Radioactive beam production via in-flight fragmentation of stable ions at high energy

- Challenge: bad quality of radioactive beam,

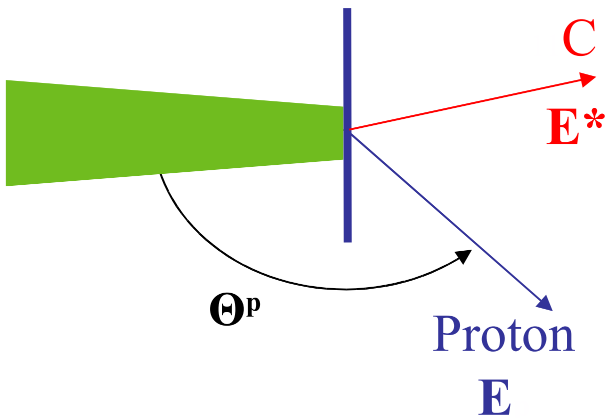
large spacial, angular and energy dispersions, mixture of different ion species

- Position and time of each projectile hit are needed

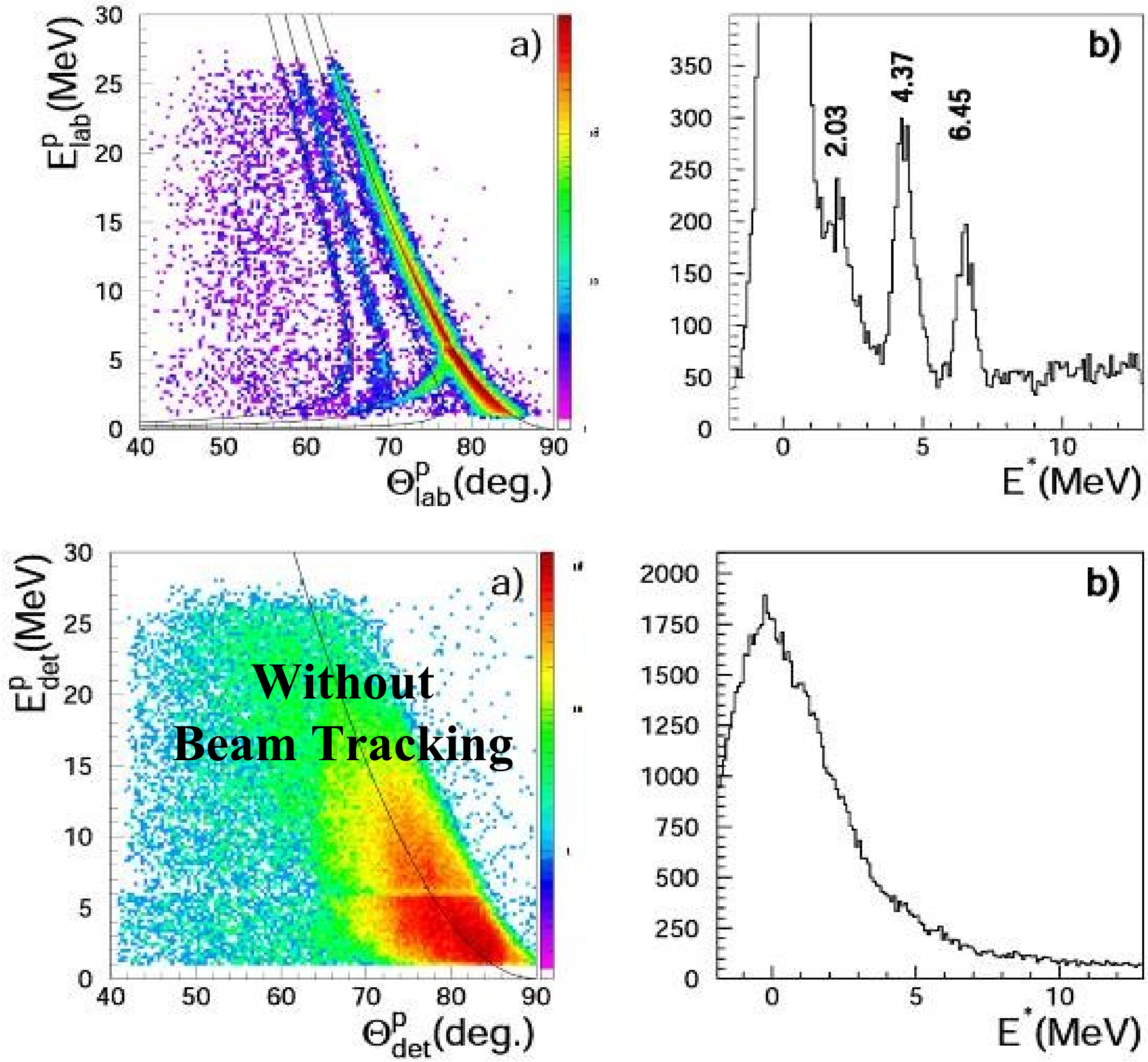
- Missing information can be obtained by tracking projectile ions one-by-one

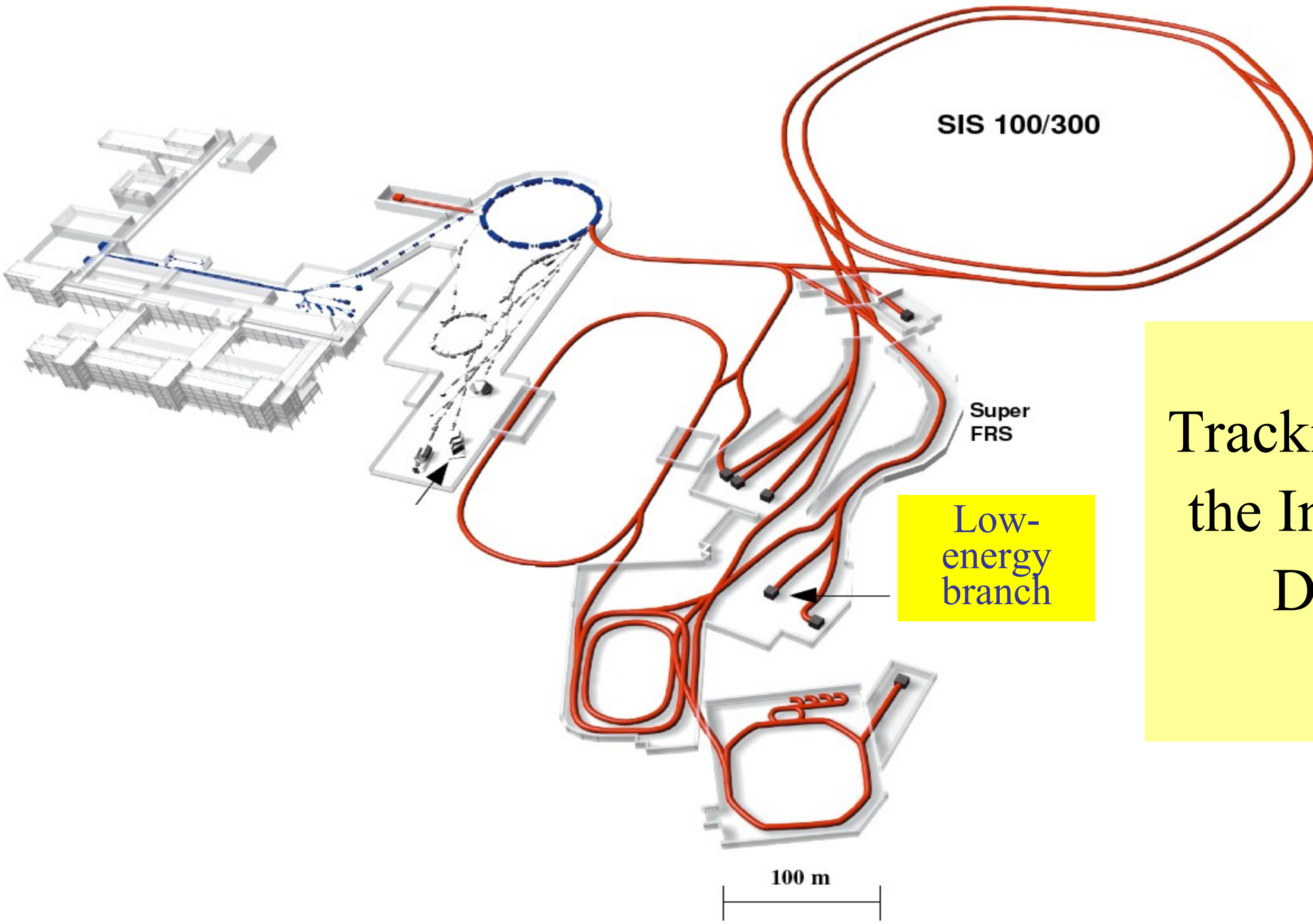
Why tracking is needed ? Physics data reconstruction

$p(^{11}C, p')$ E=40 MeV/u



C. Jouanne et al,
Phys.Rev. C72, 014308 (2005)



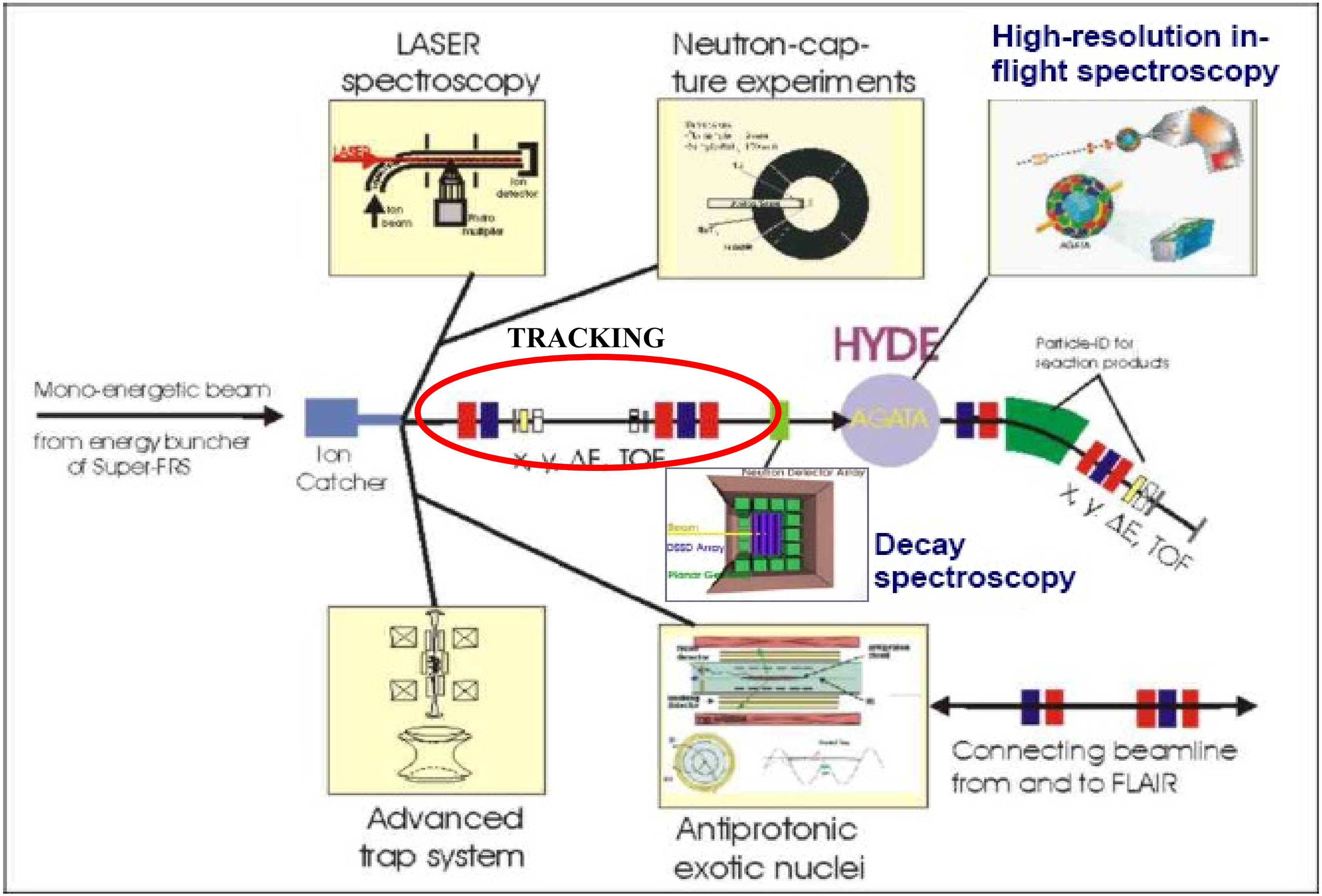


Tracking detectors to be used in the International FAIR project Darmstadt, Germany

Institutions involved into tracking

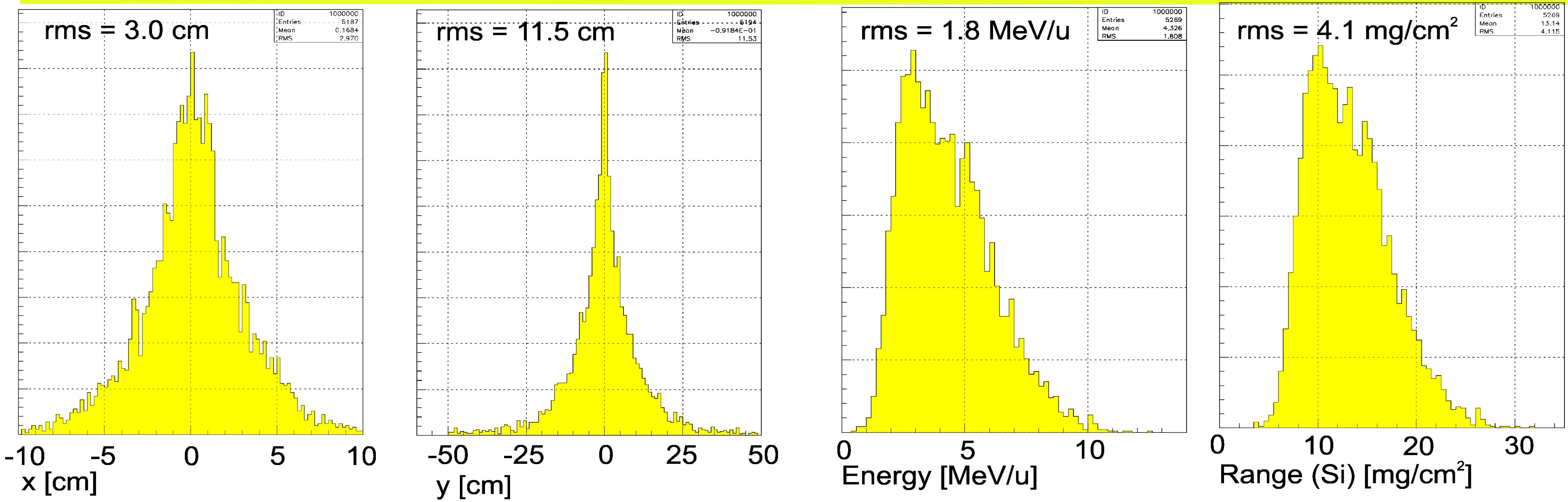
1) GSI Darmstadt	**Germany**	**Diamond detectors**
2) Universität Köln	**Germany**	**SeD**
3) IFIN-HH Bucharest	**Romania**	**simulations**
4) University of Huelva	**Spain**	**DSSD**
5) University of Sevilla	**Spain**	**SeD, simulations**
6) University of Dehli	**India**	**Stintillator detectors**

Beam tracking for HISPEC/DESPEC experiments planned at FAIR



Expected radioactive beam profiles

Simulations for ^{232}Fr (540 MeV/u → 4 MeV/u)



initial values

Energy [MeV/u]	540 → 4
Deg. [mg/cm^2]	5195
ε_x [mm mrad]	82
ε_y [mm mrad]	38
2 σ_p / p [%]	1.21

optical transmission : ~ 52%

total transmission : ~ 31%

For beam tracking detectors at HISPEC/DESPEC, we are investigating:

- ► a large area tracking detectors;
- ► good position, energy and time resolutions;
- ► the corresponding integrated fast electronics (FPA and ADC).
- ► with the possibility of working with high counting rate;
- ► the corresponding radiation hardness, and
- ► low level noise.

The ideal detector for tracking:

- Large area of 20 x 50 cm^2
- Counting rate ~ 10^8 particles/sec with corresponding radiation hardness
- NO noise degradation
- Time resolution (with beam) < 100ps
- Energy Resolution $\Delta E/E$ ~ 1%
- Position Resolution ~ 1mm

Beam tracking Detectors for the Low-Energy Branch of NUSTAR

Ivan Mukha

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN
CSIC
VNIVERSITAT DE VALÈNCIA

Intermediate-energy beams <200 MeV/u

- **Thin diamond CVD detectors.**
- **Fast DSSD and ultra-fast organic-scintillator detectors.**

Low-energy beams 5-10 MeV/u

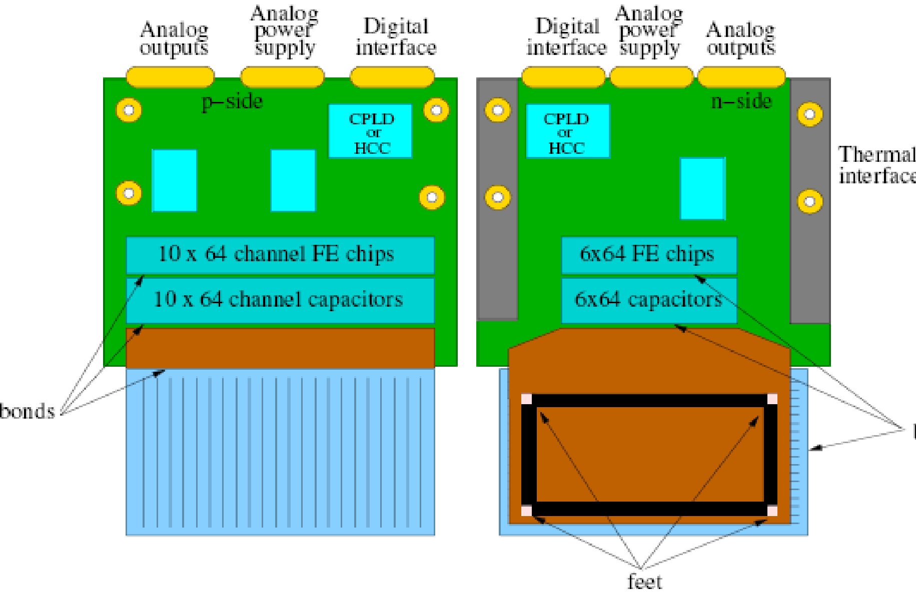
- **Position-sensitive MCP detectors with large area**
- **Low-pressure gas-amplification detectors with dedicated ASIC electronics, (Se-D based on MWPC or "low-pressure MICROMEGAS" devices**
- **Diamonds detectors tested as secondary-electron detectors.**

  The fast front-end electronics to be developed

Physics principle of semiconductor detectors for particle registration.

Most silicon particle detectors work by doping narrow strips of silicon to make them into diodes, which are then reverse biased. As charged particles pass through these strips, they cause small ionization currents which can be detected and measured.

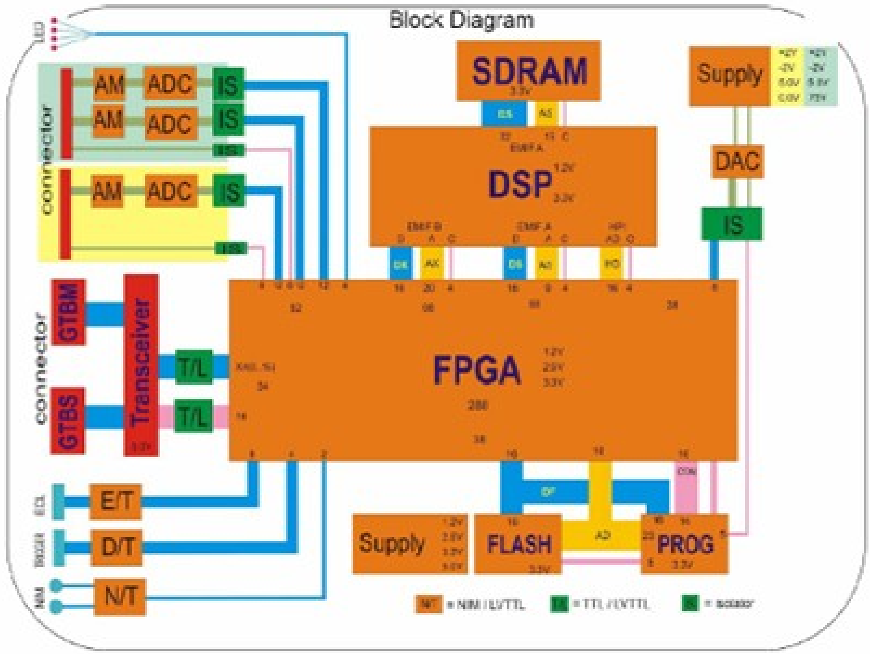
Example 1. Fine spacial tracking with microstrip detectors

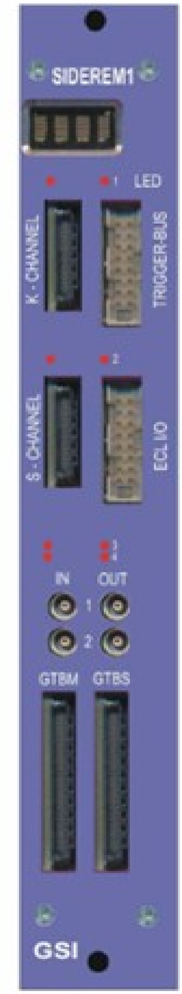


Dimensions 70x40 mm^2,
100m strip pitch,
in total 1000 channels
http://dpnc.unige.ch/ams/GSItracker/www/

- FEE based on ASIC VA64_hdr9 (IDEAS) with high dynamic range, 100 keV - 14 MeV
- Low noise to separate protons (dE of a proton in 300µm Si at 500AMeV: ~166keV)
- Energy resolution – ~50 keV
- Sensors produced by CSEM/COLYBRIS
- 1024 readout channels/detector
- Small pitch to provide good angular resolution
- Designed to work in vacuum (W< 3 W/detector)
- Remote bias setting/control
- Remote temperature control

GSI readout board SIDEREM



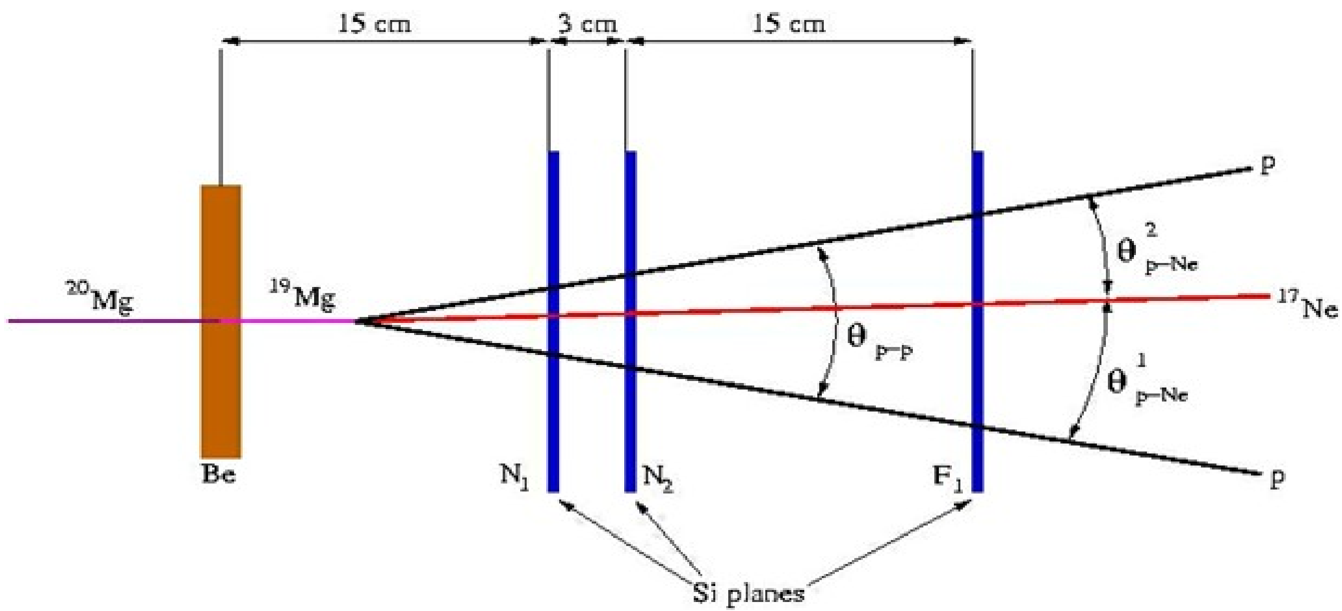


- 3 fast 12 bit ADCs, pedestal suppression, processing by DSP
- Conversion + processing time ~ 100 μs ⇒ maximum rate 10^4 events/s
- Interface to GSI DAQ via GTB (VME system)

* Serial read-out, digitalization,
* pedestal and common-noise subtraction.

J. Hoffmann,
N. Kurz,
W. Ott

Tracking scheme in the GSI experiment S271, "Two-proton decay of ^{19}Mg"

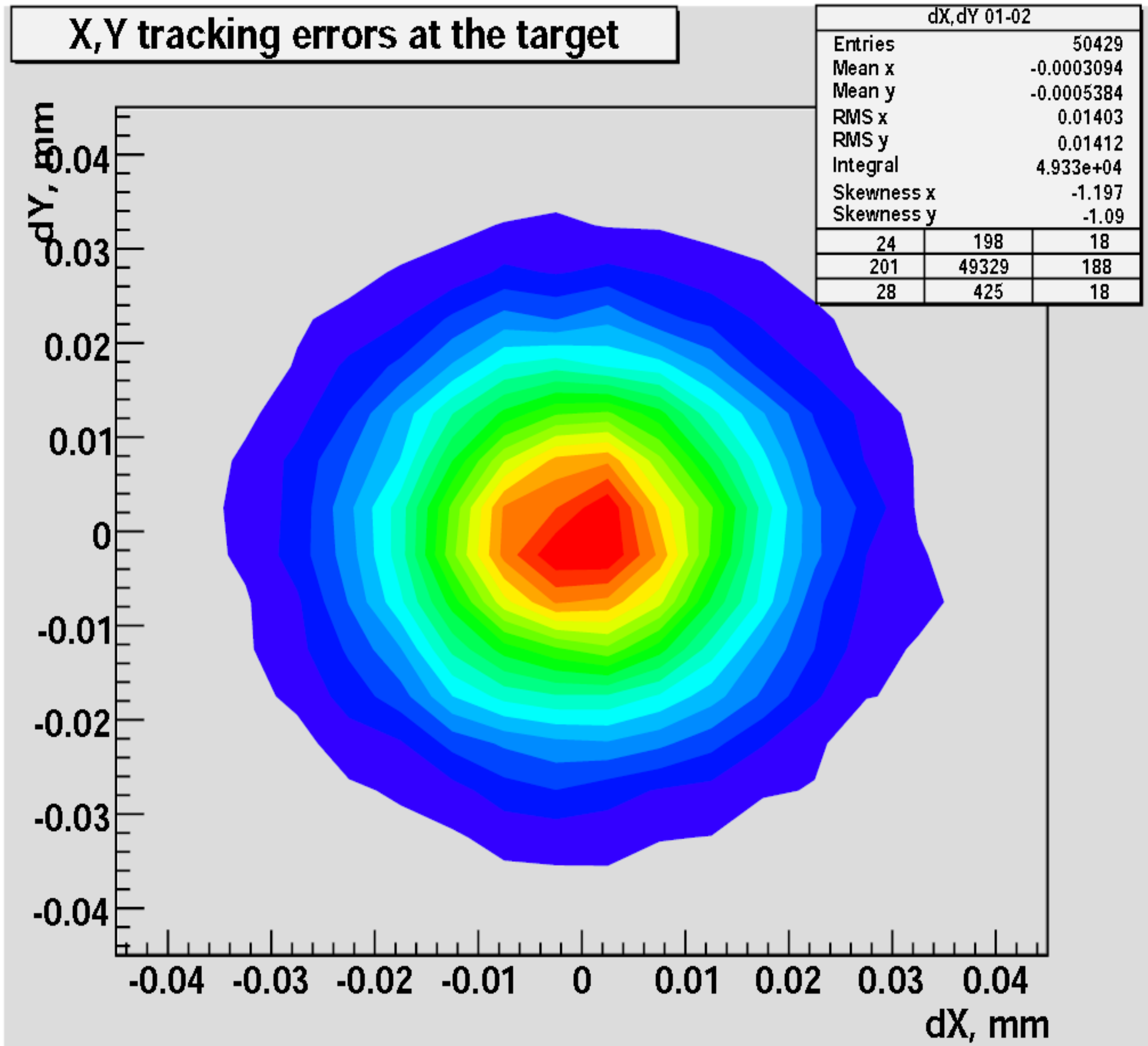


Fragmentation ^{20}Mg->^{18}Ne+p+p

Reaction ^{20}Mg->^{19}Mg->^{17}Ne+p+p

X,Y uncertainties of tracking

for heavy-ions ~14 μm, for protons ~30 μm



Beam tracking detectors for radioactive ions

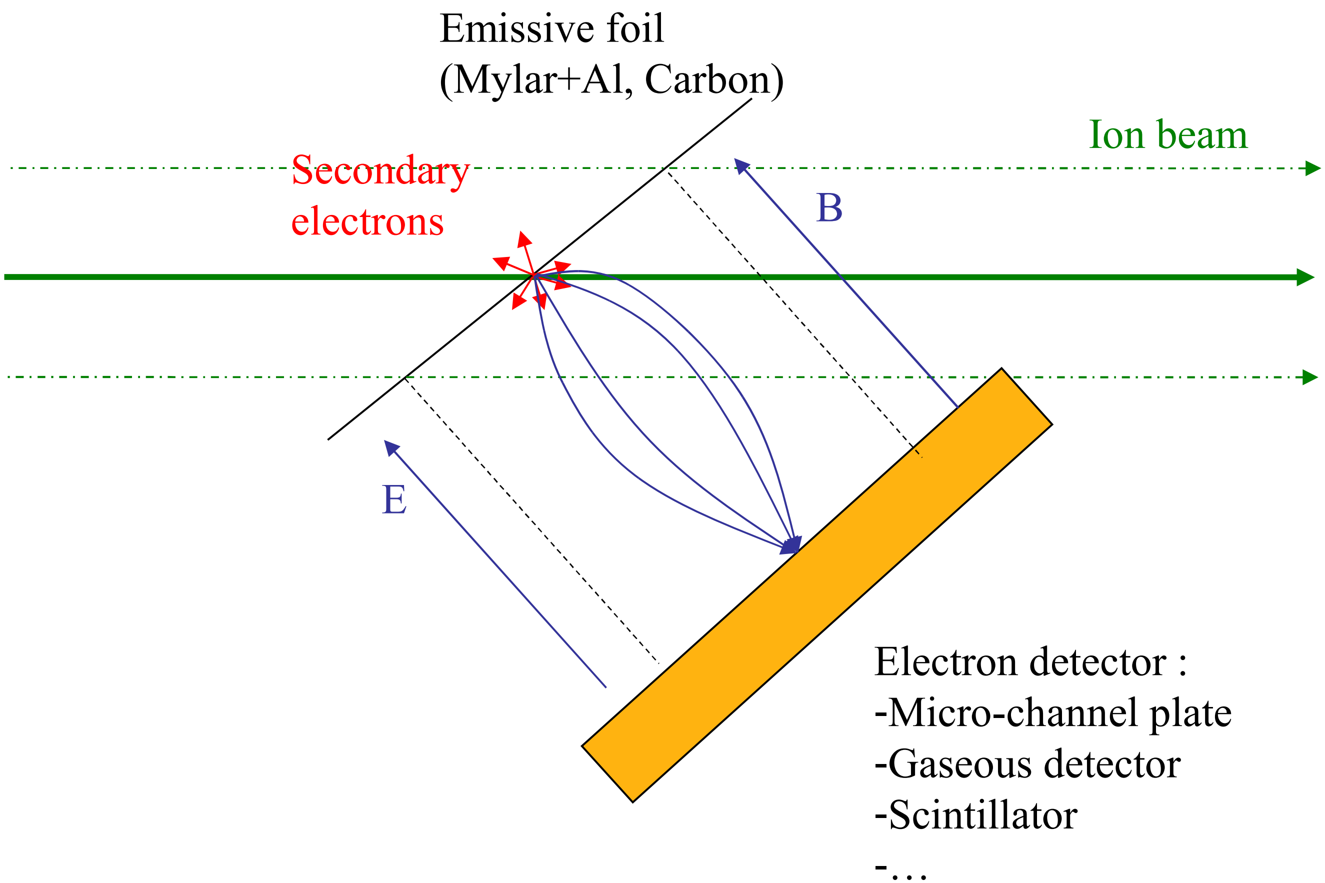
Low-energy heavy ions (5-10*A* MeV)

Participants: (*U-Seville; GSI; LNL; GANIL; CEA Saclay; U-Manchester; U-Huelva; STFC Daresbury; IKP-Köln; U-Surrey; U-Liverpool; U-York; IPN Orsay; IFIN-HH; IFJ-PAN Krakow*)

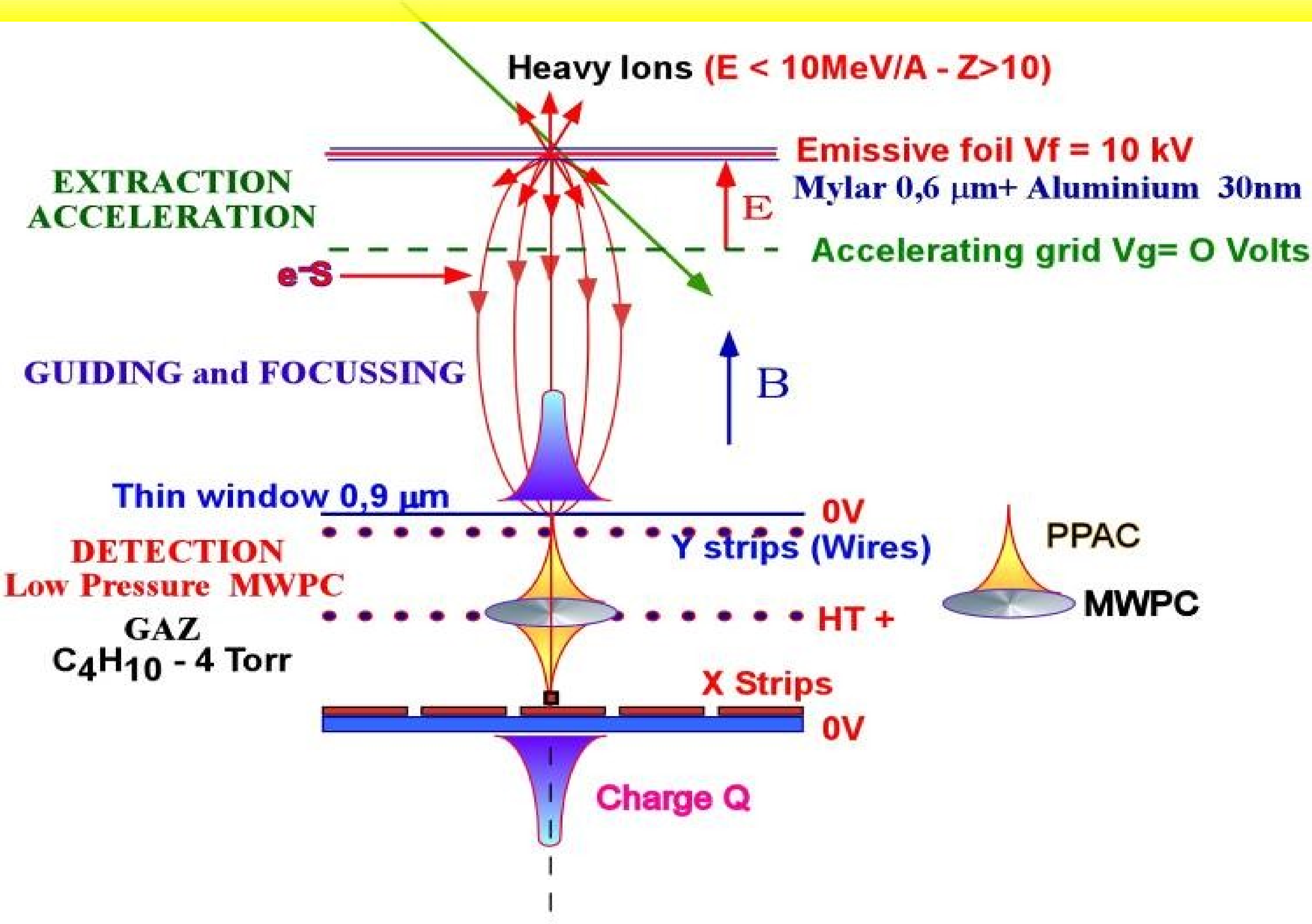
Secondary electron detectors (Se-D):

- Ultra-fast position-sensitive MCP detectors with large area. The time and position readout to be investigated.
- Low-pressure gas-amplification detectors with dedicated ASIC electronics, like the Se-D based on MWPC at the VAMOS spectrometer. An alternative is "low-pressure MICROMEGAS" detectors. The performance of these detectors at low pressures has to be investigated.
- Diamonds detectors are very fast and radiation-hard. They will be tested as secondary-electron detectors in conjunction with fast current-sensitive preamplifiers (rise-time 0.5 ns).
- Fast DSSD and ultra-fast organic-scintillator detectors.
- **The fast front-end electronics to be developed and produced.**

Example 2. Emissive foil detectors (SeD)

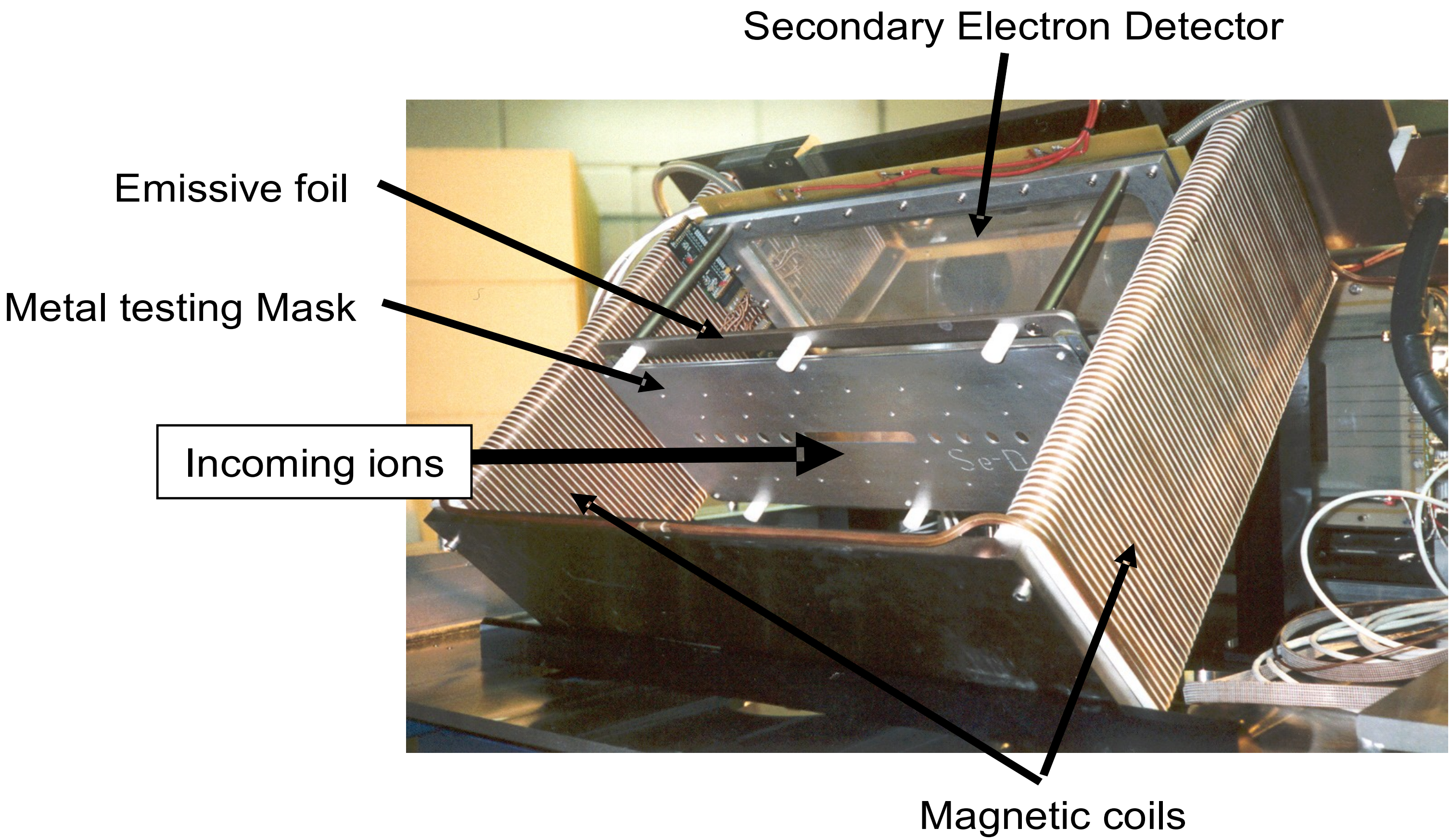


Secondary electron Detectors at VAMOS, GANIL



Antoine Drouart DSM/DAPNIA/SPhN

Se-D active area 10x40 cm^2



Results of tests & experiments at GANIL

Ions	E (MeV/A)	dE/dx (MeV/mm)	Efficiency	Time resolution (FWHM ps)
Heavy Fission frag. Average Z~53	**0.6**	**13800**	**100%**	**250**
Light fission frag. Average Z~45	**1**	**13200**	**100%**	**250**
^{76}Ge	**2**	**10500**	**100%**	**500**
^{24}Mg	**12**	**1050**	**85%**	**800**
^{12}C	**10**	**320**	**75%**	**1000**
Alpha	**1.5**	**160**	**40% (70%*)**	**1200***

Conclusions

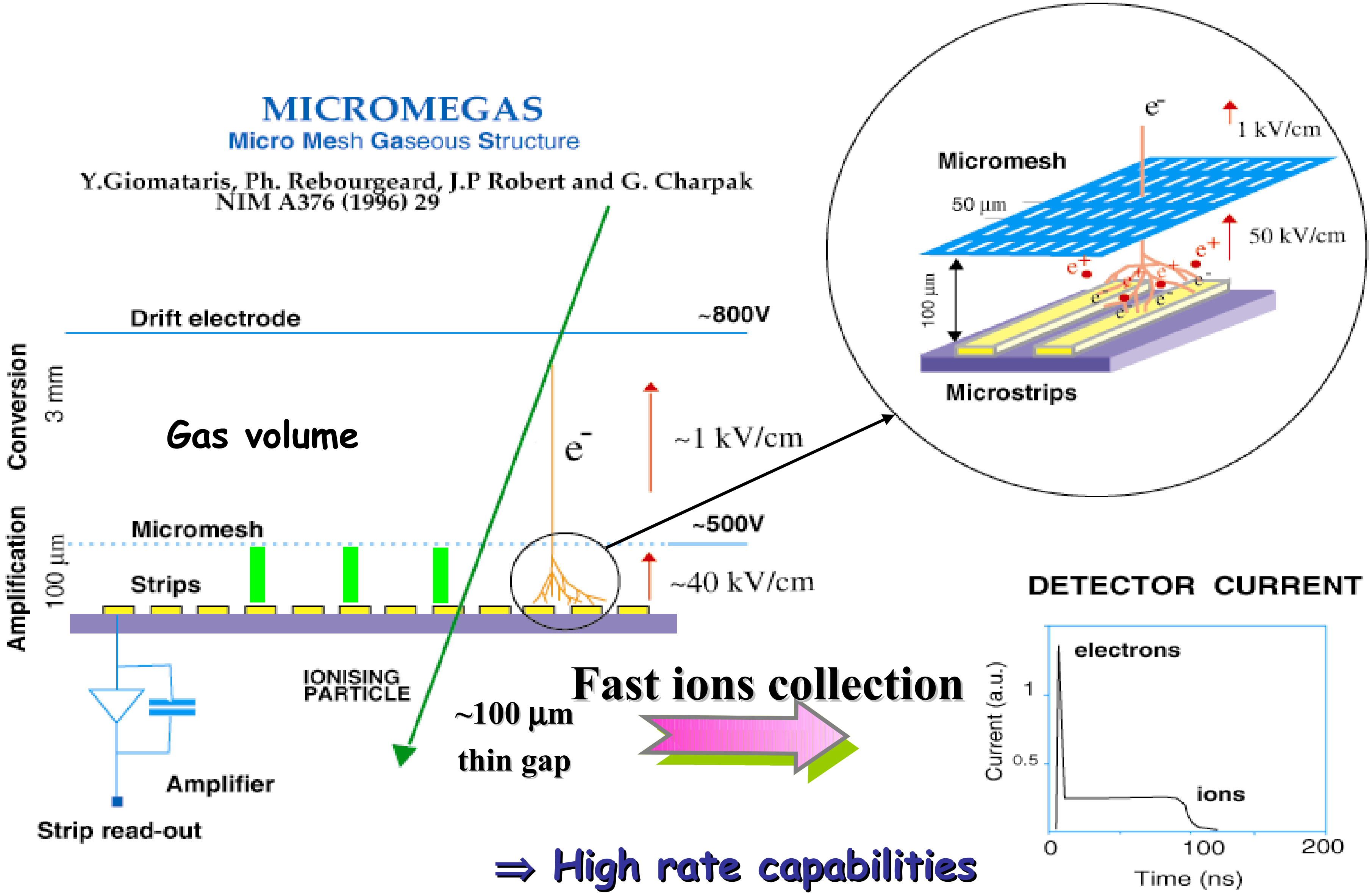
-Detector able to cope with a few **10 ^{3}pps** (limited by electronics dead time)

-Spatial resolution : **1-2mm**

-Time resolution : **1.5ns (light ions) to 300ps (heavy ions Z>40)**

-Total thickness in the beam : 0.6µm Mylar foil = **75µg/cm²**

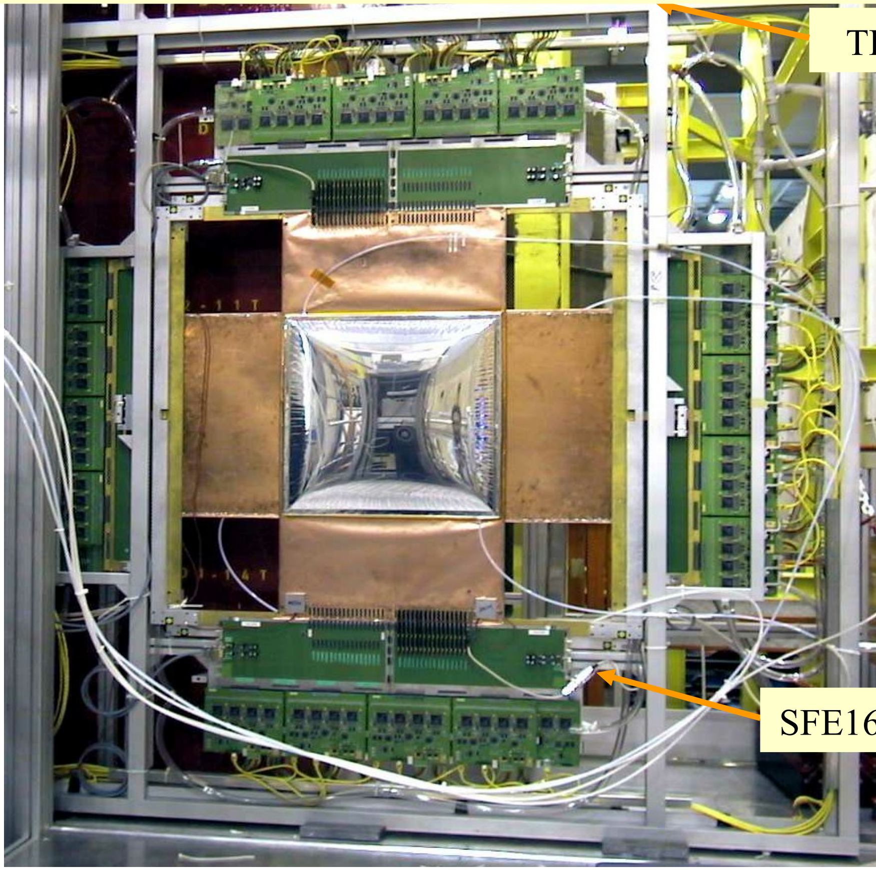
SeD development: the Micromegas concept



⇒ **High rate capabilities**

SeD development: to implement the technology of Micromegas CERN/COMPASS

X,Y active area 40x40 cm²



World largest micropattern Gaseous detectors in use on an HEP experiment (2002-)

specifications

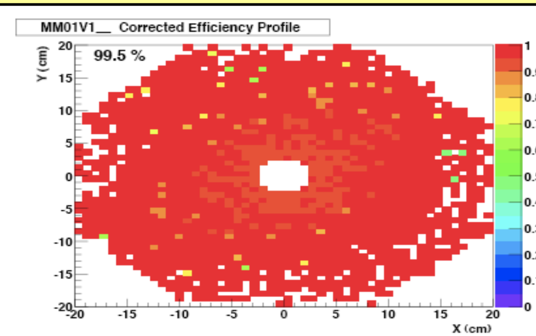
- ✓ MIP localization with σ <100 µm
- ✓ Integrated flux of 300 MHz
  5.10^5 MIP/s/cm², 450 kHz/strip

Front-end Electronics

- ✓ 16 channels ASIC developped at SeD
  tp=85 ns, σ_{ENC}<1250e-, seuil à 4000 e-

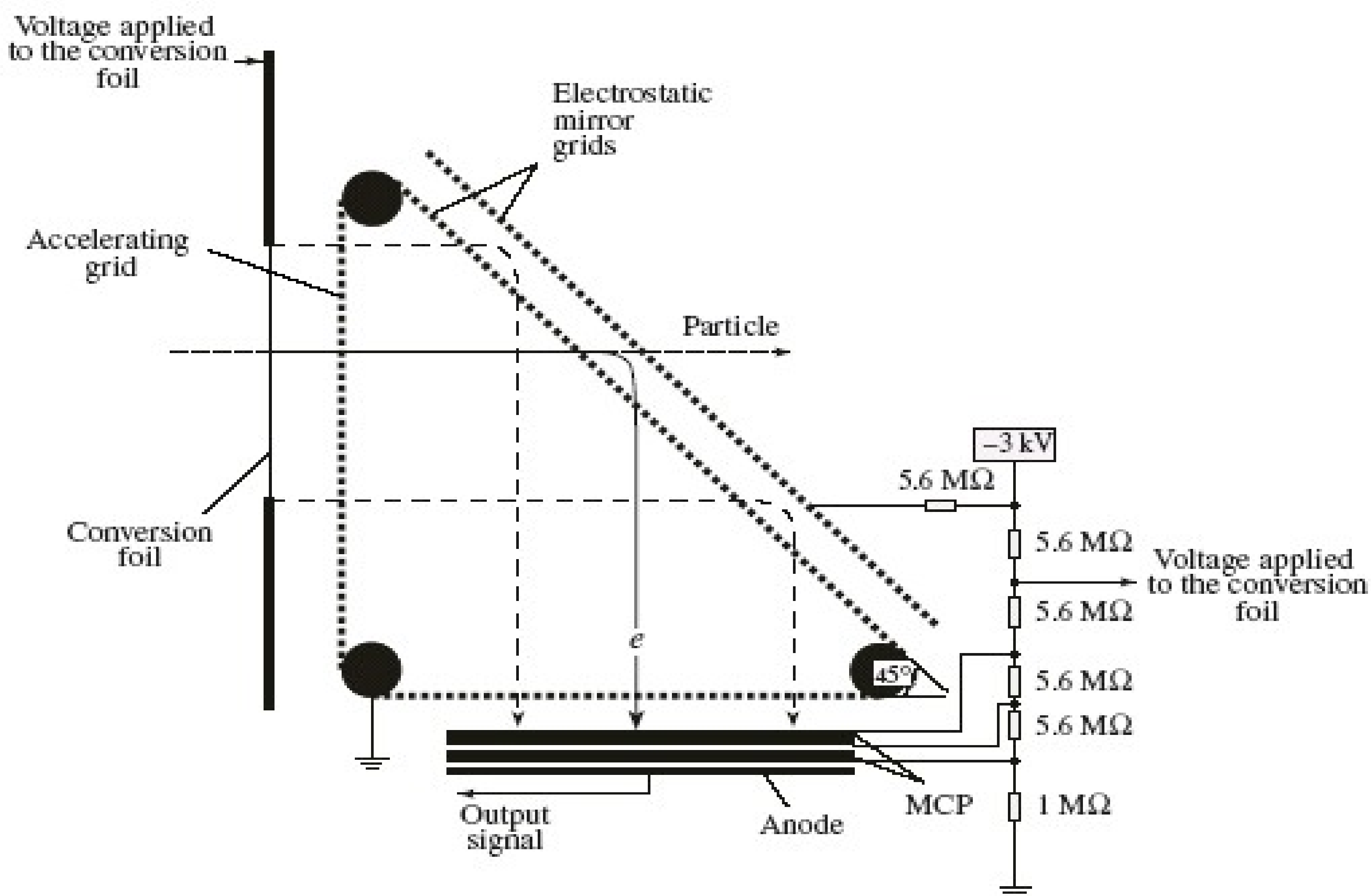
performances

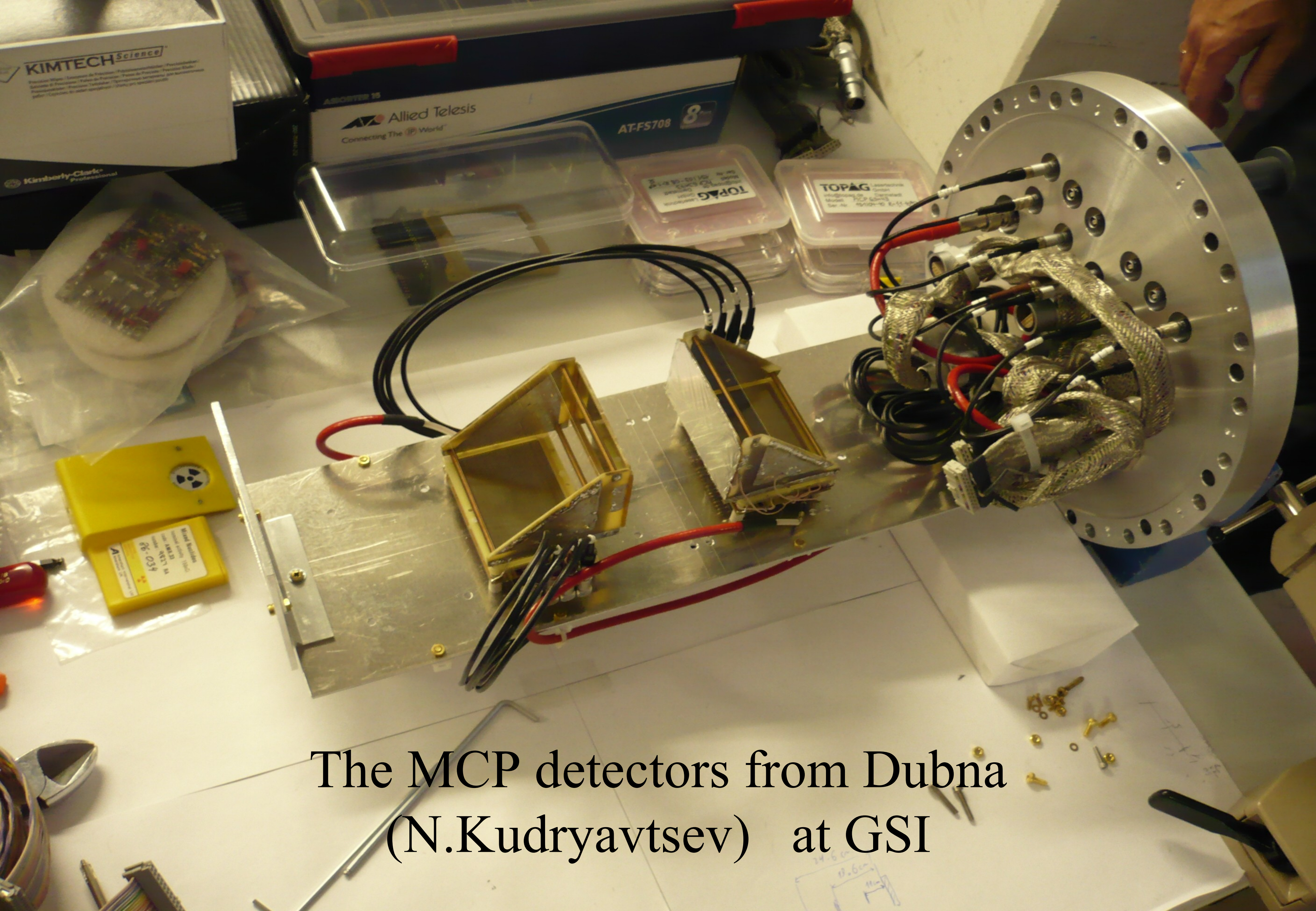
- ✓ spatial resolution σ =70 µm
- ✓ temporal resolution of 9 ns
- ✓ 0.15 discharges/spill, local dead time < 3 ms



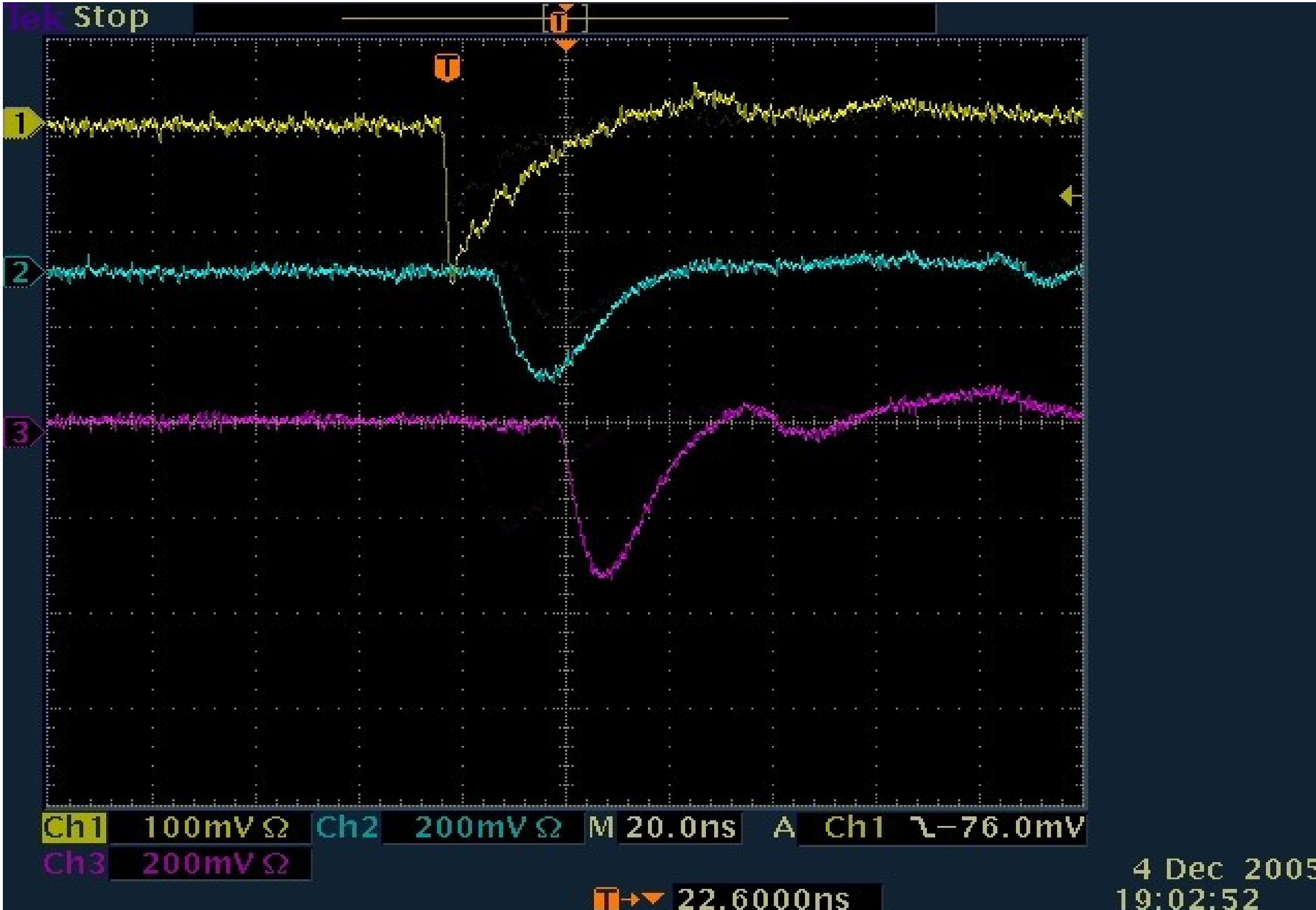
96-99,5% efficiency

Example 3. Fast timing with MCP detectors

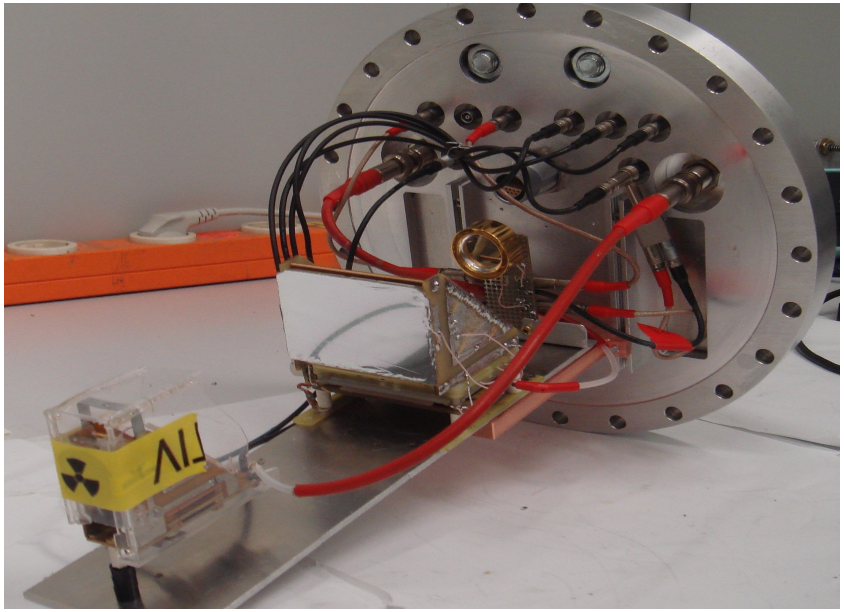


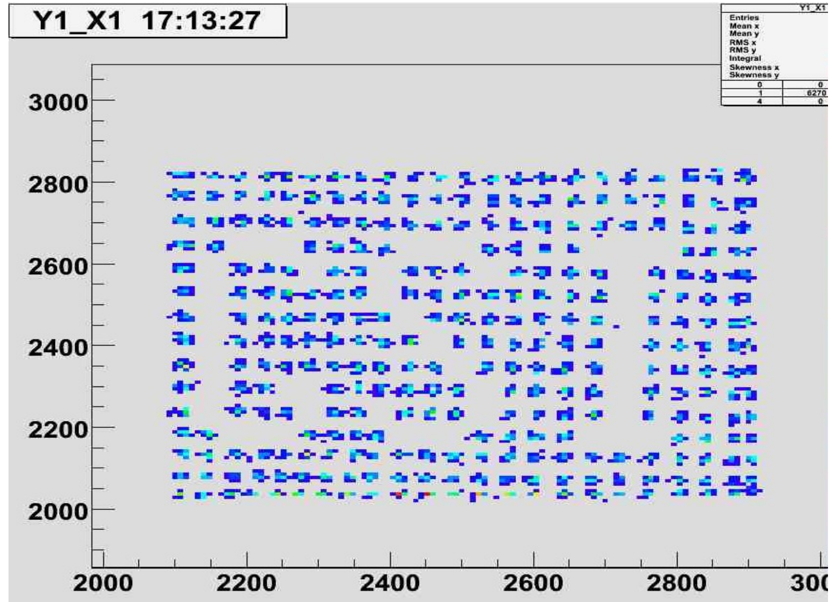


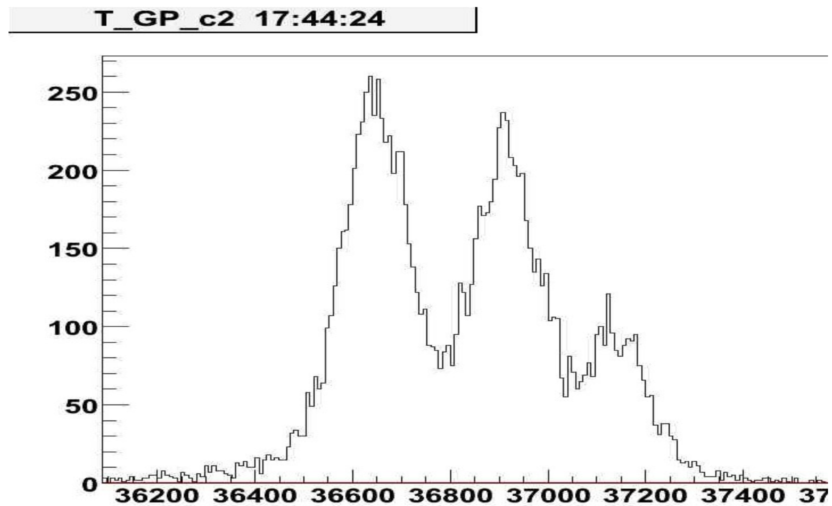
The MCP detectors from Dubna
(N.Kudryavtsev)   at GSI


Tek Stop
1
2
3
Ch1 100mV Ω
Ch2 200mV Ω
M 20.0ns
A Ch1 ⌊ −76.0mV
Ch3 200mV Ω
4 Dec 2005
19:02:52
22.6000ns

Test of MCP detectors in GSI







- Time resolution – 100ps
- Position resolution
- for alpha particle – 3mm
- for fission fragments – 0.5 mm

TEST - Experiment (Slowed down beams) at GSI - 09/2008, S2-FRS

A 600MeV/u of 64Ni beam is slowed down to 2MeV/u by Al degraders;

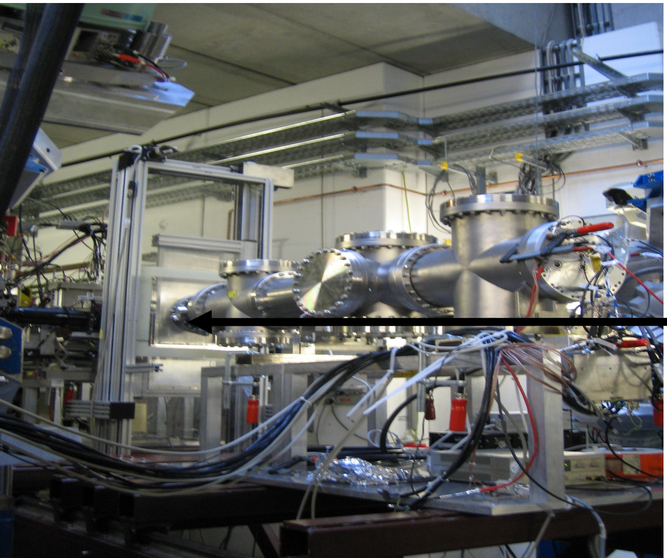
Energy of the slowed and scattered 64Ni ions is measured by a TOF method, before target with a scintillator detector and after target with the MCP detector.

The Si detector stop the particles detecting their energy; ExTOF analysis.

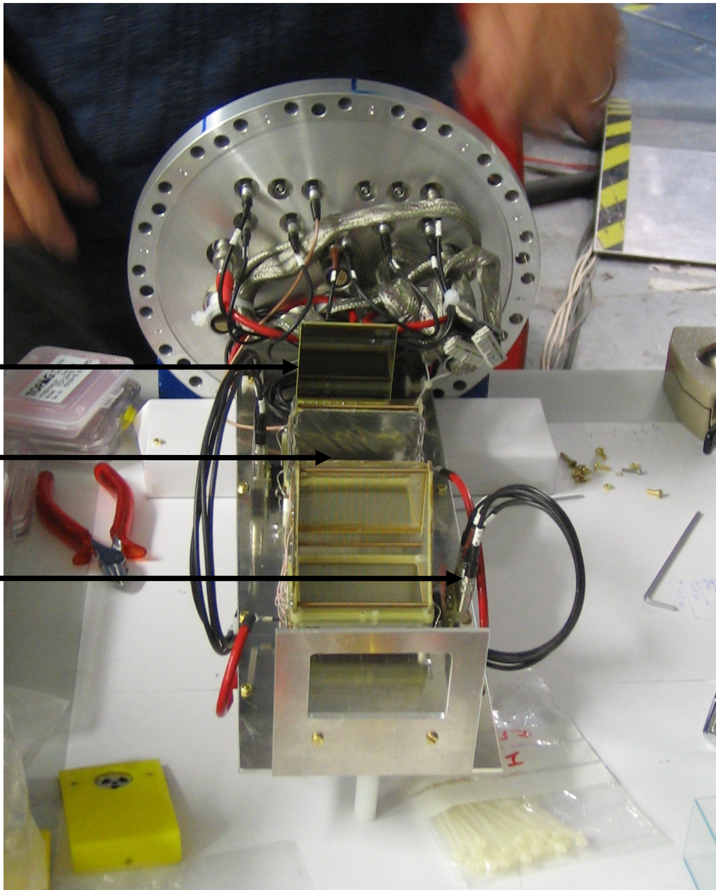
The MCP detector consisted of a thin 6cmx4cm foil; Associated to the fast pre-amp allowed to obtain:

► **Spatial Resolution of about 0.5 mm and**

► **Timing ~ 100 ps.**



Silicon
+
Multi Channel Plate
+
FPA (Dubna)
+
Scintillator

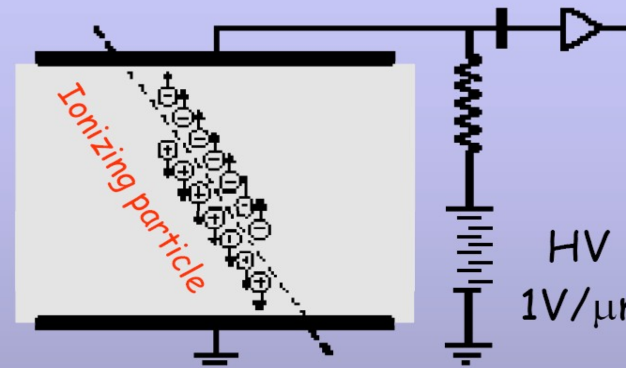


Example 4. Fast timing with diamond detectors

Superior properties of diamond as a charged particle detector

	Silicon Z=14	Diamond Z=6
Band gap [eV]	1.12	5.5
Dielectric constant	11.9	5.7
Resistivity [Ωcm]	$2.5 \cdot 10^5$	10^{11}
Thermal conductivity [W/cmK]	1.5	20
Carriers mobility [cm^2/Vs]	e: 1350 h: 480	4500 3800
Displacement energy[eV]	24	80
e-h pair creation energy [eV]	3.6	13

+ operation at RT
+ small capacitance, noise reduction
+ negligible leakage current, noise reduction
+ the best known heat conductor
+ fast signals
+ radiation hardness
- small induced signal



Position sensitivity:

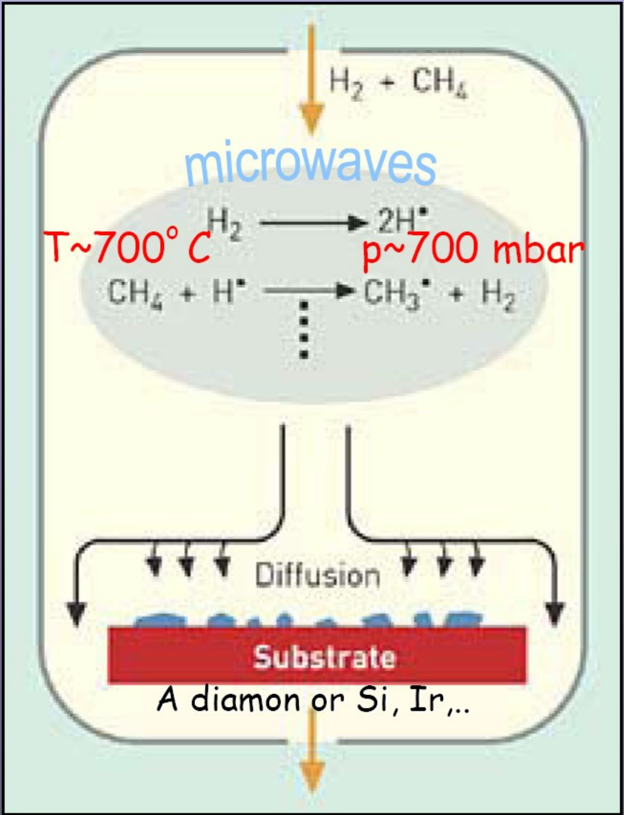
- Stripes
- Pixels

Applications:

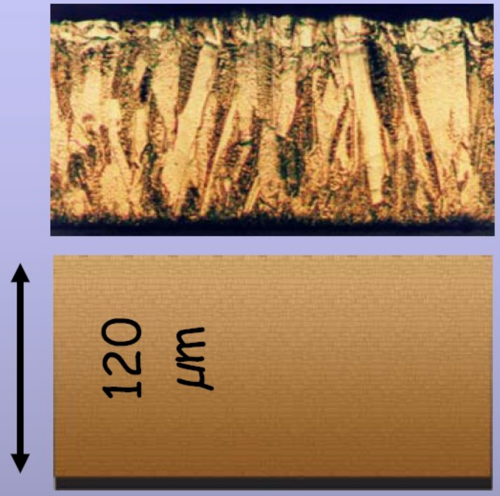
- Beam monitoring: CERN, GSI
- ToF spectrometry, GSI, MSU

Chemical Vapour Deposition - a break through in diamond detectors production

Natural,
HPHT synthetic diamonds
- High costs
- Limited sizes
- Impurities



Poly crystaline - CVDD:
- ∅ = up to 5", 1-500μm
- CCE ≈ 50%
- detection efficiency ~70%
- fast timing
- price 2.5 US$/mm²

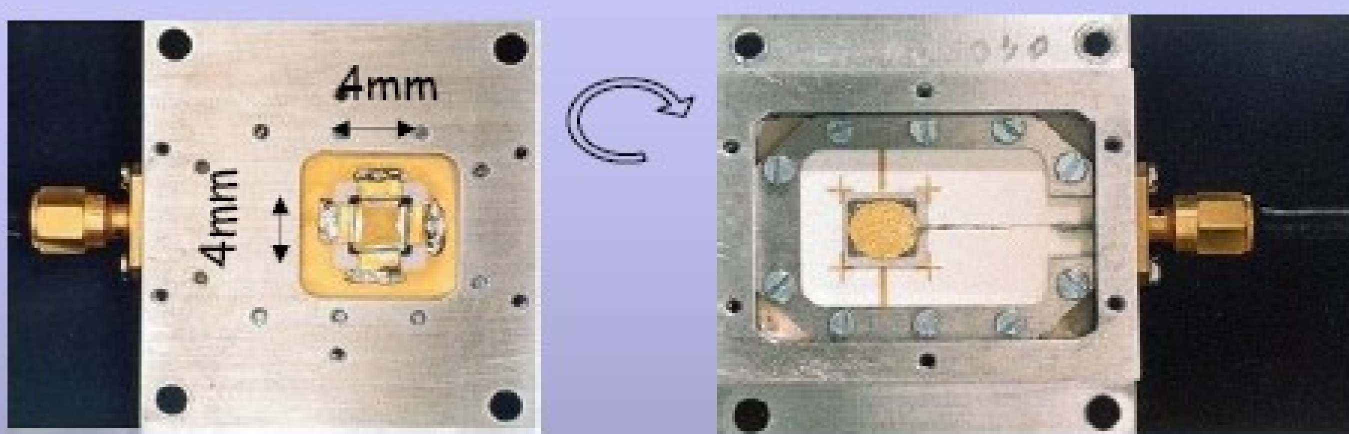


Single crystal - CVDD:
- 4 x 4 mm², 1-500μm
- CCE = 100% -good energy resolution
- detection efficiency ~100%
- fast timing
- price 50 US$/mm²

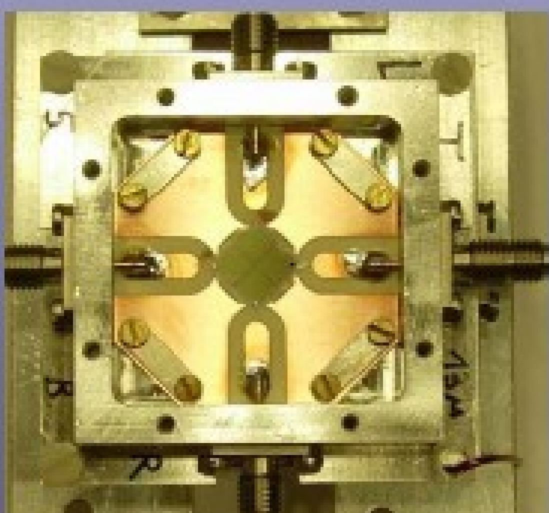
NEW!

Element Six (UK):
1 x 1 cm² SC CVDD

Detectors



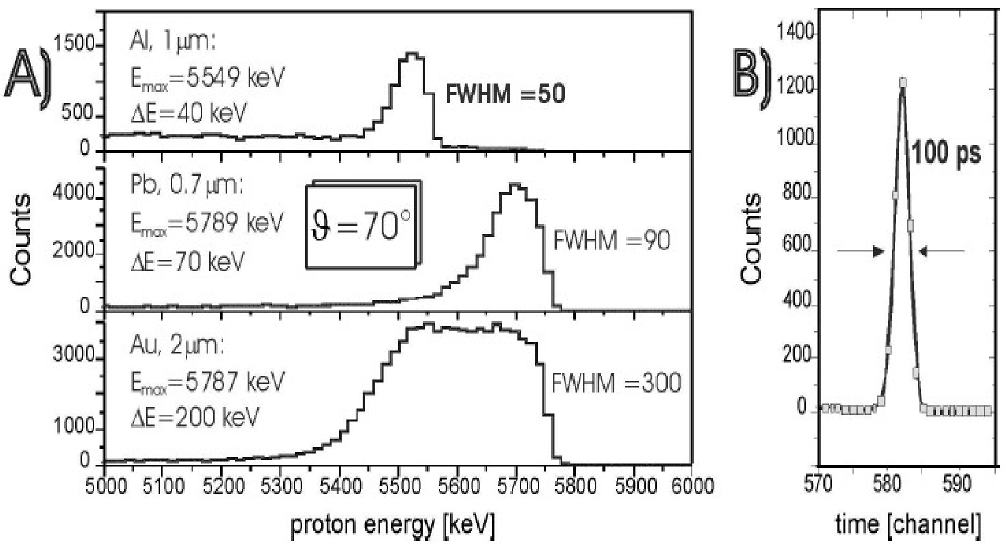
- SC CVDD detectors: $4\times4mm^2$, 110-500 μm (GSI Detector Laboratory)

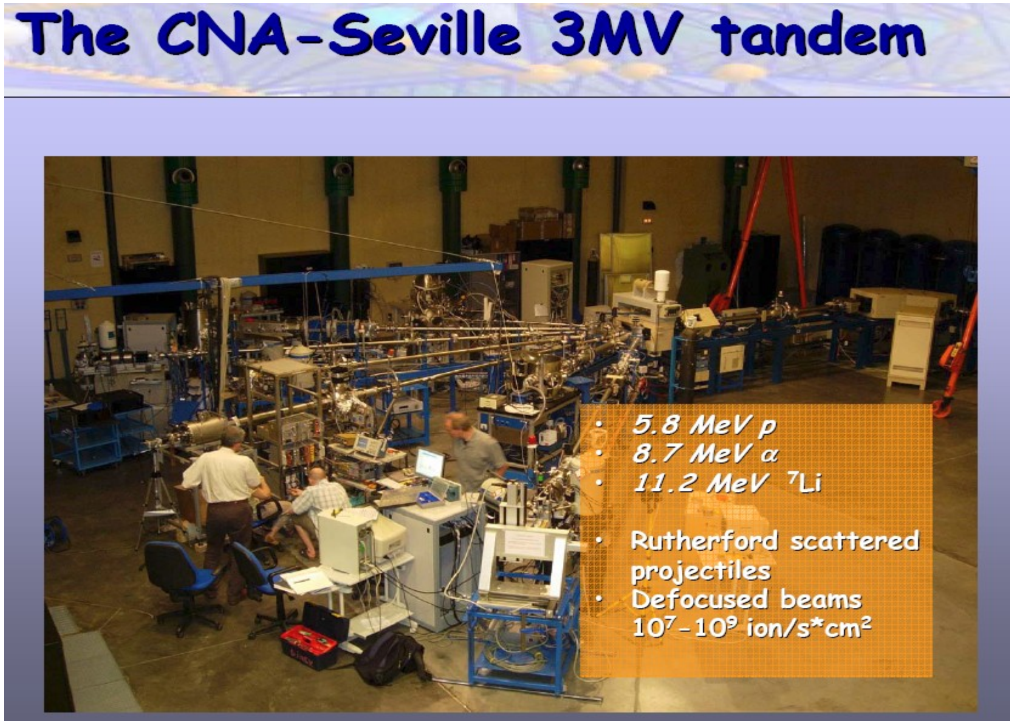


- PC CVDD 4-fold segmented detectors: $1\times1cm^2$, 13-60μm (GSI Plasma Physics dept)

In-beam evaluation of time and energy measurements with diamond detectors at a low beam energy and a high particle rate

CNA-Seville 3MV tandem laboratory





P. Bednarczyk et al., Acta Phys. Pol. (2007)

Summary.
Large-area tracking detectors and their fast readout electronics

The dream beam-tracking detectors should provide:

- fine spacial resolution and a minimum ion energy absorption,
- excellent timing resolutions (better than 100 ps),
- high efficiency and high counting rate,
- radiation hardness.

We need fast electronics:

- Vacuum-fit pre-amplifiers
- Discriminators in pico-second range
- Analog-to-digit convertors

THE NEW EUROPEAN NETWORK DITANET(2008):

DITANET: DIagnostics Technics for particle Accelerators NETwork

- University of Heidelberg
- Comissariat a l' Energie Atomique (CEA)
- Deutsches Elektronensynchrotron (DESY)
- Gesellschaft für Schwerionenforschung (GSI)
- Heidelberg Ion Therapy (HIT) GmbH
- Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH)
- Stockholm University (SU)
- Royal Holloway, University of London
- University of Seville – Centro Nacional de Aceleradores