Istituto Nazionale di Fisica Nucleare

The high performance microstrip silicon detector tracking system for an innovative crystal based collimation experiment

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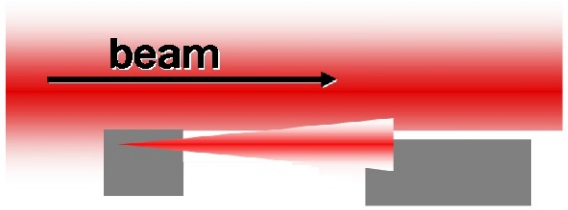
Outline

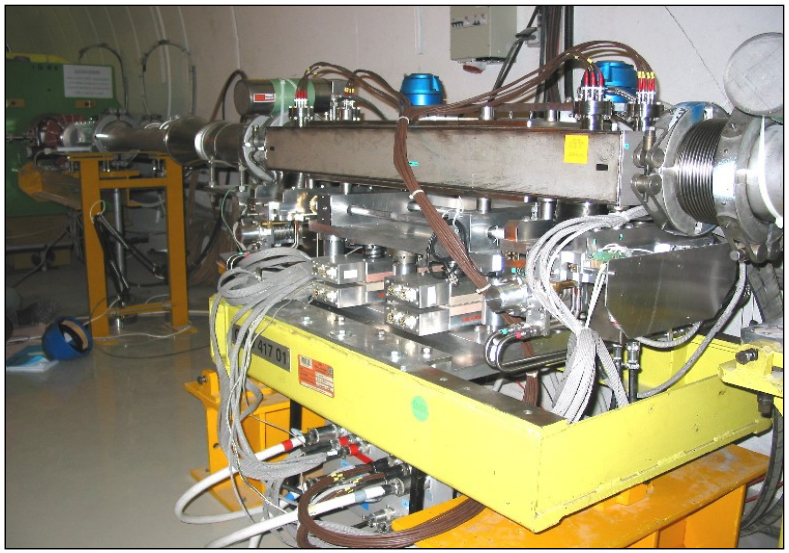
- The UA9 experiment: a new collimation concept
- The tracking system
- The commissioning phase: the prototype in the SPS
- Conclusions and outlooks

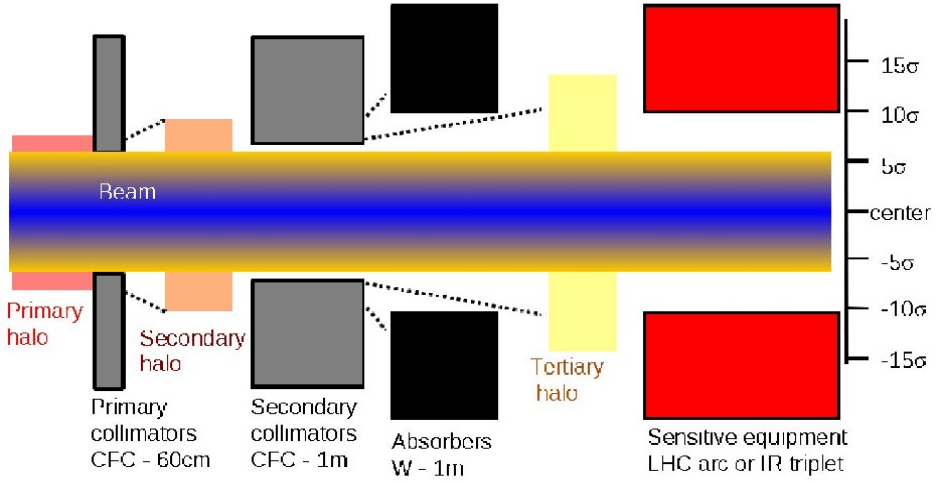
- **The UA9 experiment: a new collimation concept**
- **The tracking system**
- **The commissioning phase: the prototype in the SPS**
- **Conclusions and outlooks**

Hadron accelerator collimation system

Present system: a multistage collimation system like the LHC one







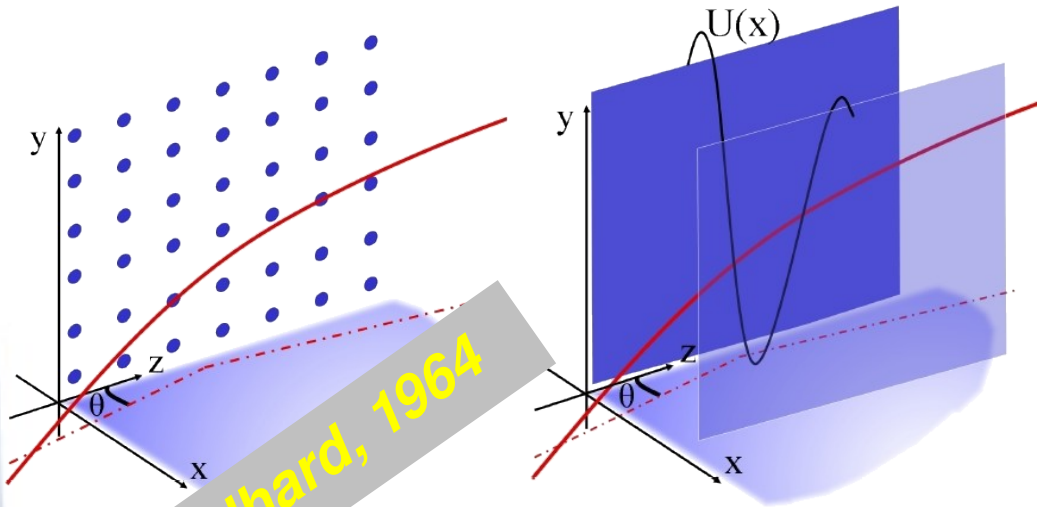
The halo beam is spread on the whole solid angle by CFC collimators:

- ⇒ **Superconducting magnets could quench**
- ⇒ **High impedance level**

40% of the nominal luminosity

A new idea: bent crystals

"In a crystal, a charged particle feels an average potential due to the atomic planes"

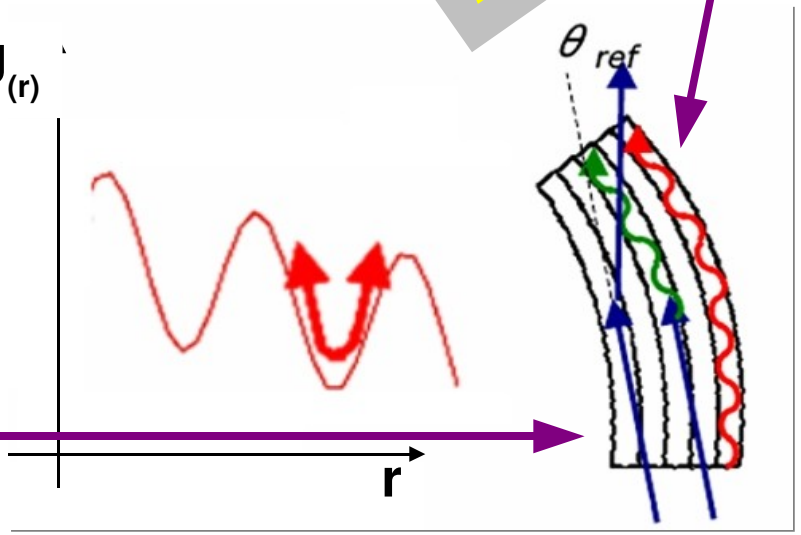


Lindhard, 1964

Channeling

"In a bent crystal, a charged particle follows the bent planes and can be deviated from the original trajectory"

Tsyganov, 1976



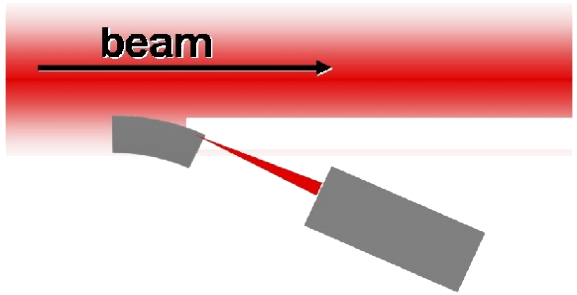
Volume reflection

"In a bent crystal, if a charged particle encounters the atomic plane tangency point it can be reflected by the crystal volume"

Taratin/Vorobiev, 1989

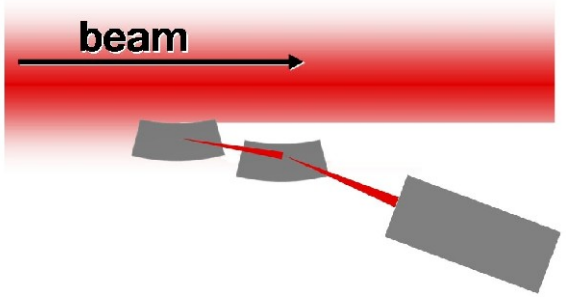
A bent crystal: a clever collimator?

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)

Multi volume reflection



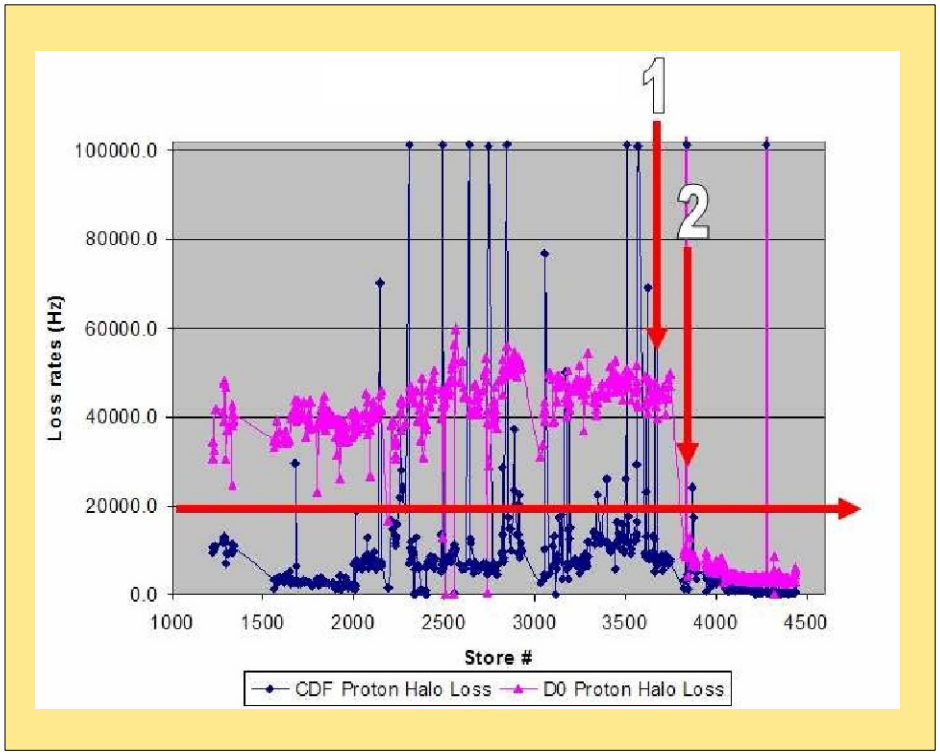
- **Larger angular acceptance** (channeling deflection angle)
- Efficiency of the order of **100%** @400 GeV/c
- Small deflection angle (~14µrad @400 GeV/c)
- It is possible to align **more than one crystal** to increase the deflection angle, keeping the efficiency high

The FNAL test (2005)

- **O-shaped crystal** (PNPI) of RHIC
- detectors = **PIN diodes**, ionization beam

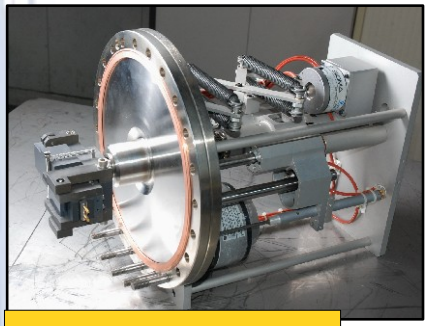
- **Effective reduction of the background**
  horizontal line = proton halo loss limit
  vertical ones = machine developments to
- **reduce background:**
  1 = installation of a double scraper
  2 = improvement of the vacuum system
  + alignment + installation of the crystal

No results in 2006/2007
due to mechanics problems

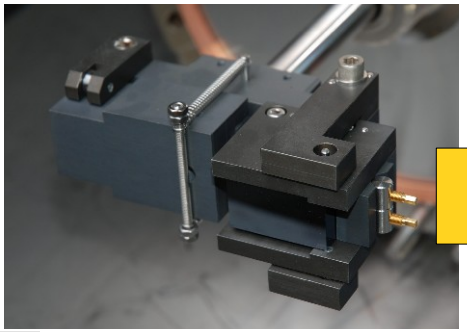


Crystal behaviour evaluation
REQUIRED

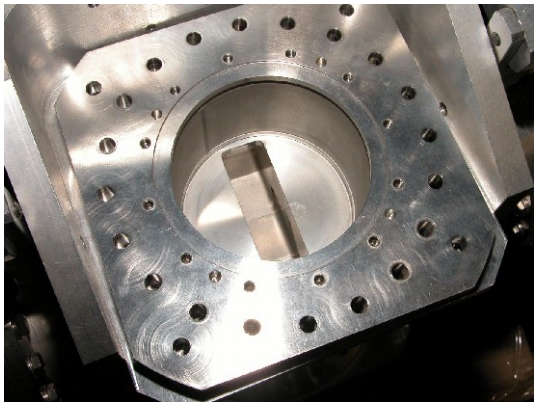
The UA9 experiment

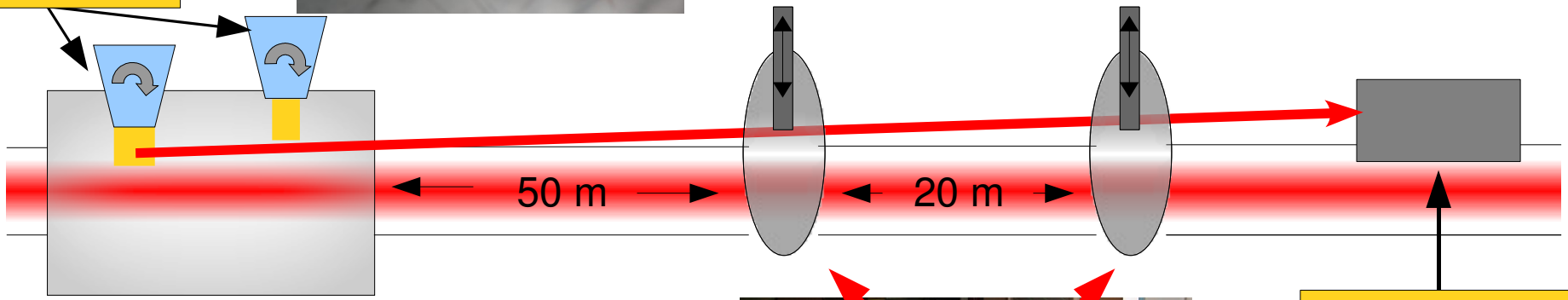


Goniometers

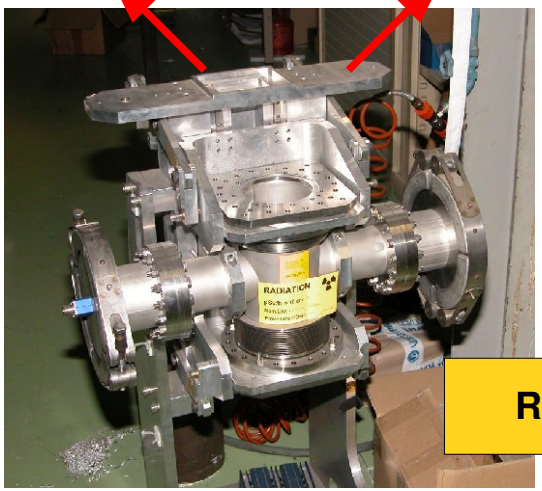


Crystals





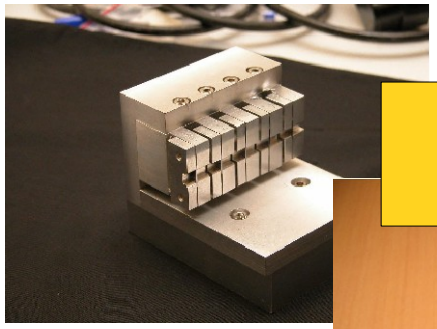
Tank



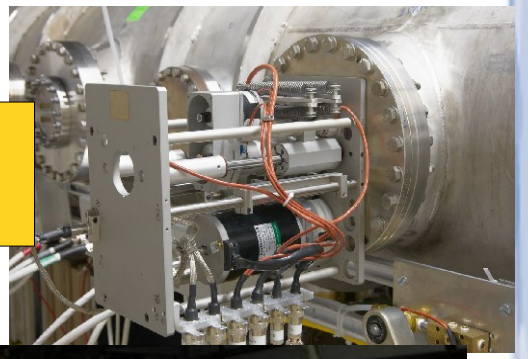
Roman pot

TAL

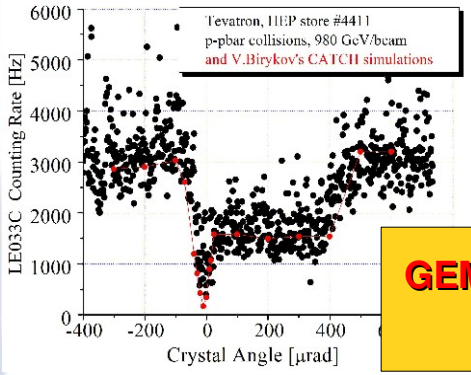
UA9 idea



Single and multi quasi-mosaic and strip **crystals**
@ 6σ from the beam core

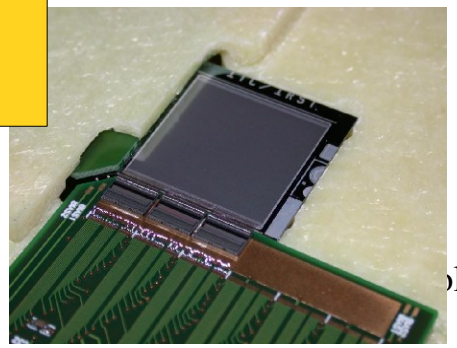


Ad-hoc beam halo:
protons @120 GeV/c



GEMs and **scintillators** to measure the nuclear interactions
of the beam with the crystal in order to align it

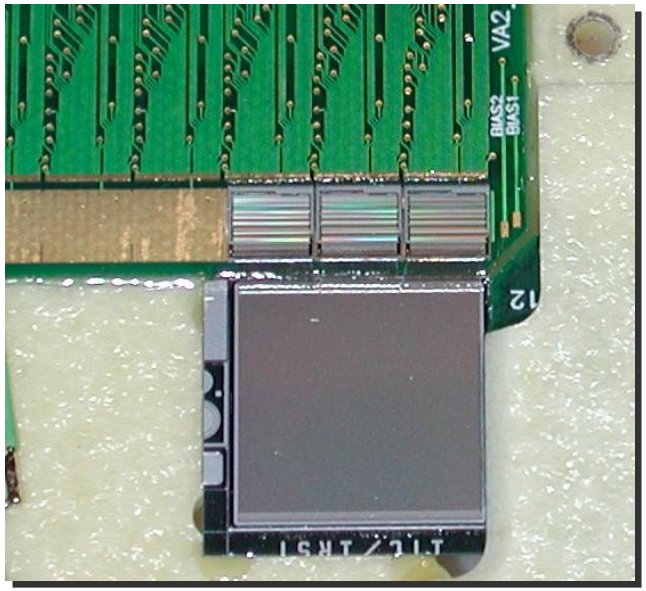
To measure....



The tracking system...

- The UA9 experiment: a new collimation concept
- **The tracking system**
- The commissioning phase: the prototype in the SPS
- Conclusions and outlooks

Golden rules

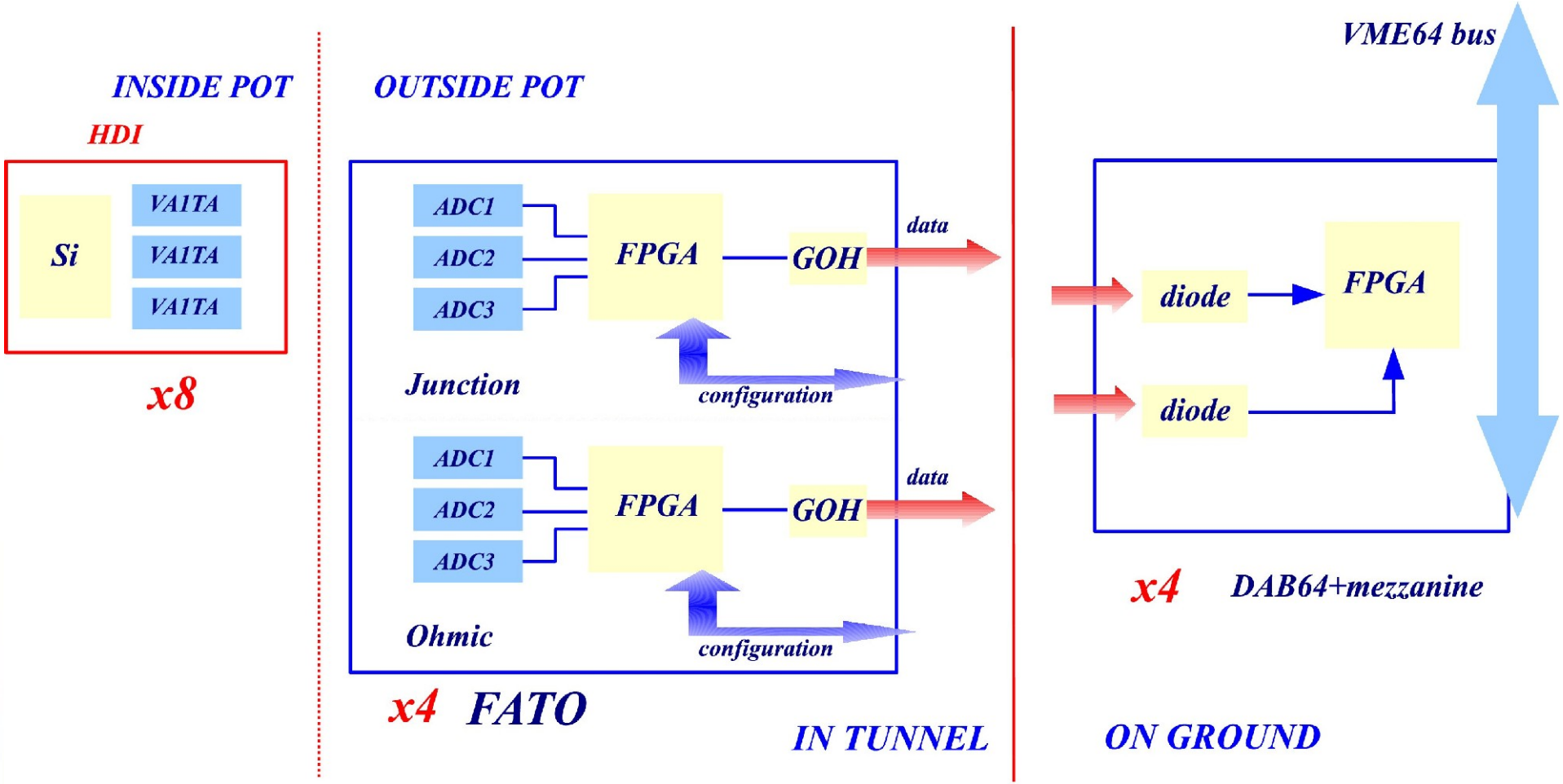


REQUIREMENTS

- Limited **multiple scattering**
- High **spatial resolution**
- **Self triggering**
- **Active region** on the beam
- Every parameter **under control**
- **No PC and power supplies** near the electronics (radiation!!)

- Double side microstrip silicon detectors: **300μm thick**;
- Readout pitch: **50μm** and floating strip system;
- Cut at **500μm** from the border;
- **VA1TA** self-triggering ASIC;
- Digital info sent by **optical links**
- Remote **configuration and monitoring** with long cables (150 m)

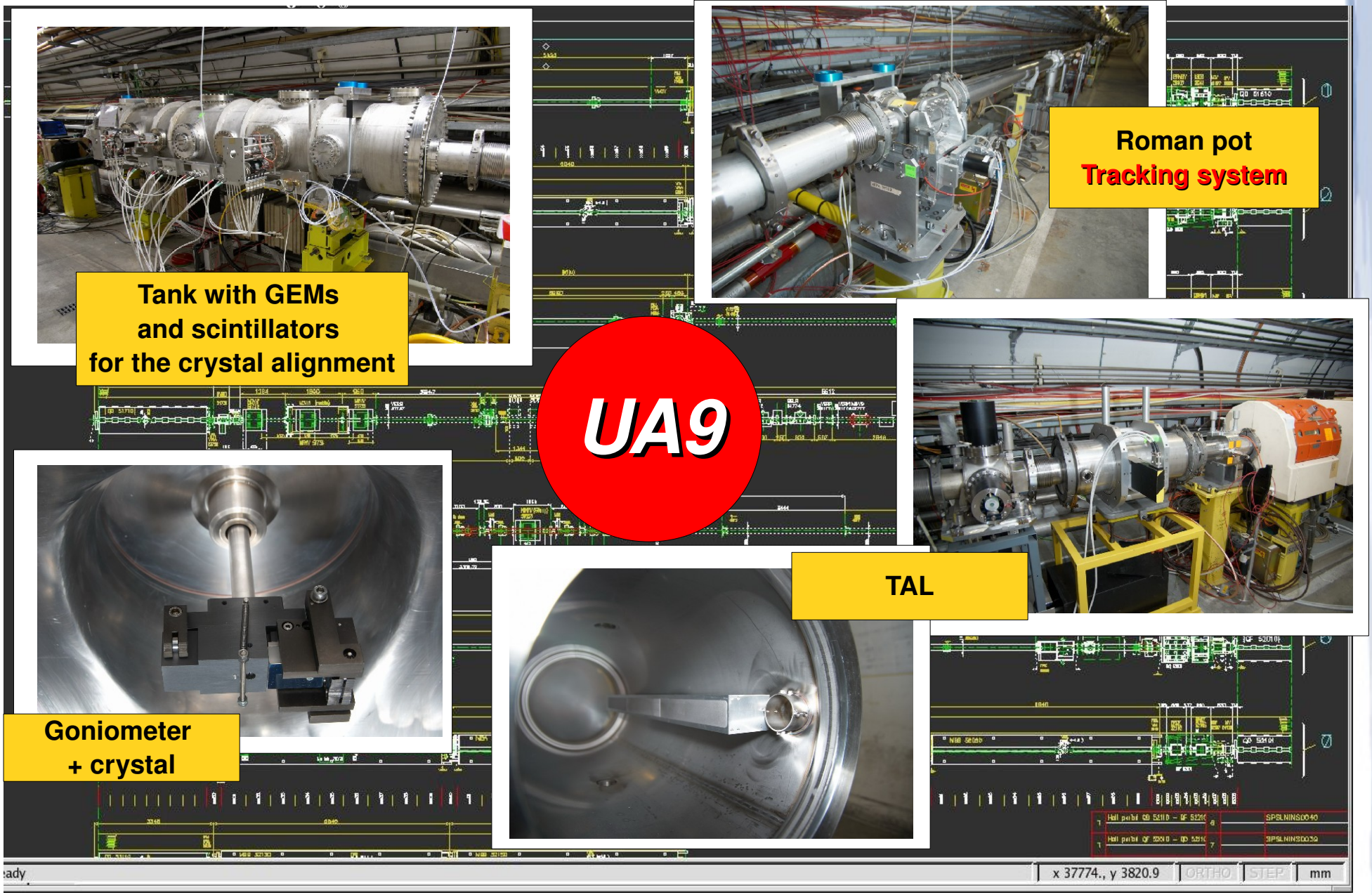
The complete electronics chain



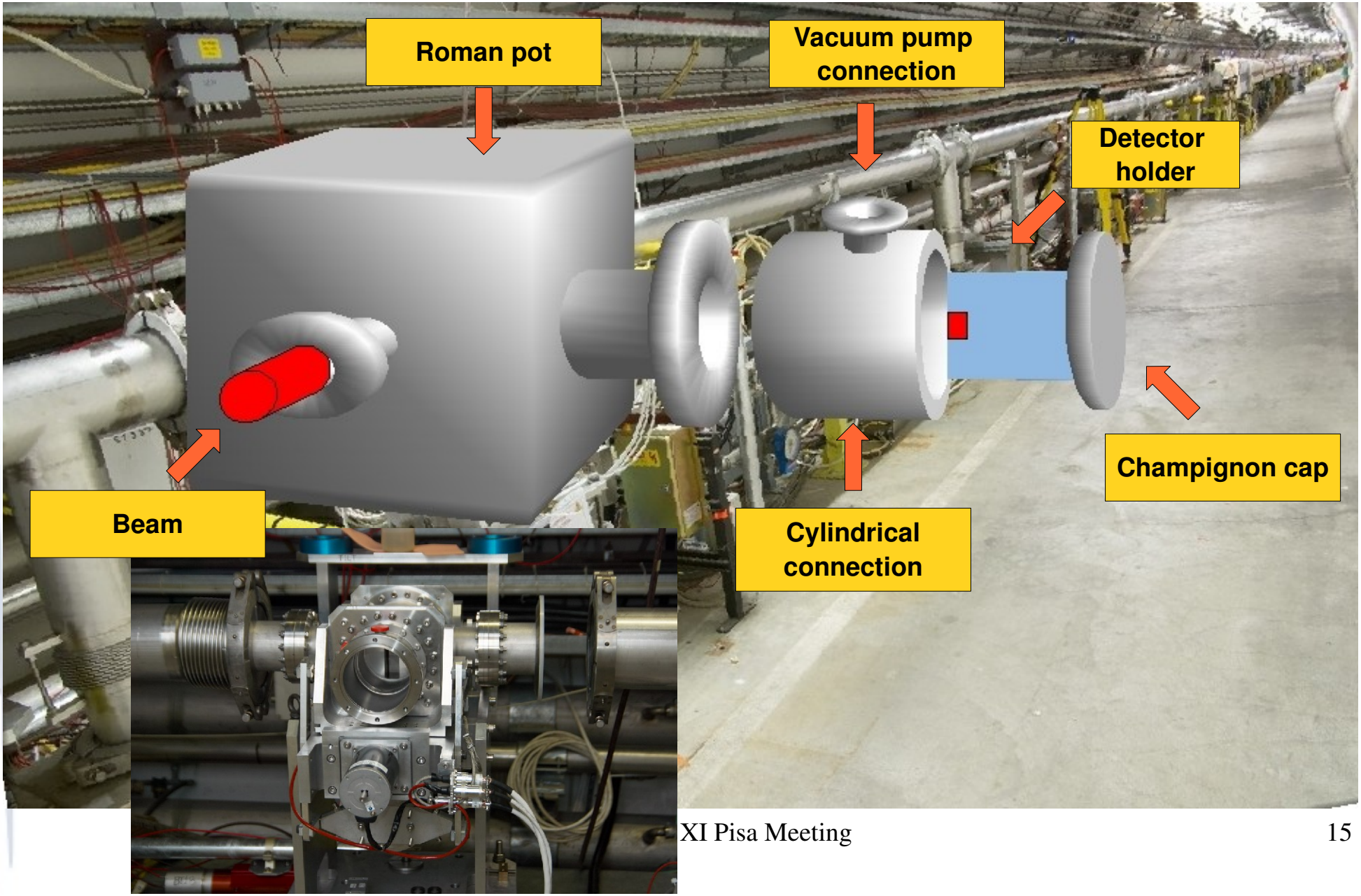
Let's start with a prototype...

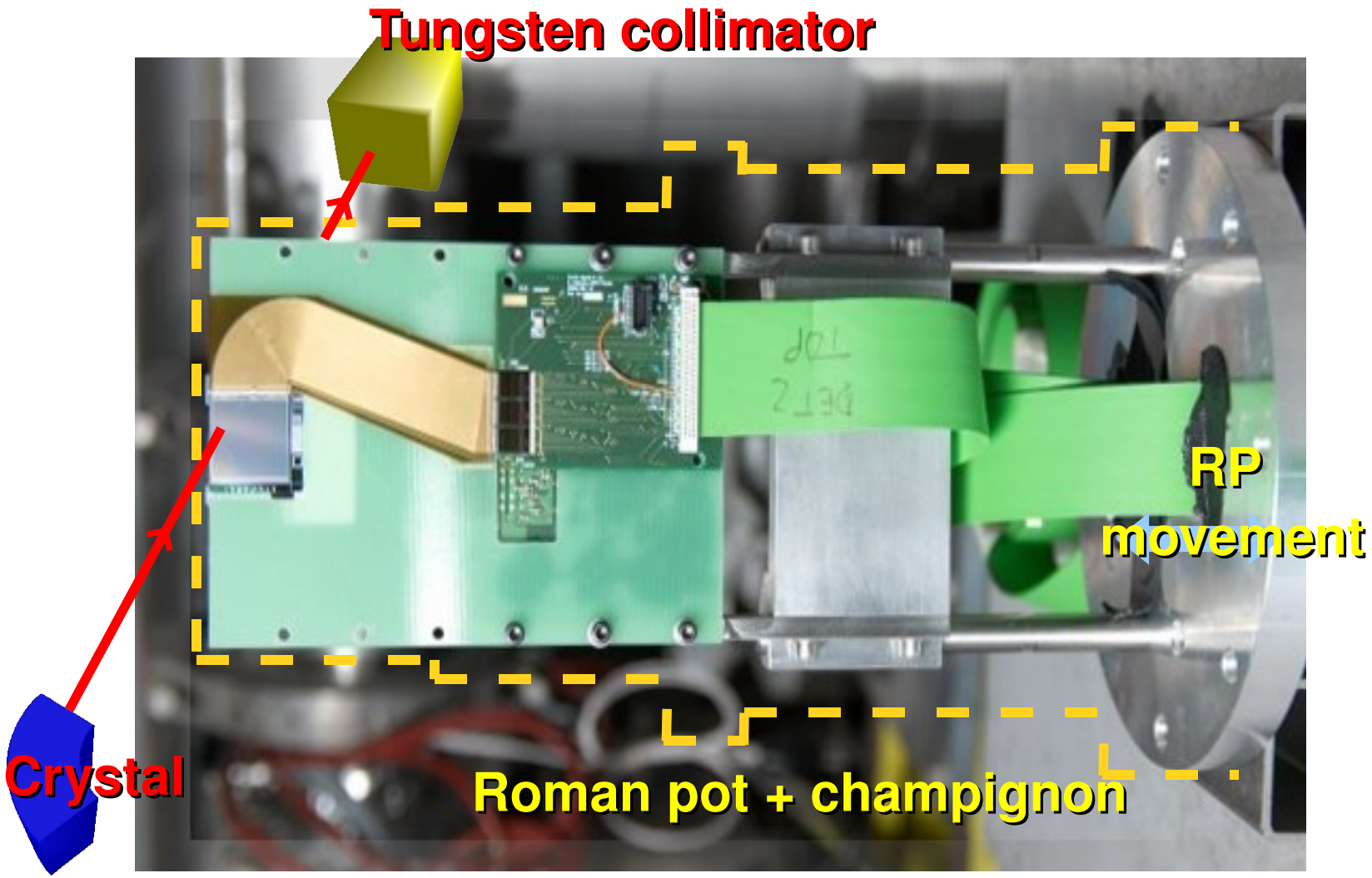
- The UA9 experiment: a new collimation concept
- The tracking system
- **The commissioning phase: the prototype in the SPS**
- Conclusions and outlooks

The installation and commissioning phase in the SPS

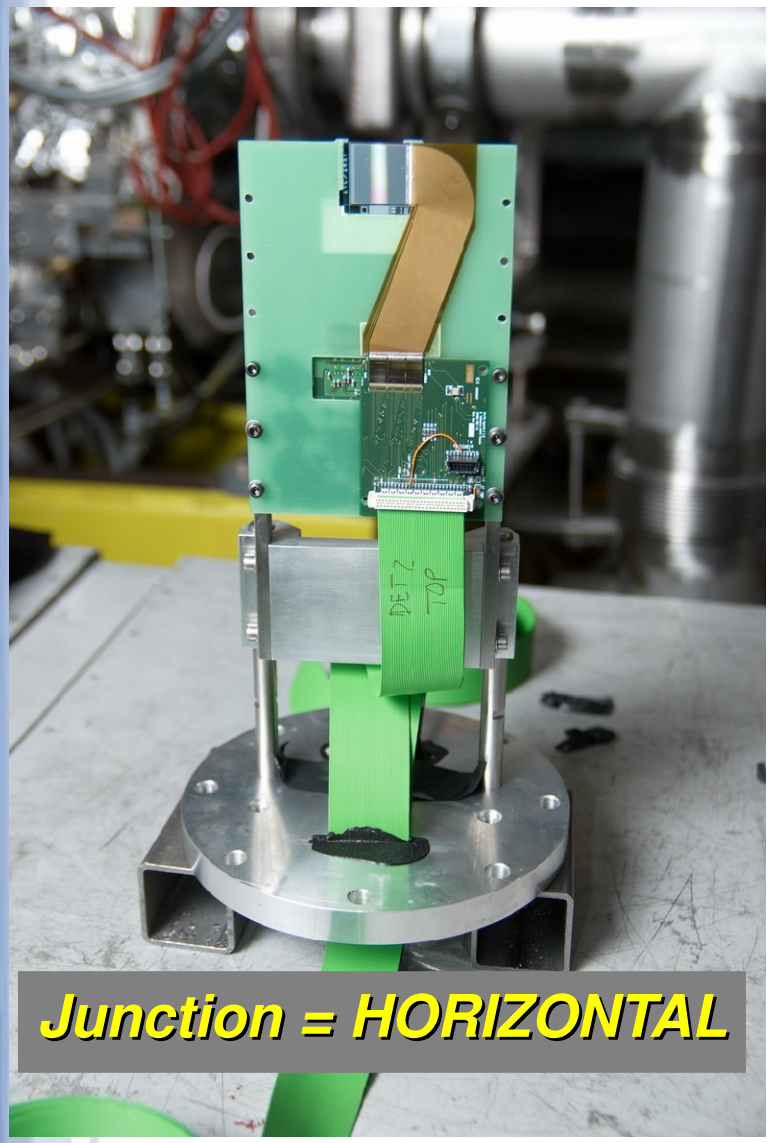


The detector on the beam: mechanics principle

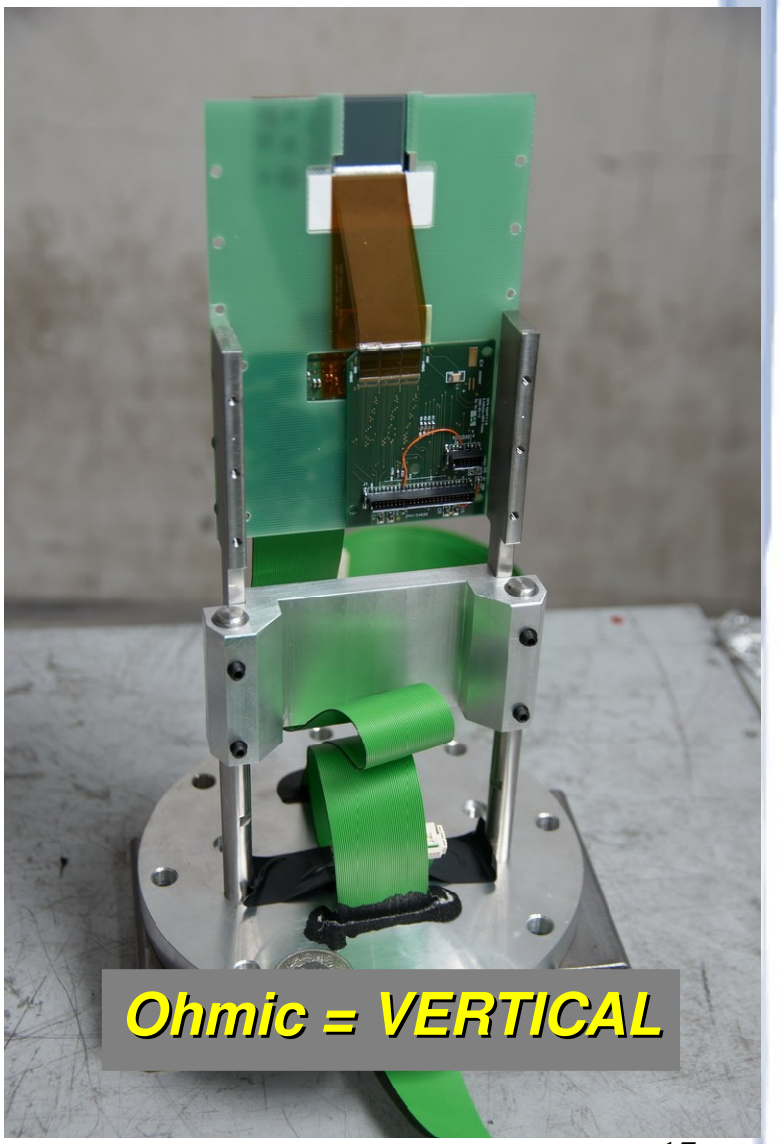



Tungsten collimator
RP
movement
Crystal
Roman pot + champignon

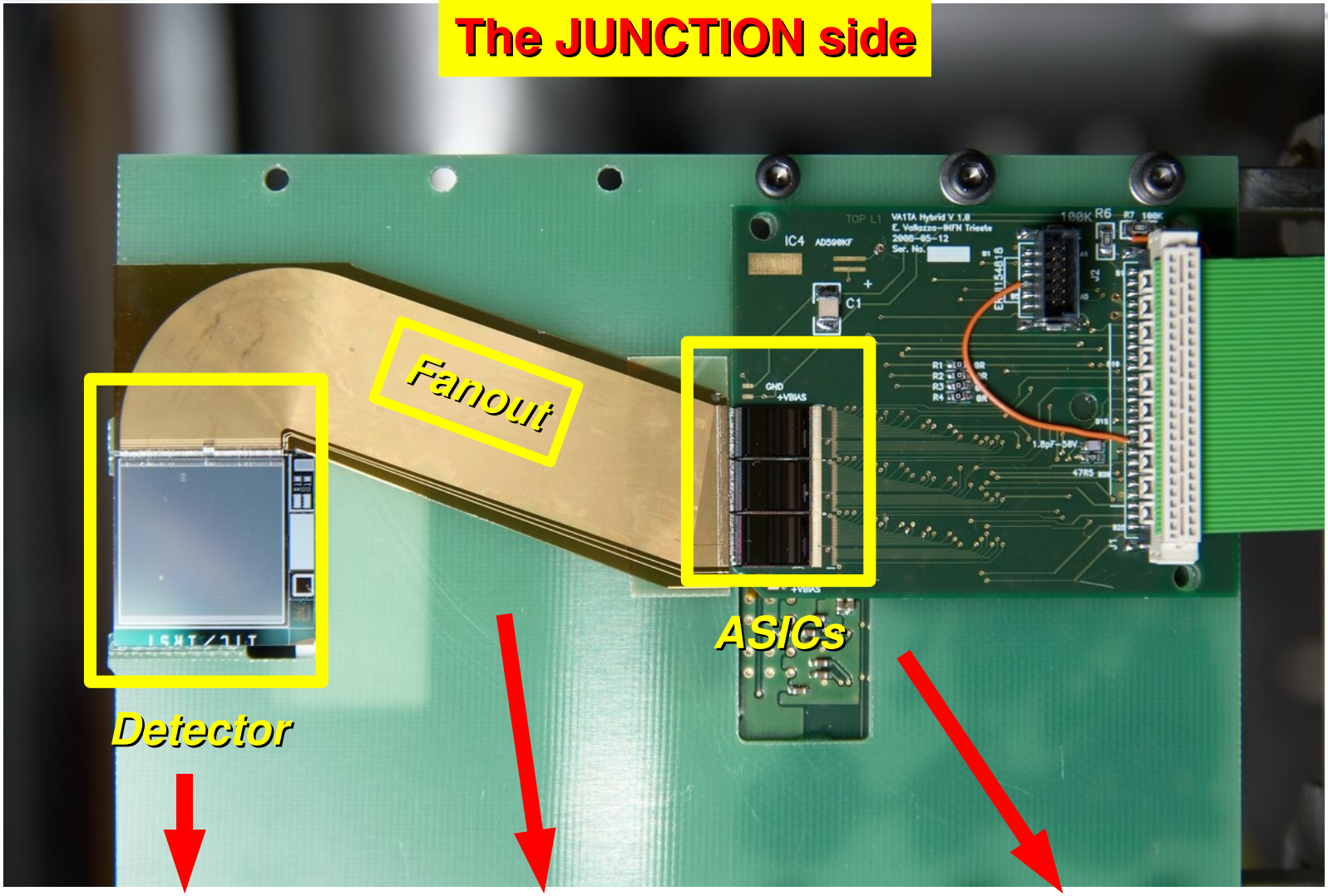
The PROTOTYPE on its holder



- 1.92x1.92cm^2 FBK double side detector
- 6 VA1TA ASICs
- 1 FR4 board for the support
- Upilex fanouts for the connection between the detector and the ASICs
- Temperature, pressure and radiation probes



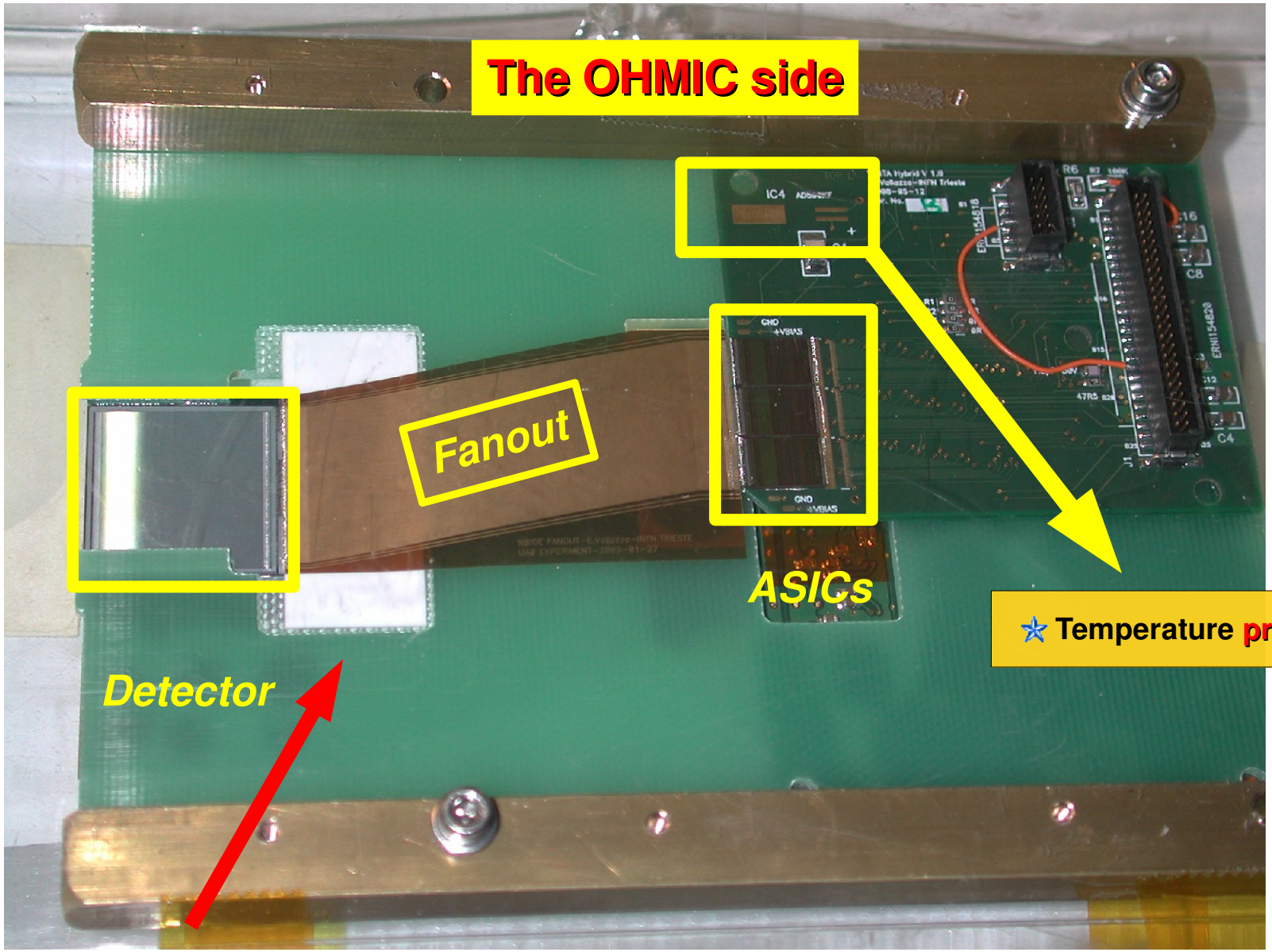
The JUNCTION side



- 1.92x1.92 cm²
- Physical pitch: 25µm; Readout pitch: 50µm = **floating strip system**
- Produced by FBK

- **Upilex fanout**
- Gold tracks, 50µm pitch
- Produced by CERN

- **VA1TA** ASIC with preamplifier, shaper and sample&hold
- Self-triggering (200 ns)
- Produced by Gamma Medica-Ideas



Ceramic support for the upilex bonding

The electronics

Tunnel

ZONE

- Radiative

WHAT

- Detector
- Frontend electronics
- FPGA programmable from the surface

External pit

ZONE

- Not radiative but not accessible

WHAT

- Repeater
- Power supply

Surface

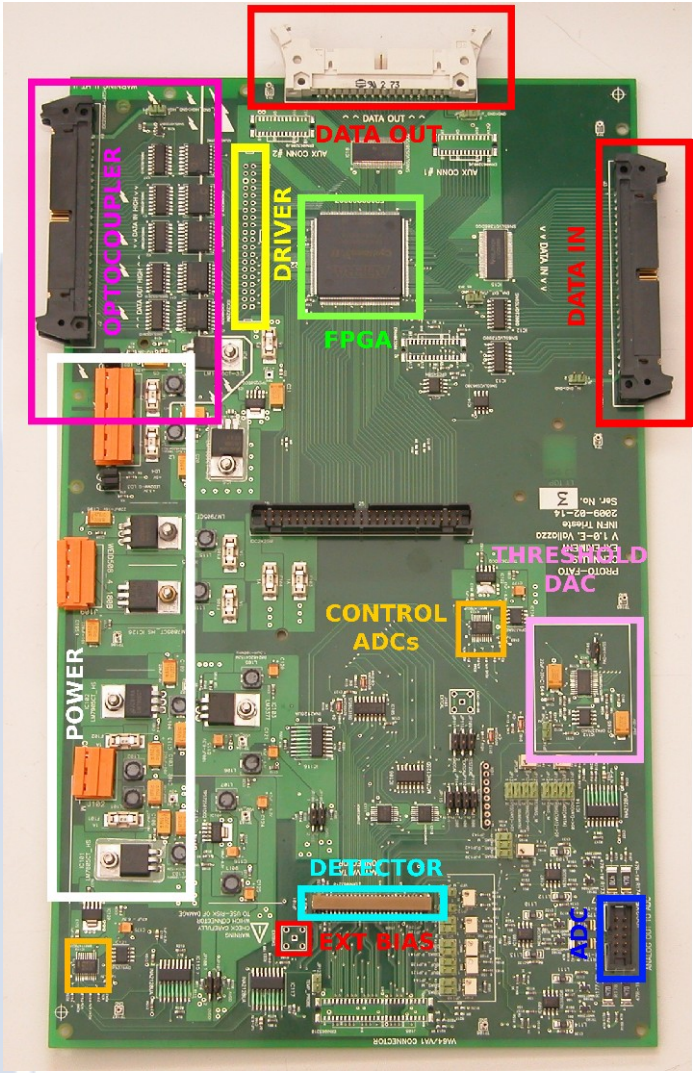
ZONE

- No radiation: accessible

WHAT

- PC
- VME crate with clever board

The prototype electronics



PROTOFATO

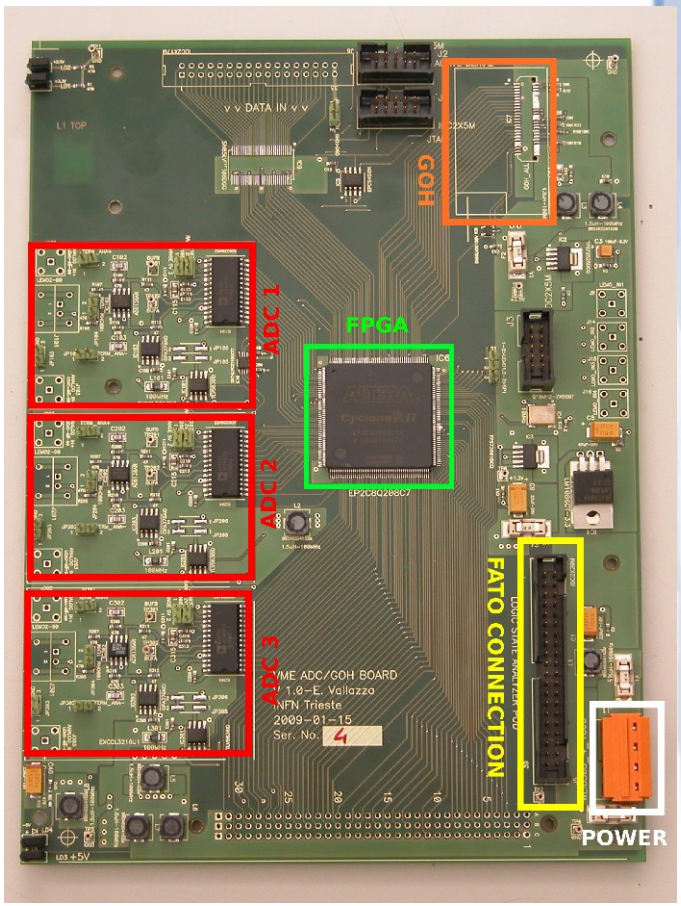
- Configuration
- Interface
- Monitoring
- Readout
- 1 Master (J) and 1 Slave (OHM)

DRIVER

- ADC (1 per ASIC)
- Fiber link (GOH)
- 1 per protofato

Being implemented

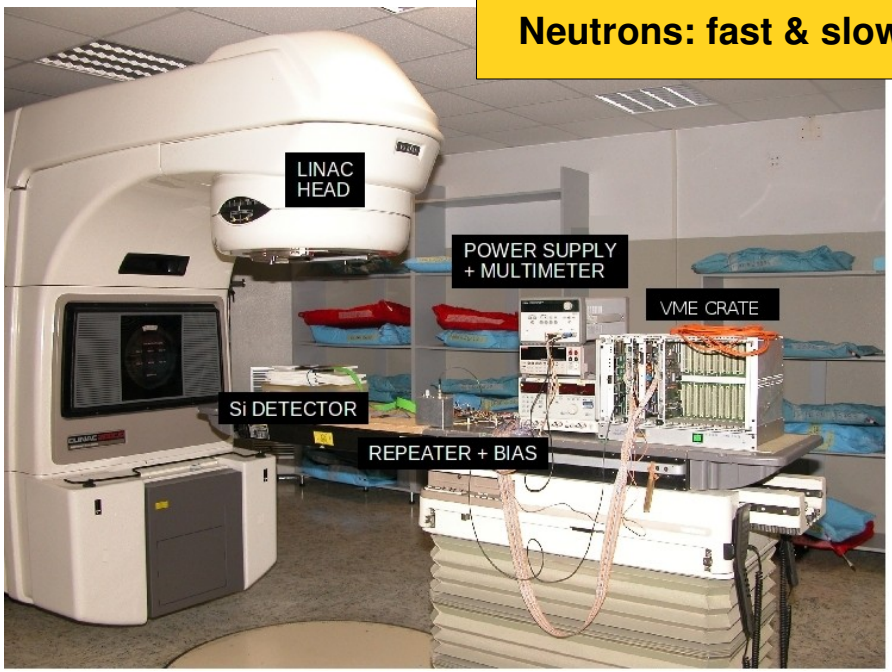
- Fiber link RECEIVER
- Zero suppression

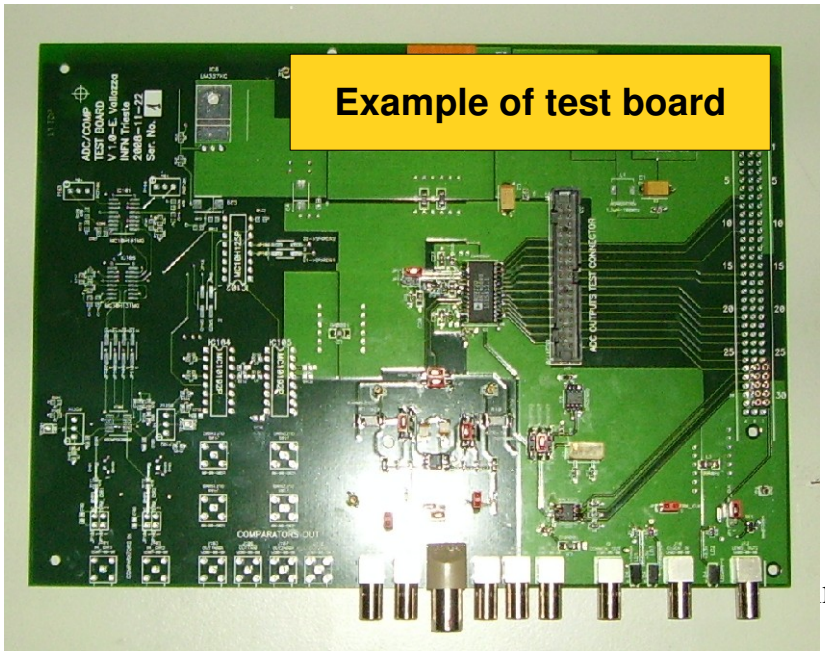


Irradiation tests

- Test performed with a clinical **LINAC** @ S. Anna Hospital in Como
- Each critical component has been tested for **radiation damage** independently with specific boards and specific setup
- Radiation tolerance tests with gamma (up to **1 kGy**, 300 Gy/year are expected); SEU with neutrons

Gamma: 6-18 MeV
Neutrons: fast & slow



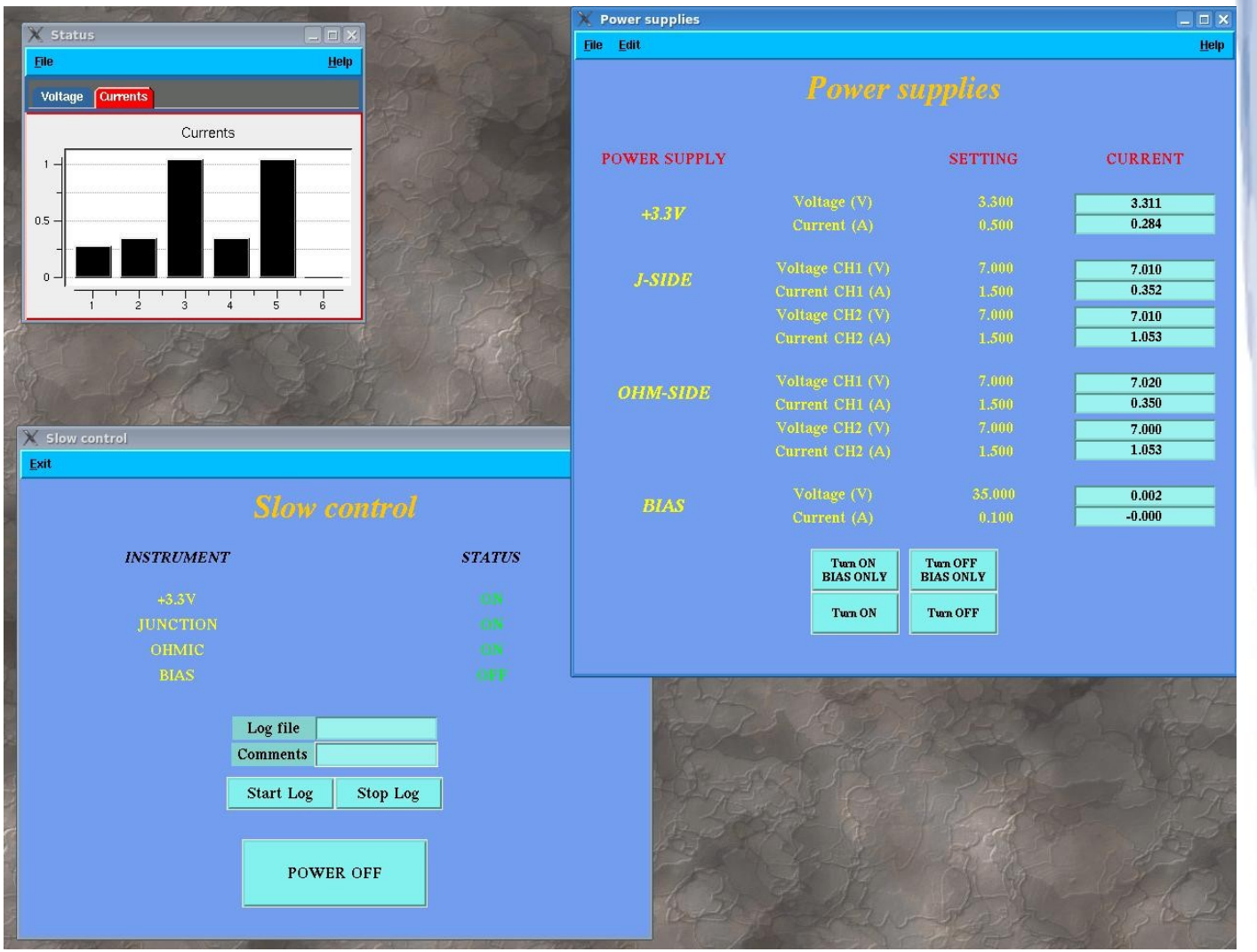


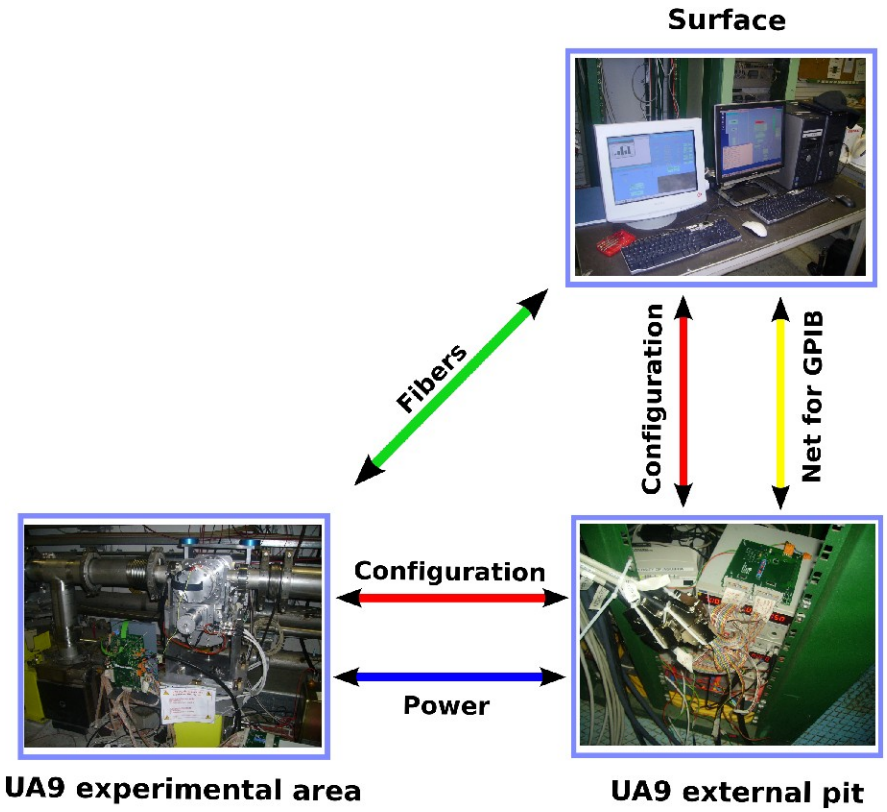
Example of test board

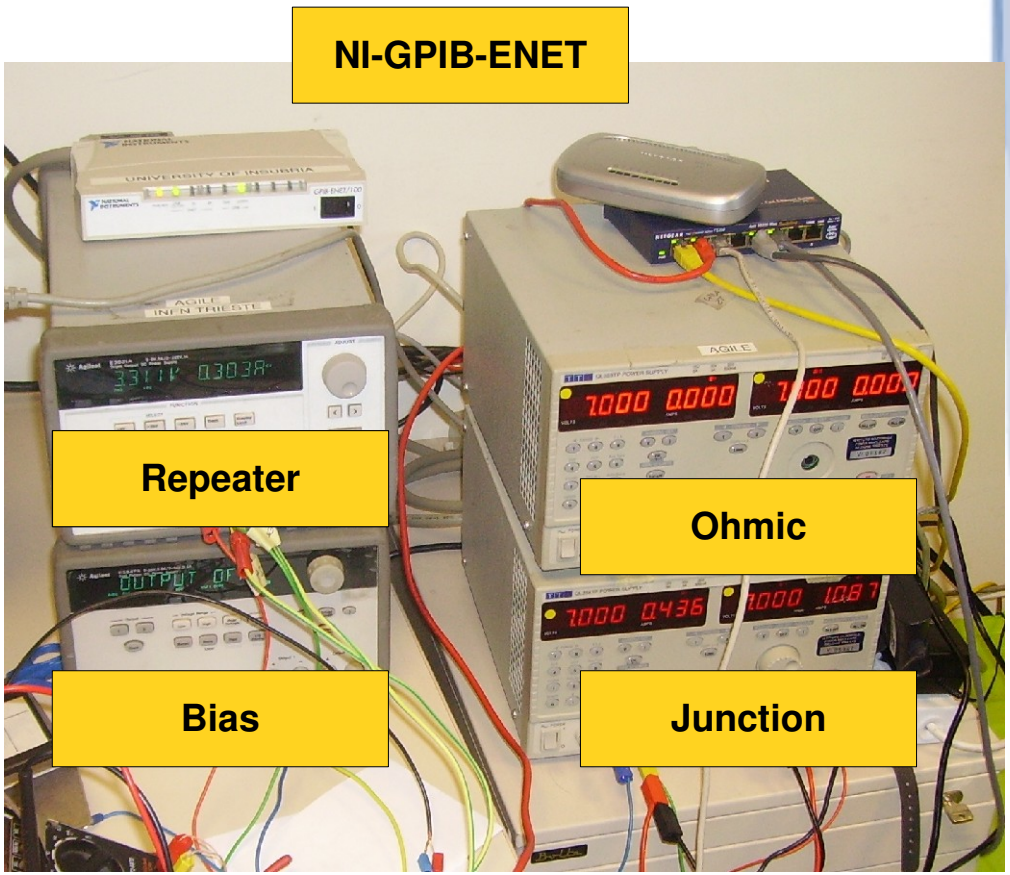
- ASIC, ADC, DRIVER, RECEIVER and REGULATORS with photon and neutrons: ***OK***
- DAC: ***KO (after a 1 year UA9 equivalent run)*** → a new more tolerant DAC has been chosen

The Slow Control system

- A slow controls system is implemented to **control and protect** the system during the operation.
- This system is able to control and log the power supplies, the ASICs currents and the temperature in the pot
- In case of problems, the system **shutdowns automatically**.
- The slow controls program is written in C and Tcl/Tk for the user interface



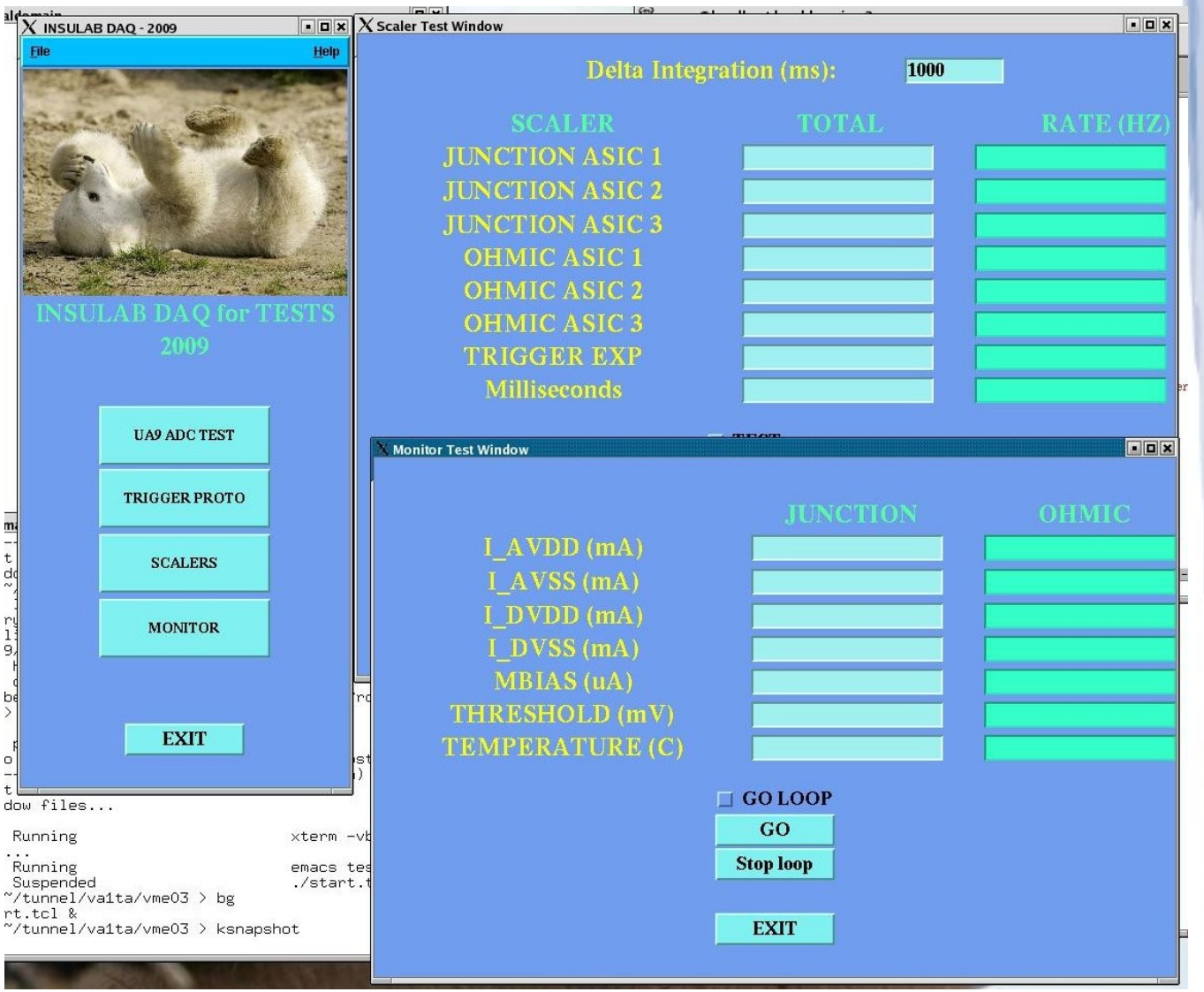




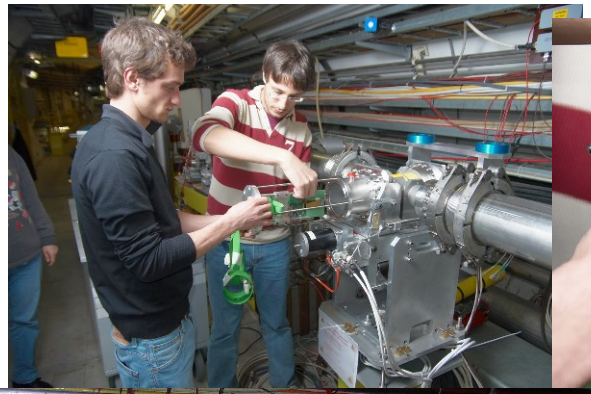
- Power supply for the intermediate station repeaters, ohmic and junction sides, silicon bias
- **Remotely controlled** by a GPIB - Ethernet

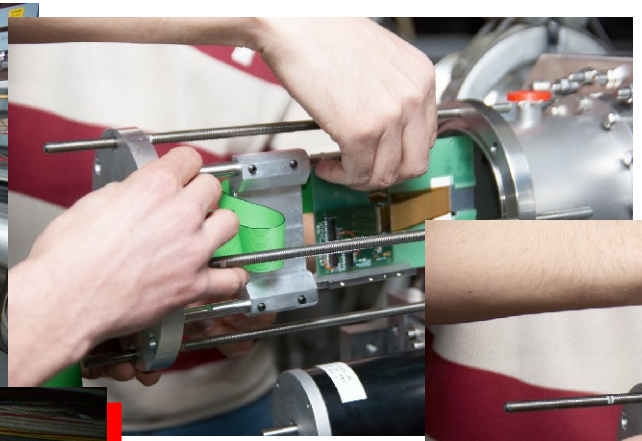
DAQ

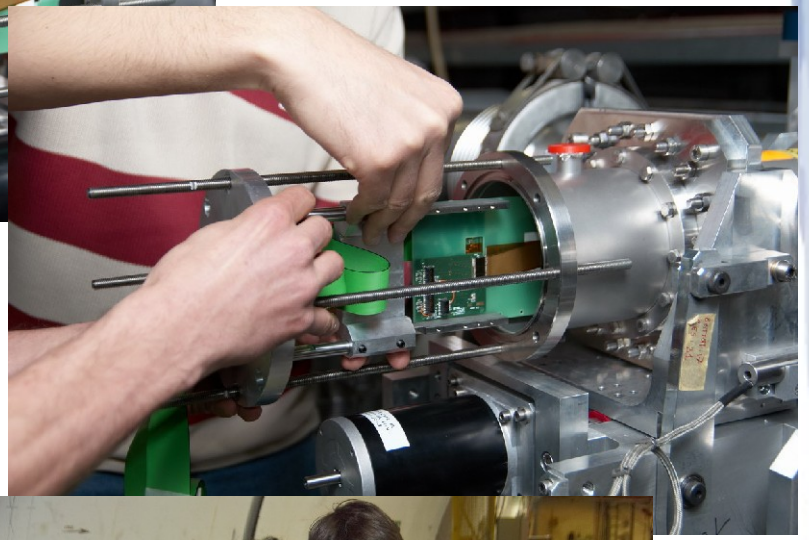
- **Remotely controlled**
- **Trigger mask and threshold selection allowed**
- **Monitor of ASIC currents, trigger threshold, bias, temperature, trigger scalers**
- **Written in C and Tcl/Tk**

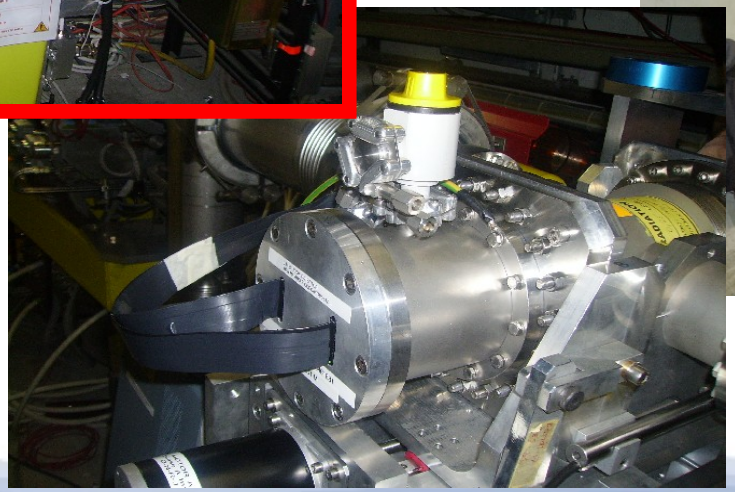


A critical step...

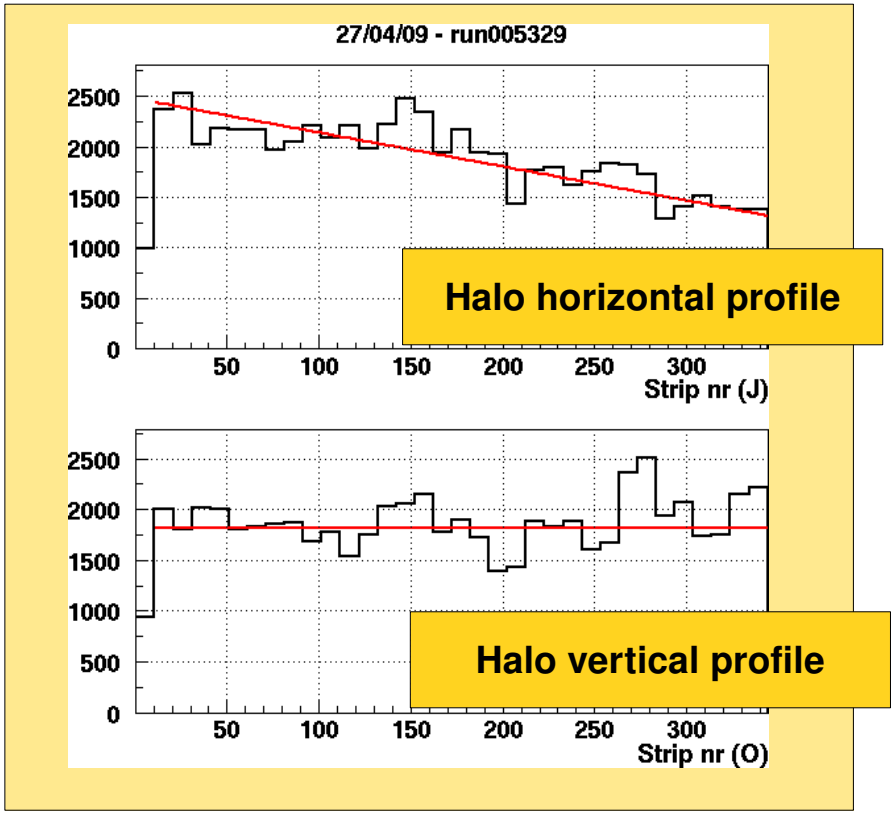






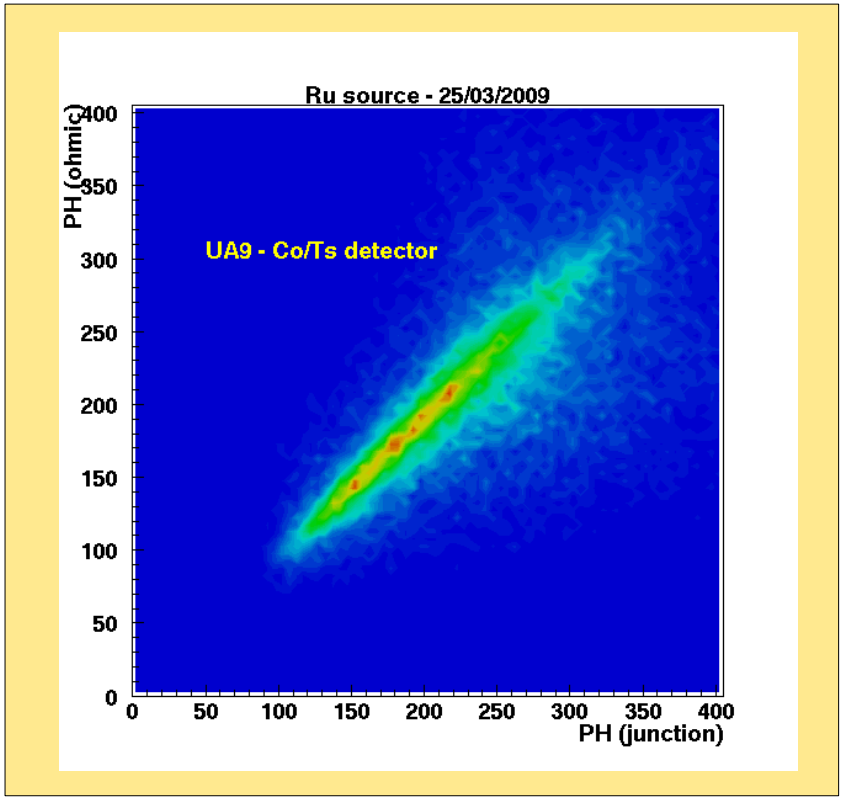


Results (1): beam profile and pulse height during SPS commissioning



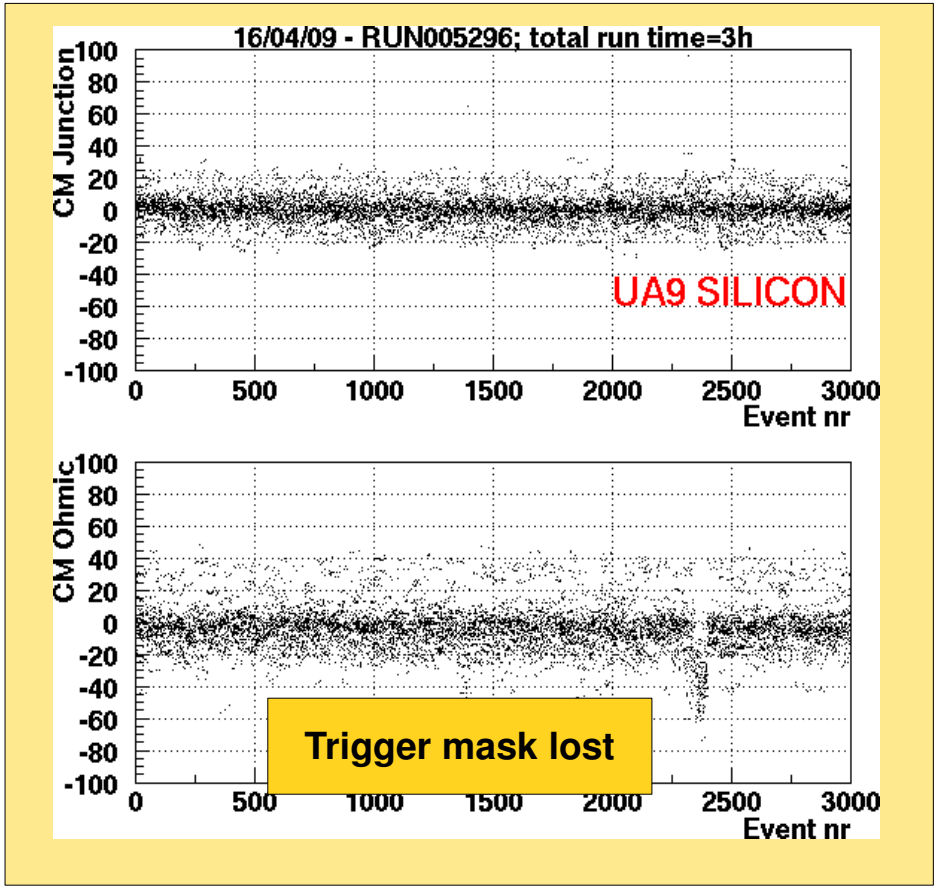
Beam profile

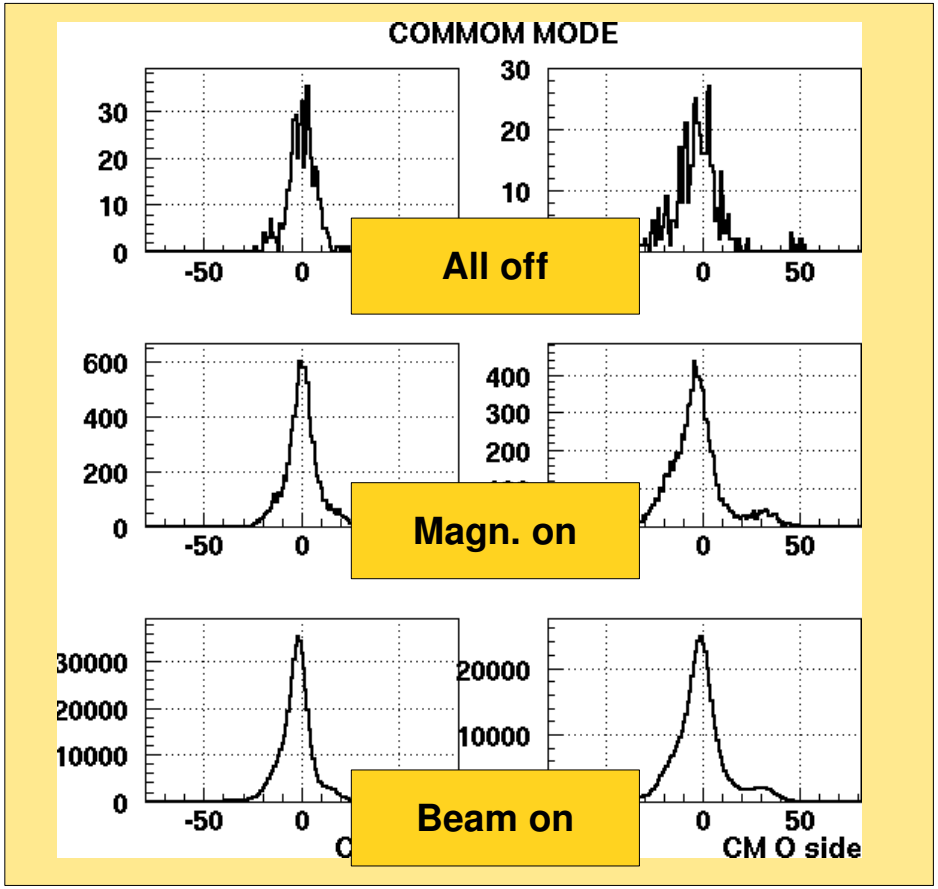
PH correlation J-Ω



April / May 2009

Results (2): system stability



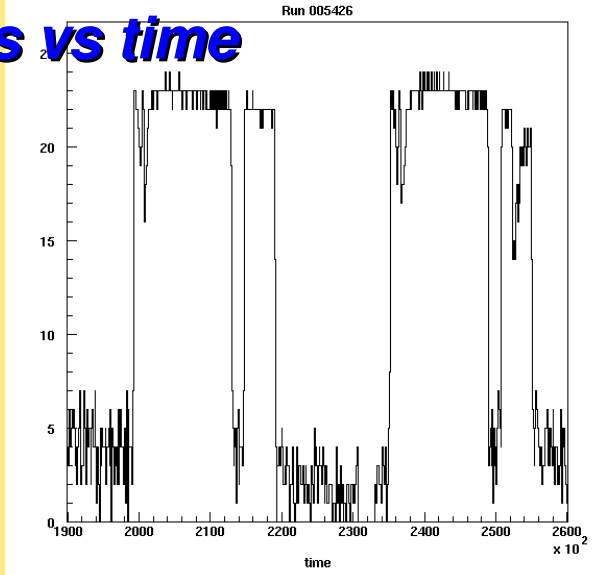


Common mode vs time

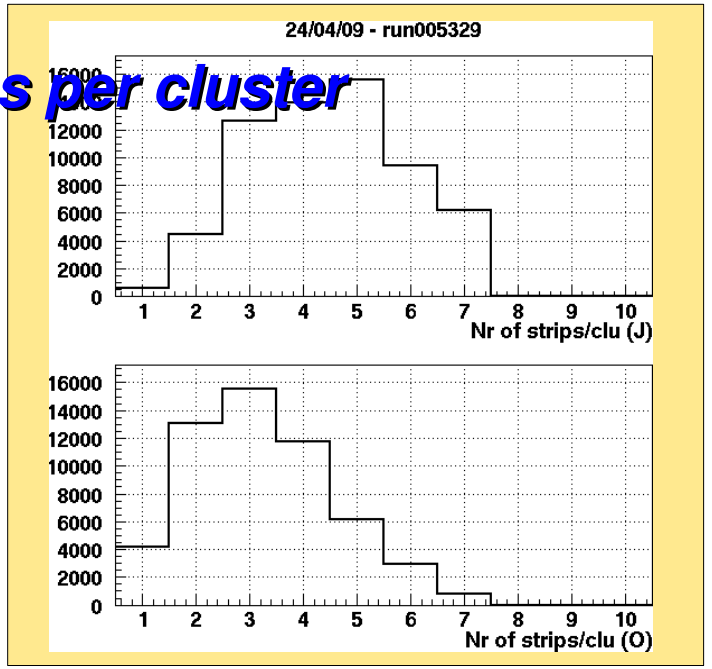
Common mode vs environment

Results (3): performance with beam

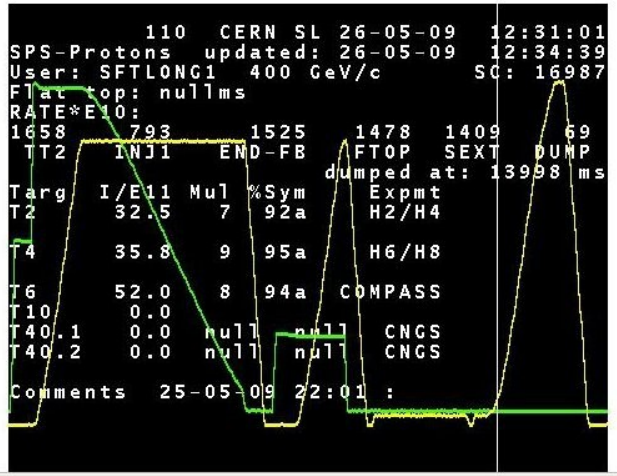
Triggers vs time



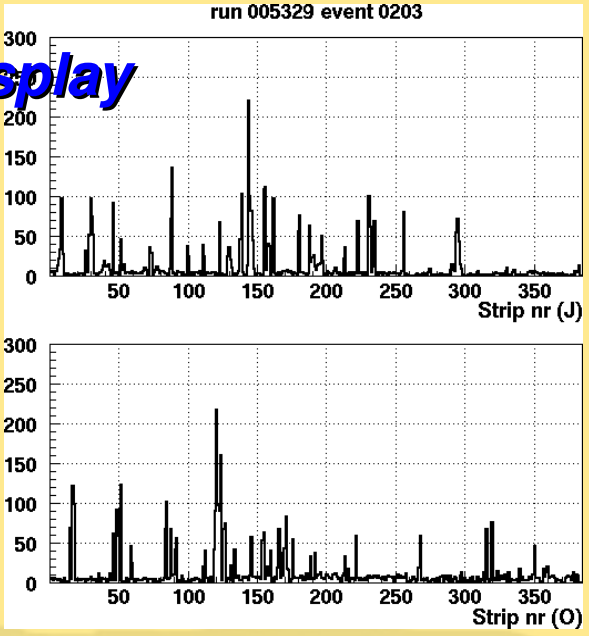
strips per cluster



SPS signal



Event display



- The UA9 experiment: a new collimation concept
- The tracking system
- The commissioning phase: the prototype in the SPS
- **Conclusions and outlooks**

Conclusions

- The UA9 experiment is being developed in order to test **an innovative collimation system based on bent crystals** developed with different technologies;

- **A single strip and a single quasi-mosaic** have been installed on 2 goniometers. The **alignment procedure** is based on the nuclear interaction rate measured by **GEMs and scintillators**; a high precision tracking system will provide a measurement of the crystal effects;

Conclusions

- **A double side microstrip silicon detector system has been developed to track the 120 GeV/c proton halo beam with a high precision. A prototype has been installed in the SPS and has been successfully tested;**

- **The tracking system will exploit a fiber optic link for the data transmission to send the ~50kHz of data to the ground.**

- **In 2009 the beam will be tuned in order to obtain a controlled beam halo for the test; a second detector will be installed in a second roman pot in summer 2009 to complete the tracking system. At the end of 2009 the preliminary results are expected.**

Istituto Nazionale di Fisica Nucleare

The high performance microstrip silicon detector tracking system for an innovative crystal based collimation experiment

http://insulab.dfm.uninsubria.it