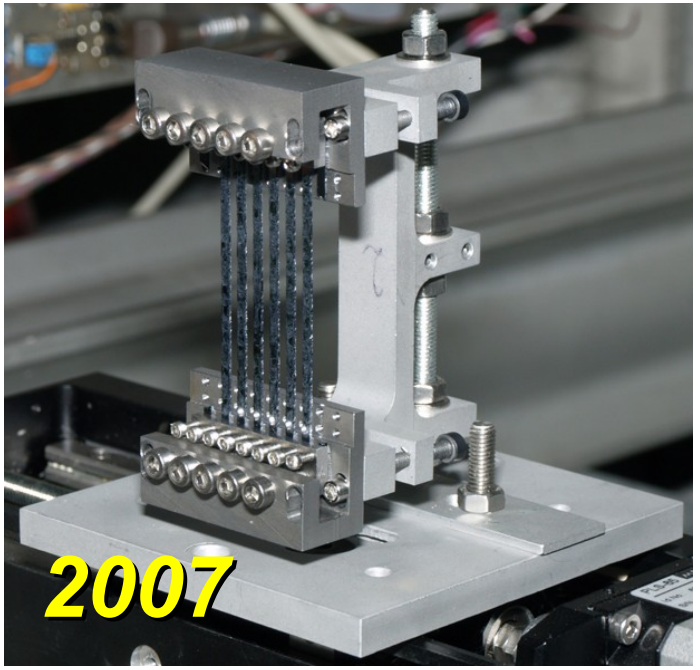


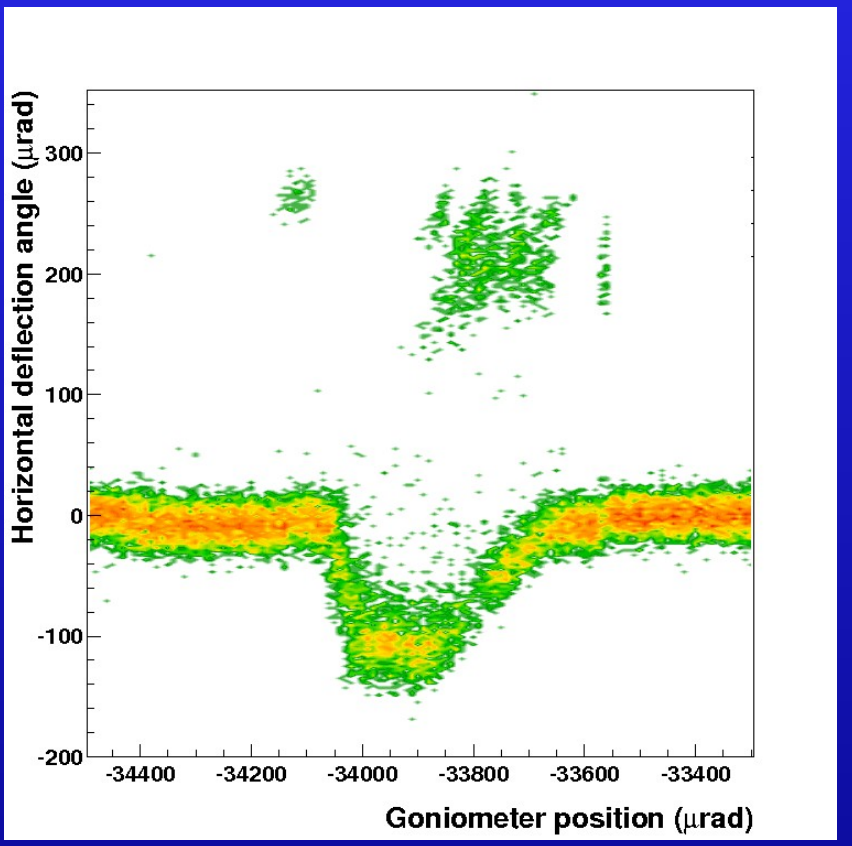


ST9

- ***Single pass efficiency of planar channeling > 75% and 85% with quasi parallel particles***

Multistrip: next in SPS





- *Deflection angle = 109μrad*
- *Efficiency ~ 94%*
- *New holder conception → dedicated studies on the distribution of the masses during 2008 testbeams*

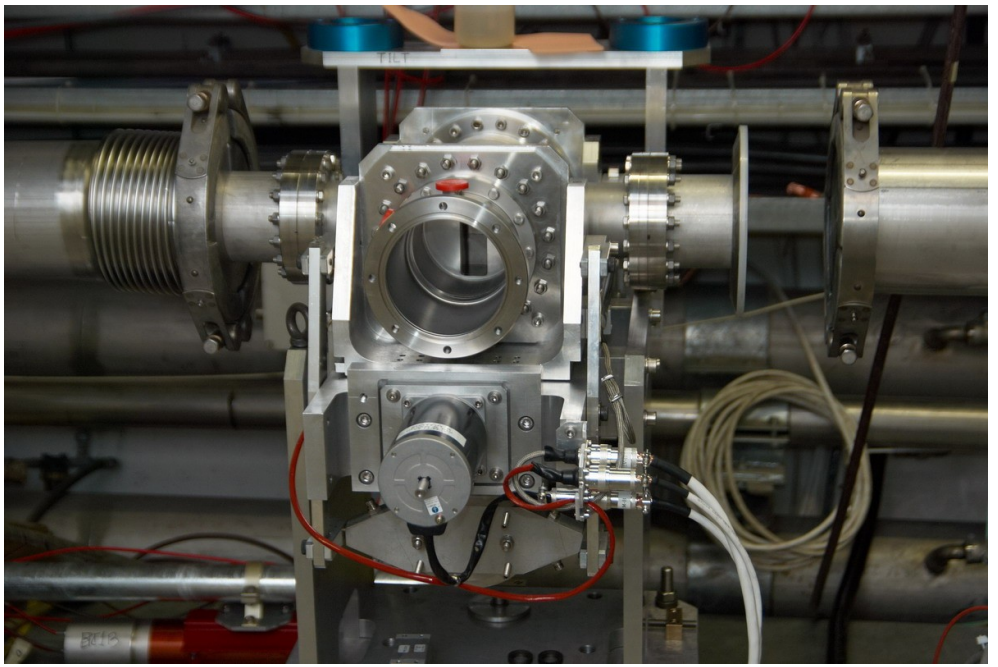
Legnaro contribution

ITEM

➔ *Roman pot 1 mechanics*

PEOPLE

➔ *G. Della Mea, A. Lombardi, R. Milan (LNL)*
➔ *A. Vomiero (Univ. Brescia)*



Como/Trieste contribution

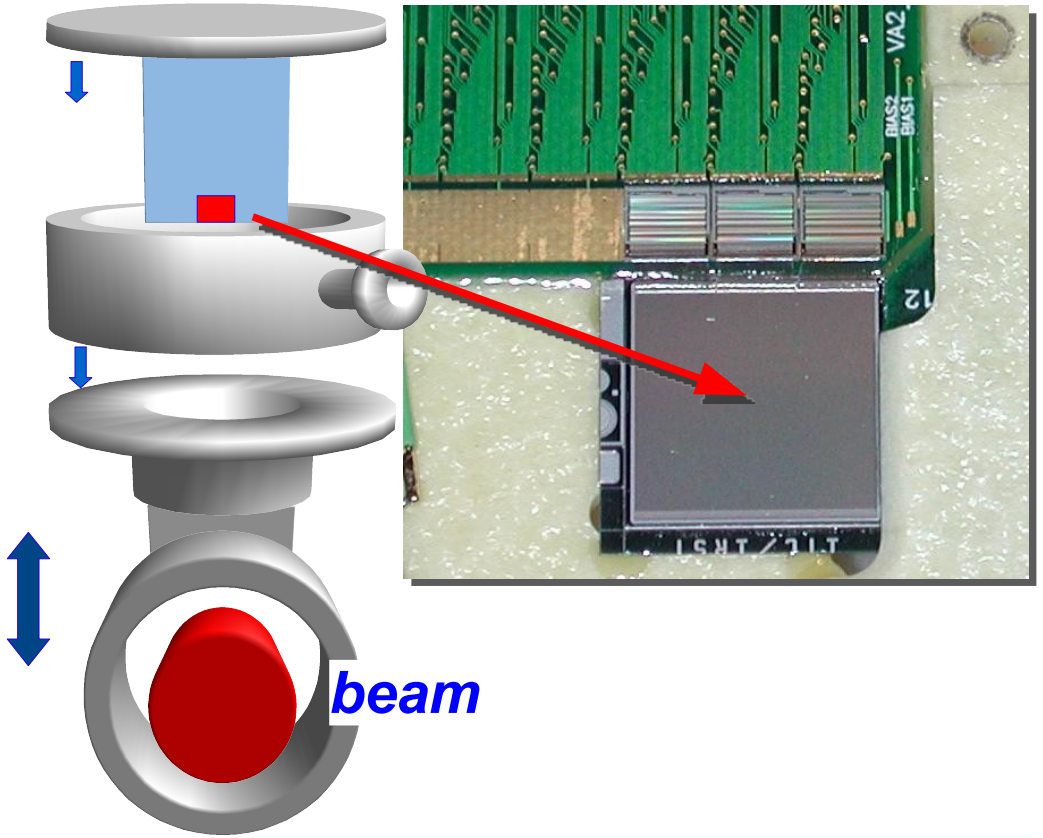
ITEMS

- Tracking silicon detectors with self triggering electronics
- DAQ and slow controls
- Online analysis
- Simulation (crystal emulator – CRYM, roman pot and detector simulation, TAL)

PEOPLE

- D. Bolognini, S. Hasan, A. Berra, A. Mattera, D. Lietti, M. Prest (Uninsubria/ MiB)
- E. Vallazza (Ts)

http://insulab.dfm.uninsubria.it/ and follow the UA9 indication

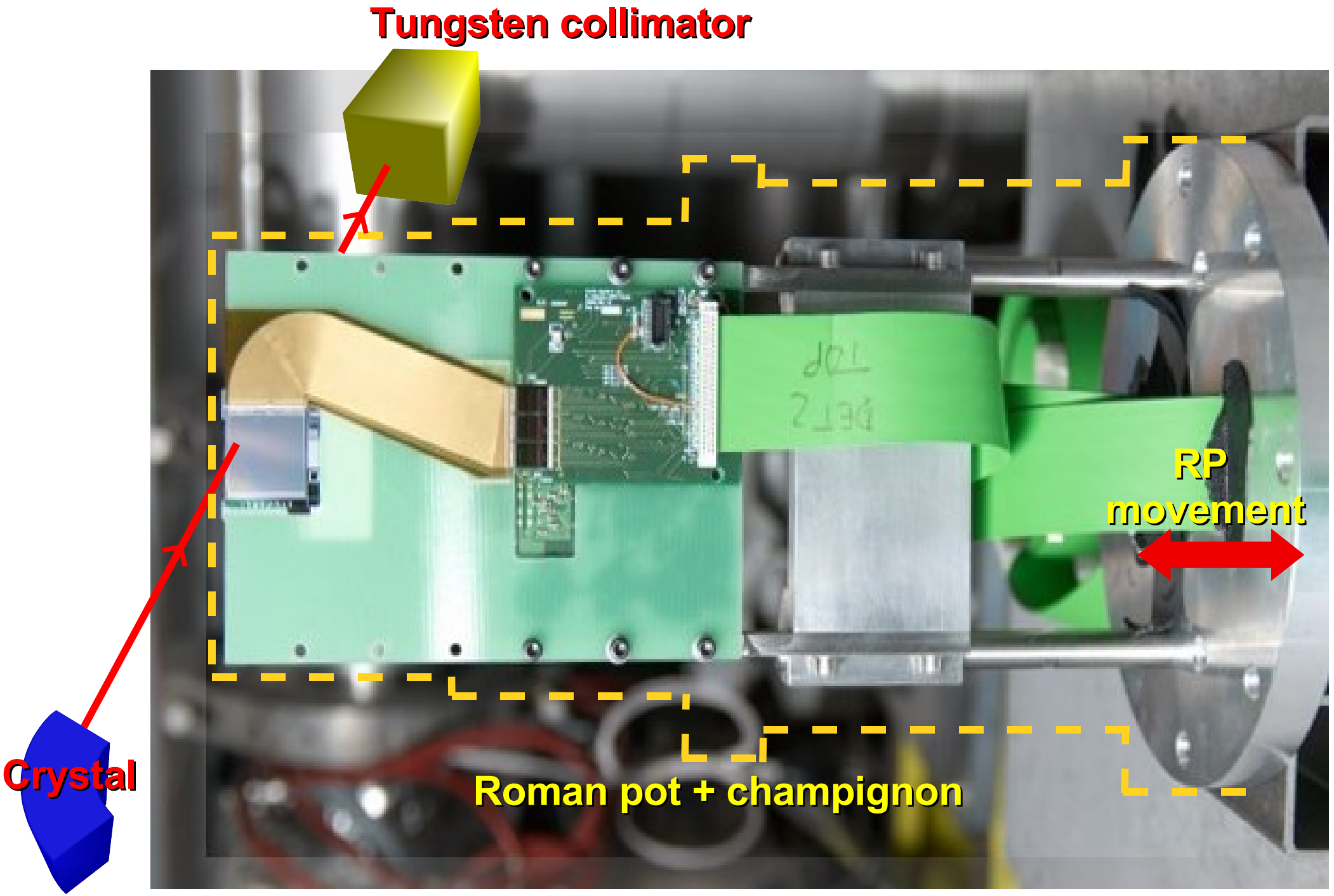


REQUIREMENTS

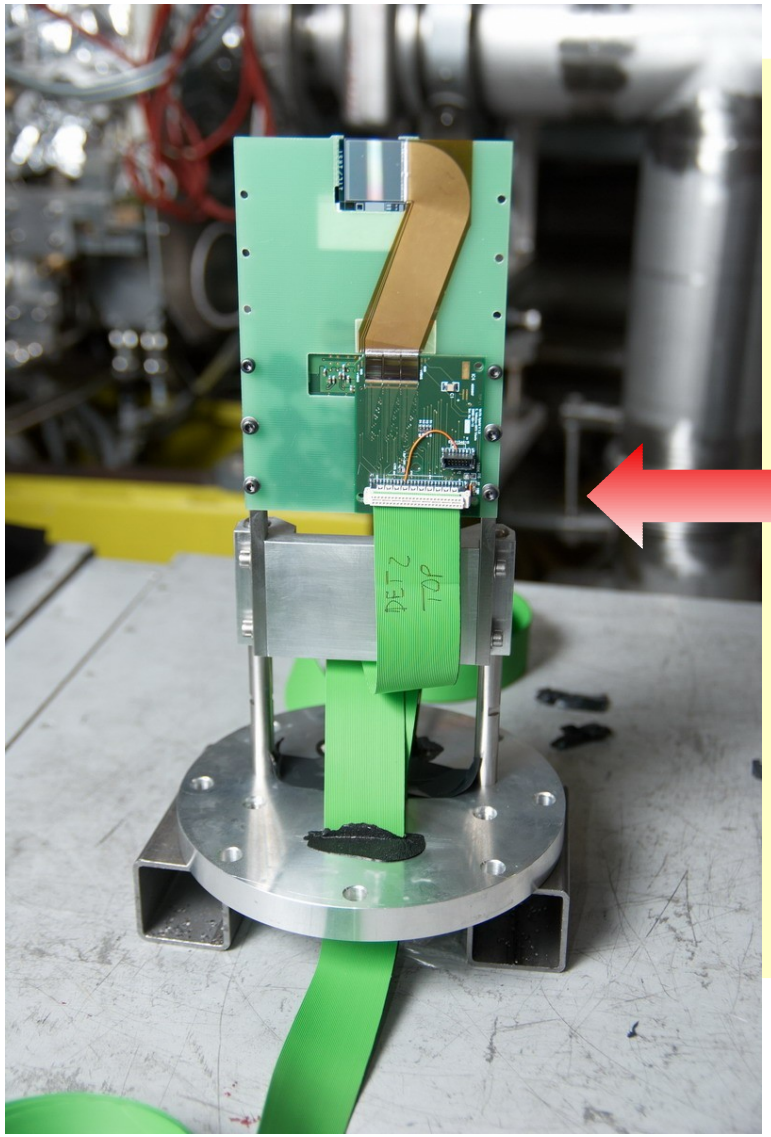
- Limited multiple scattering
- High spatial resolution
- Self triggering
- Active region inside the beam

FULFILLED WITH

- Double side silicon detector with a strip pitch of 50μm
- Cut at 500μm from the border
- Self-triggering ASIC (VA1TA)
- SOC (System On Chip)


Tungsten collimator
RP
movement
Crystal
Roman pot + champignon

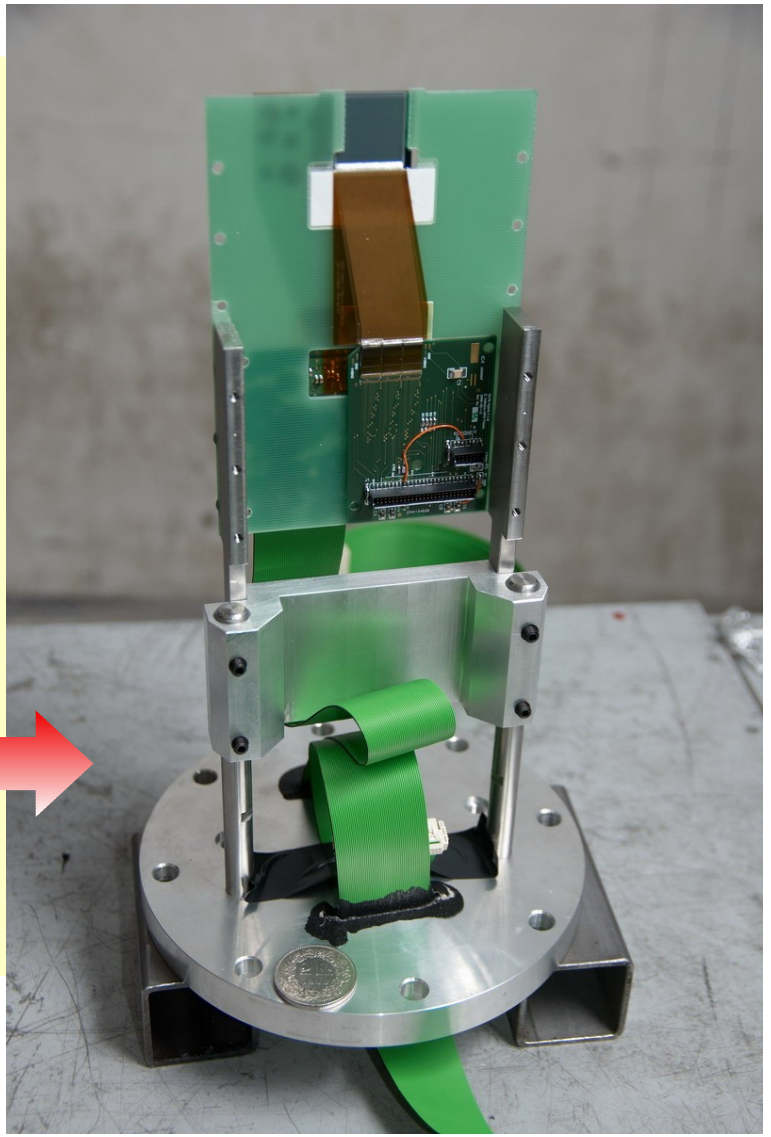
The prototype



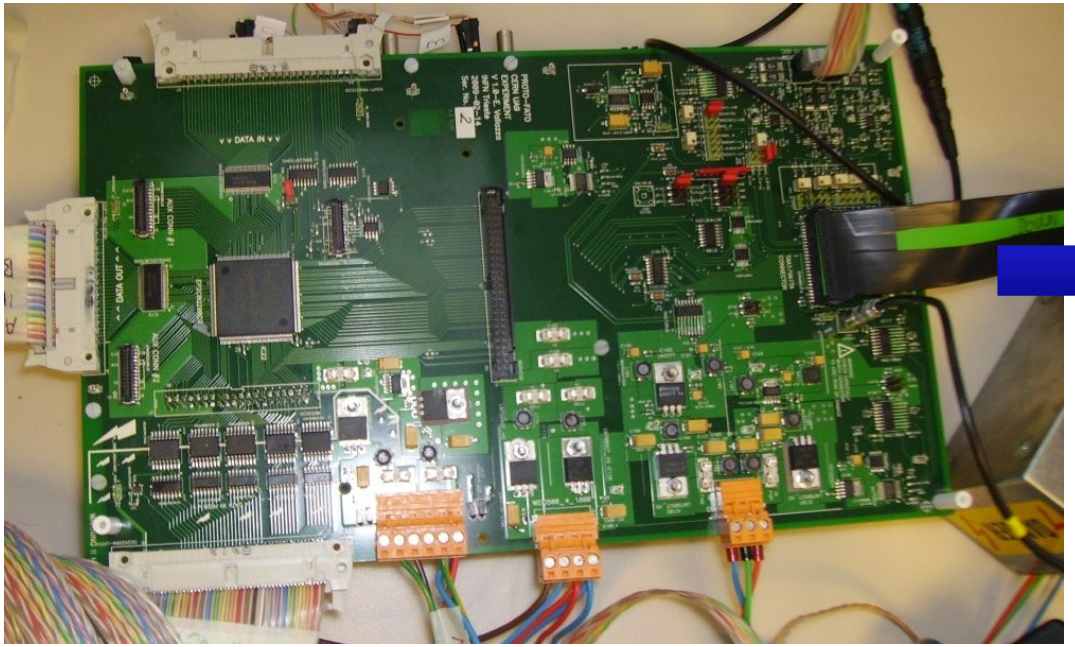
- ✔ *1 FBK detector readout by 6 VA1TA ASICs*
- ✔ *1 FR4 board for the support of the detector*
- ✔ *upilex fanouts for the connection between the silicon and the ASICs*

JUNCTION
(HORIZONTAL)

OHMIC
(VERTICAL)

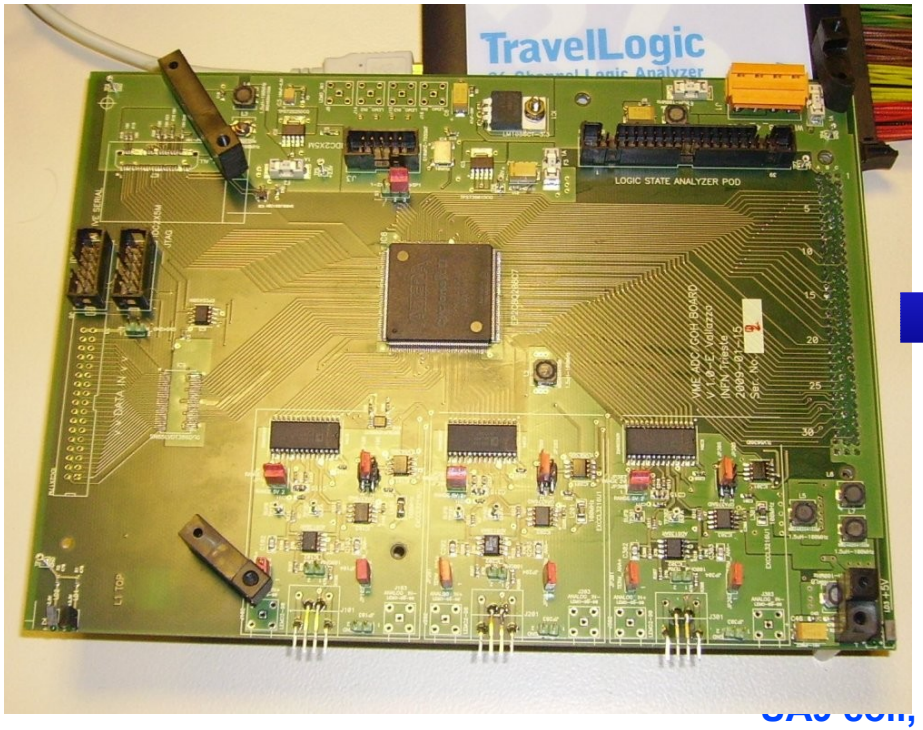


Electronics



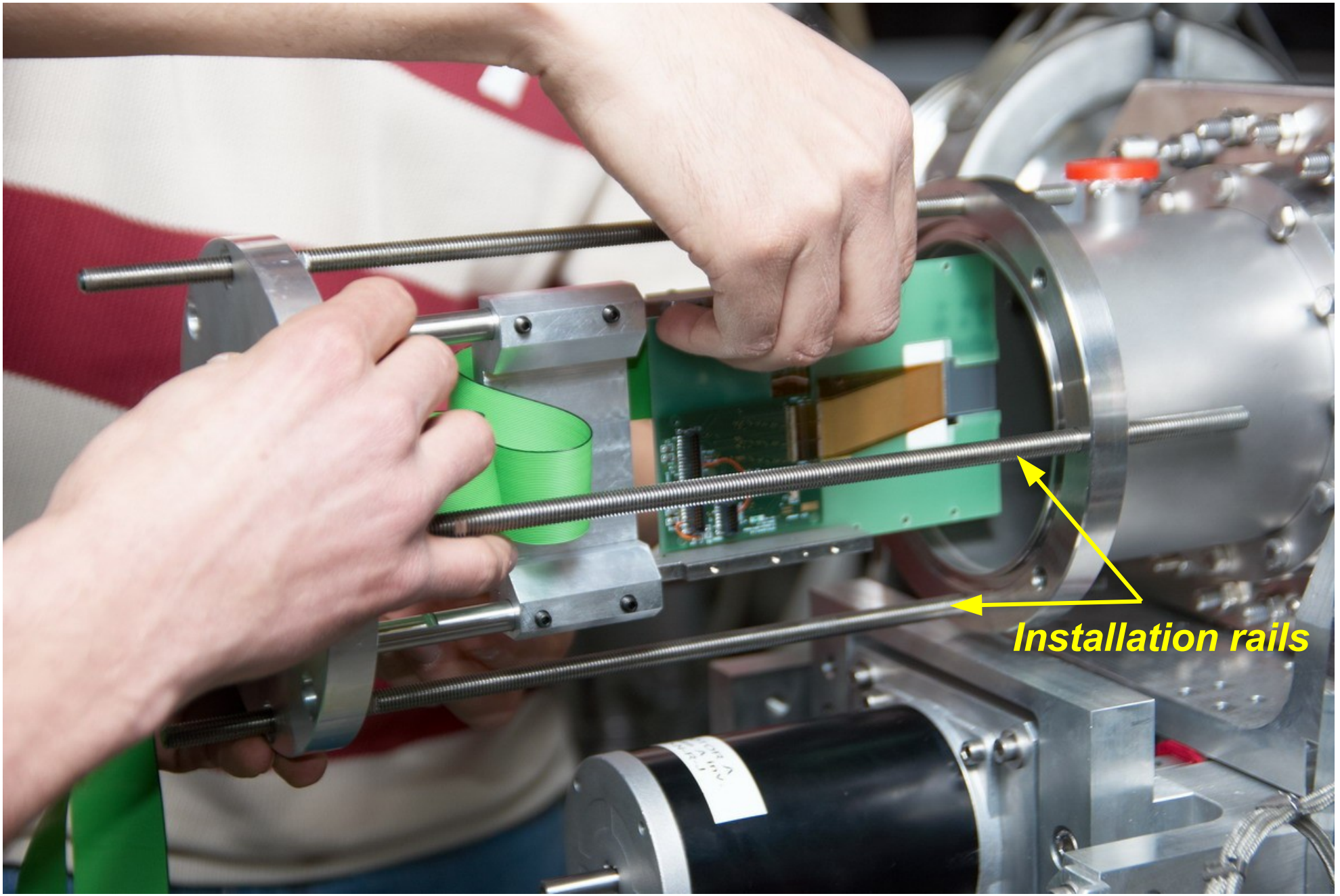
PROTOFATO

- Configuration
- Interface
- Monitoring
- Readout
- 1 MASTER (junction) and 1 SLAVE (ohmic) boards
- ~1000 components
- ~1500 VHDL lines

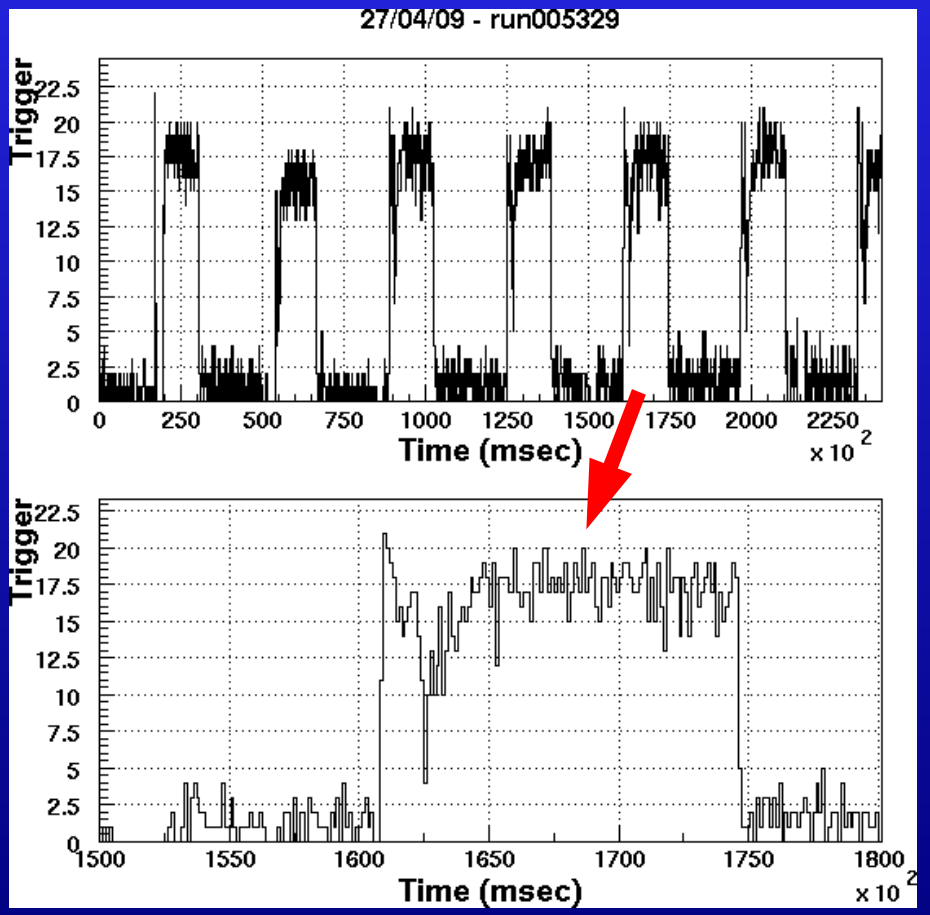


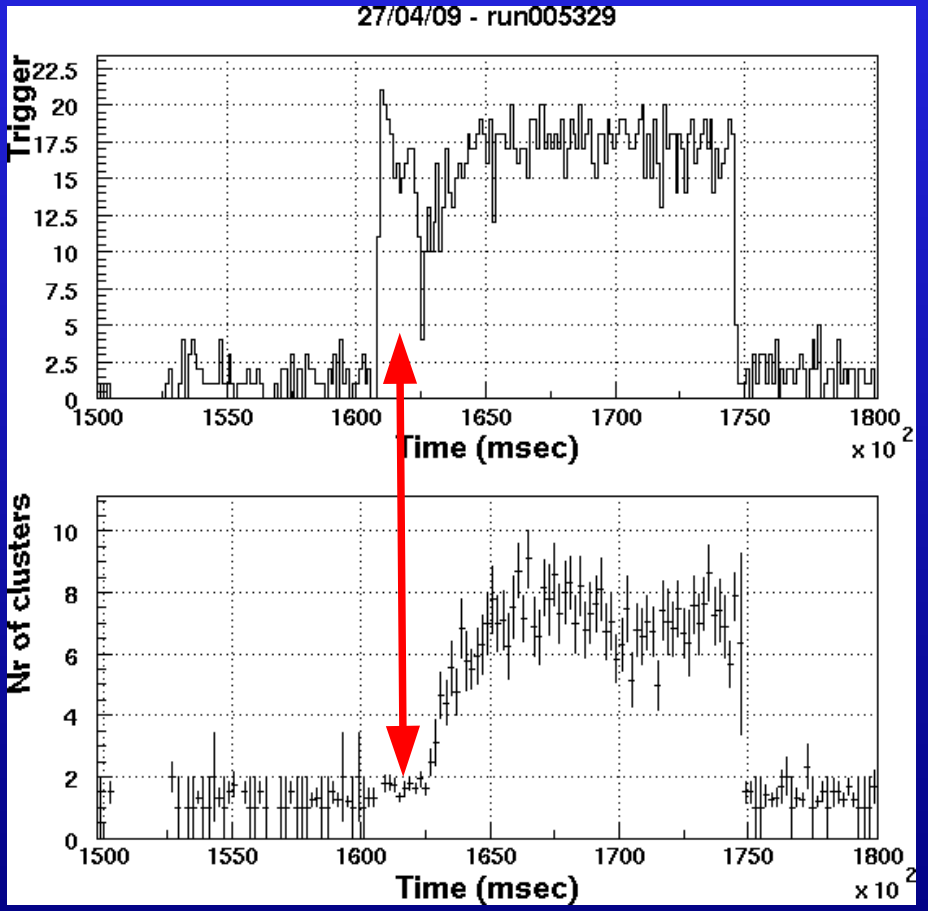
DRIVER

- ADC (one per ASIC)
- Fiber transmission
- 1 per protofato
- ~500 components
- ~800 VHDL lines

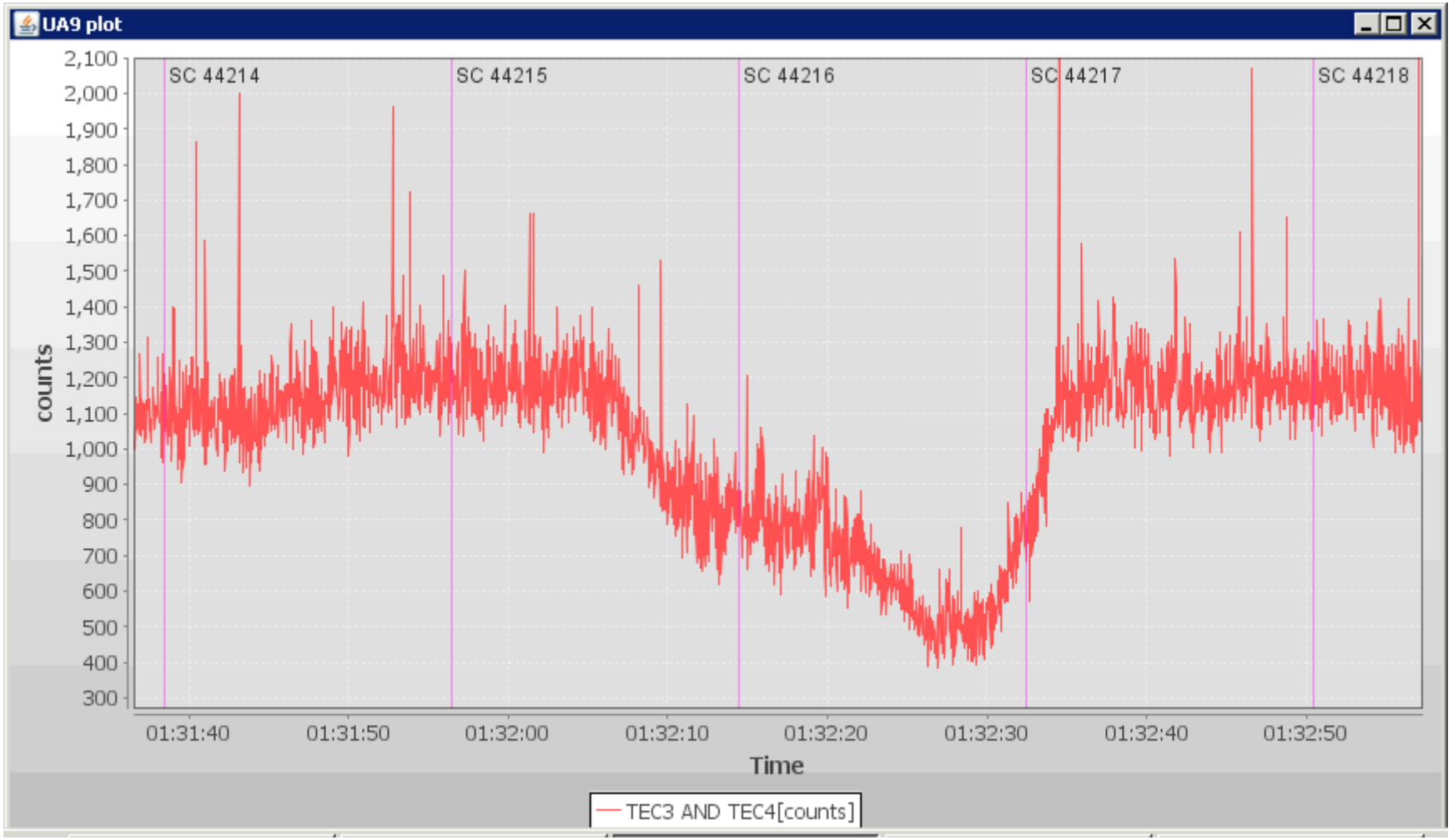

Installation rails

Trigger e cluster



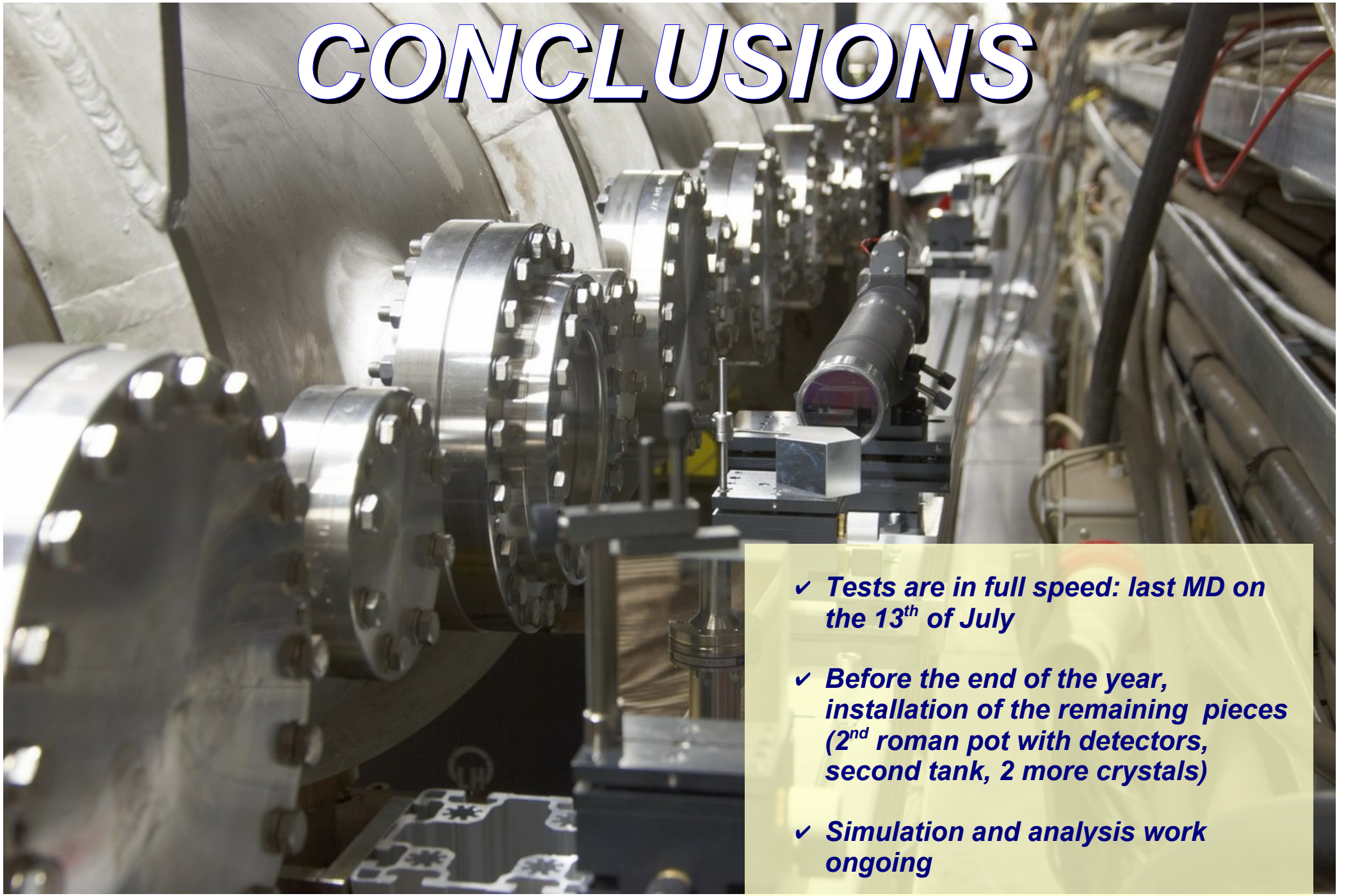


First alignment of the crystal in the SPS



01/07/2009

CONCLUSIONS



- ✔ *Tests are in full speed: last MD on the 13th of July*
- ✔ *Before the end of the year, installation of the remaining pieces (2nd roman pot with detectors, second tank, 2 more crystals)*
- ✔ *Simulation and analysis work ongoing*