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TAMIA, a Versatile Tool for Materials Analysis

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Faculty of Science

Department of Physics

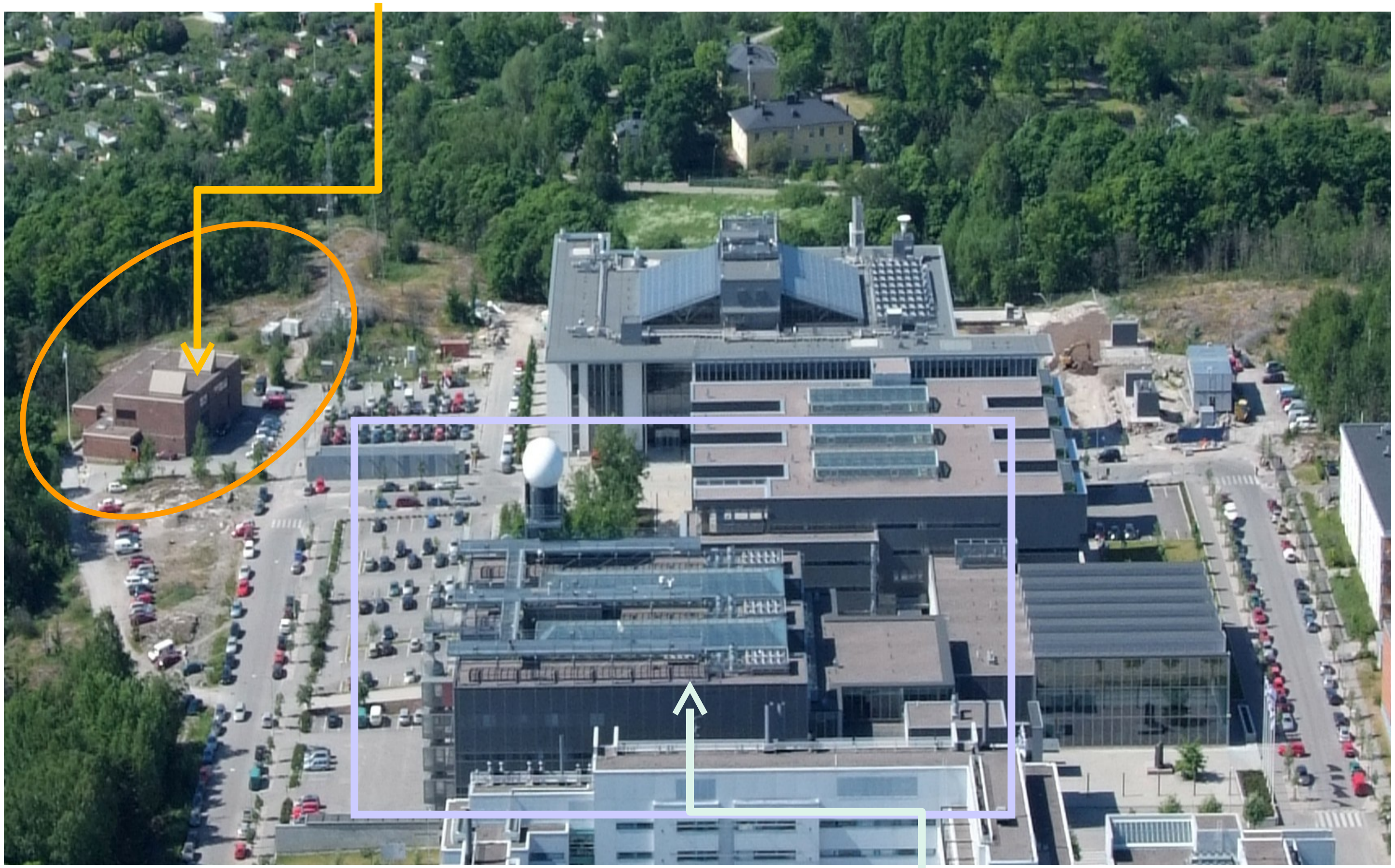
Division of Materials Physics

Outline

- The laboratory & current status
- Accelerator upgrade
  - Injector platform
  - Ion sources
  - Ion optics
  - Beam diagnostic
  - Inside tank
- Applications
  - Proton irradiations
  - Space
  - TOF-ERDA
  - AMS
- The Team

Department of physics

Accelerator building

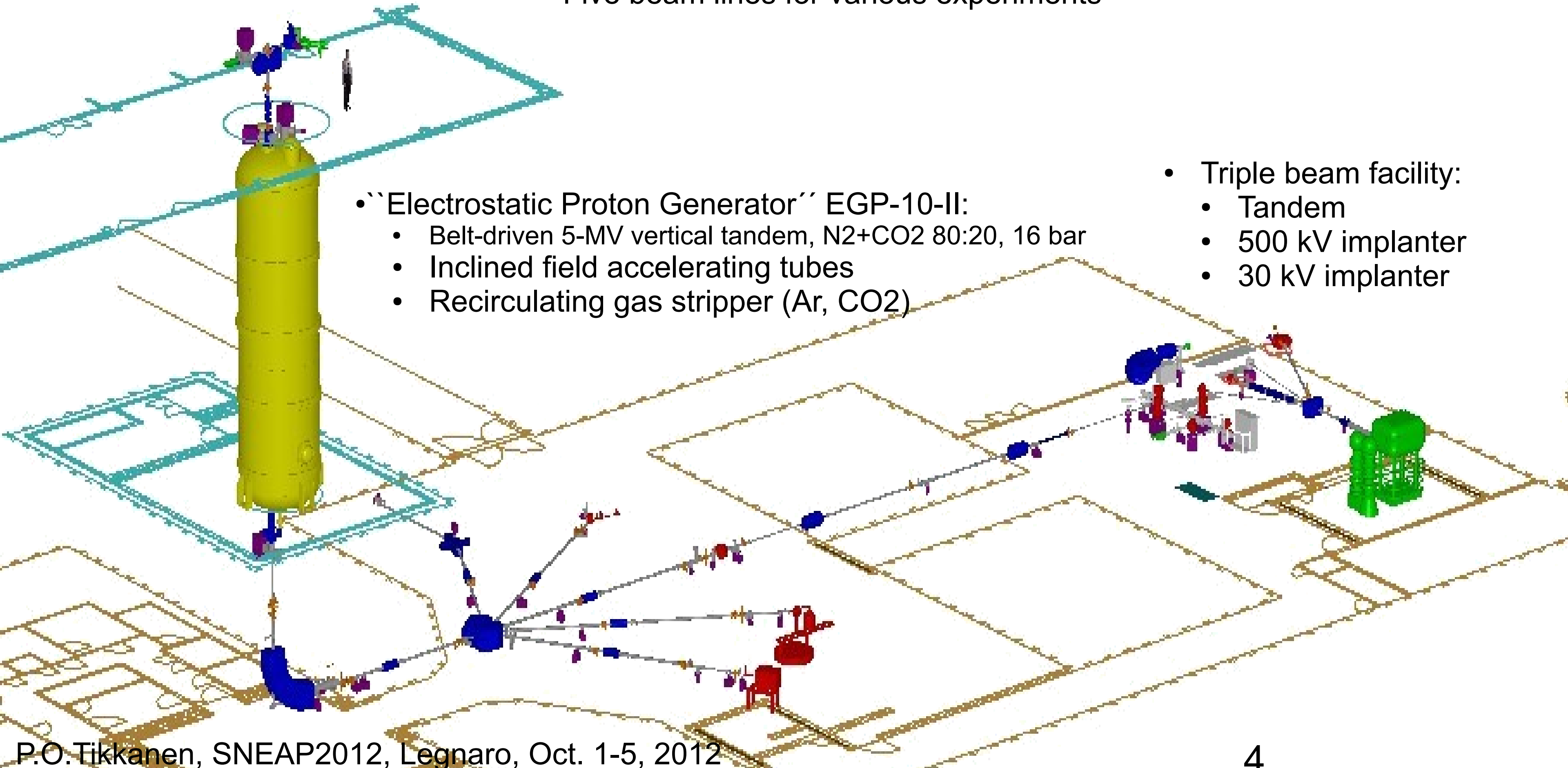


Physicum

A versatile 5-MV tandem (TAMIA)

- Several ion sources (3+1)
- Alphatross, MISS, MC-SNICS, DUO)
- Electrostatic & magnetic analyzers

  ESD & IM, analyzing, switching magnets)
- Five beam lines for various experiments



- ``Electrostatic Proton Generator´´ EGP-10-II:
  - Belt-driven 5-MV vertical tandem, N2+CO2 80:20, 16 bar
  - Inclined field accelerating tubes
  - Recirculating gas stripper (Ar, CO2)

- Triple beam facility:
  - Tandem
  - 500 kV implanter
  - 30 kV implanter

Renovation of building & accelerator

Tandem entrance & building renovation

Injector hall in September 2010

Ion source room

Injector magnet

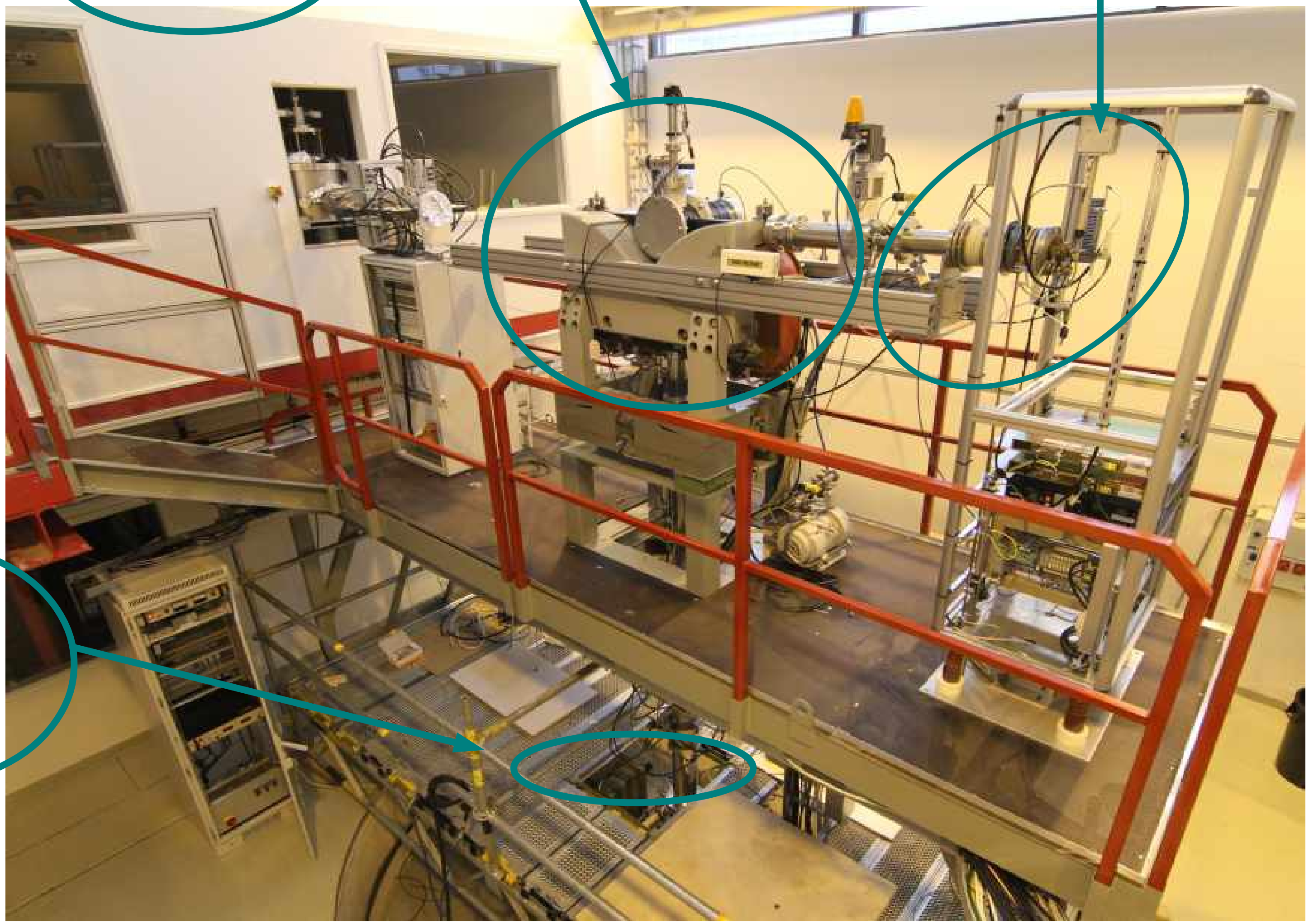
Tandem entrance

Injector magnet platform today

Room for
Ion Sources

Injector magnet

MISS-483M ion source



Tandem
entrance

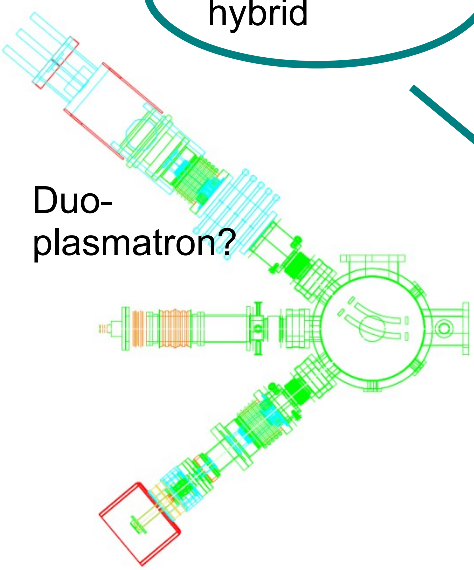
Ion sources room

MC-SNICS-40
hybrid

Electrostatic
analyzer

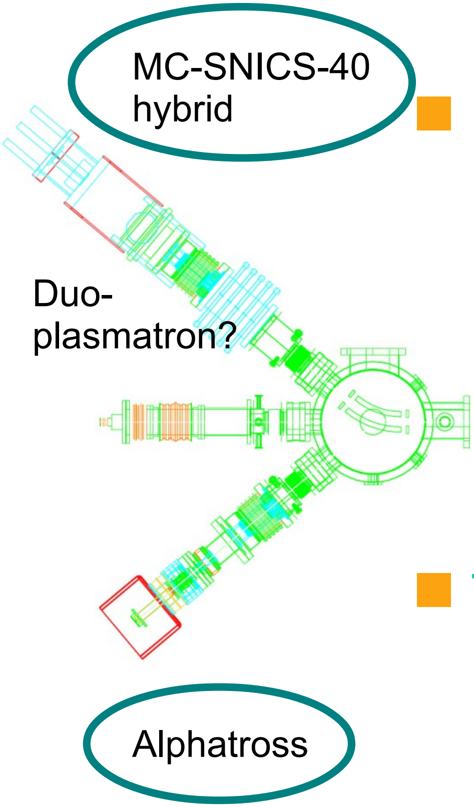
MC-SNICS
HV platform

Duo-
plasmatron?



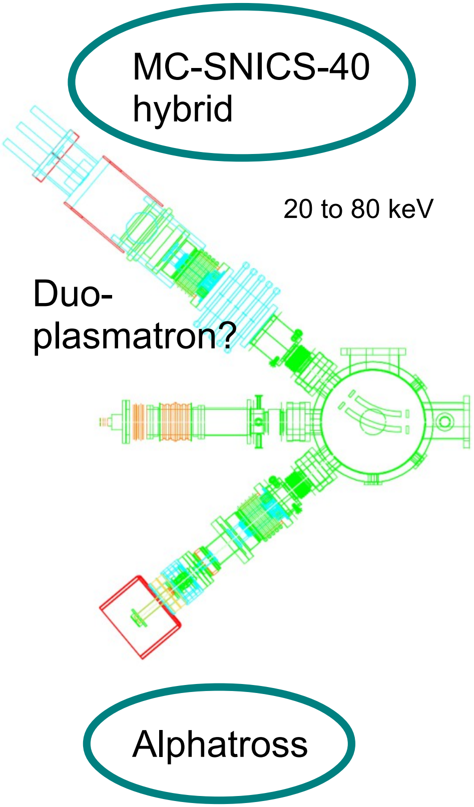
Alphatross

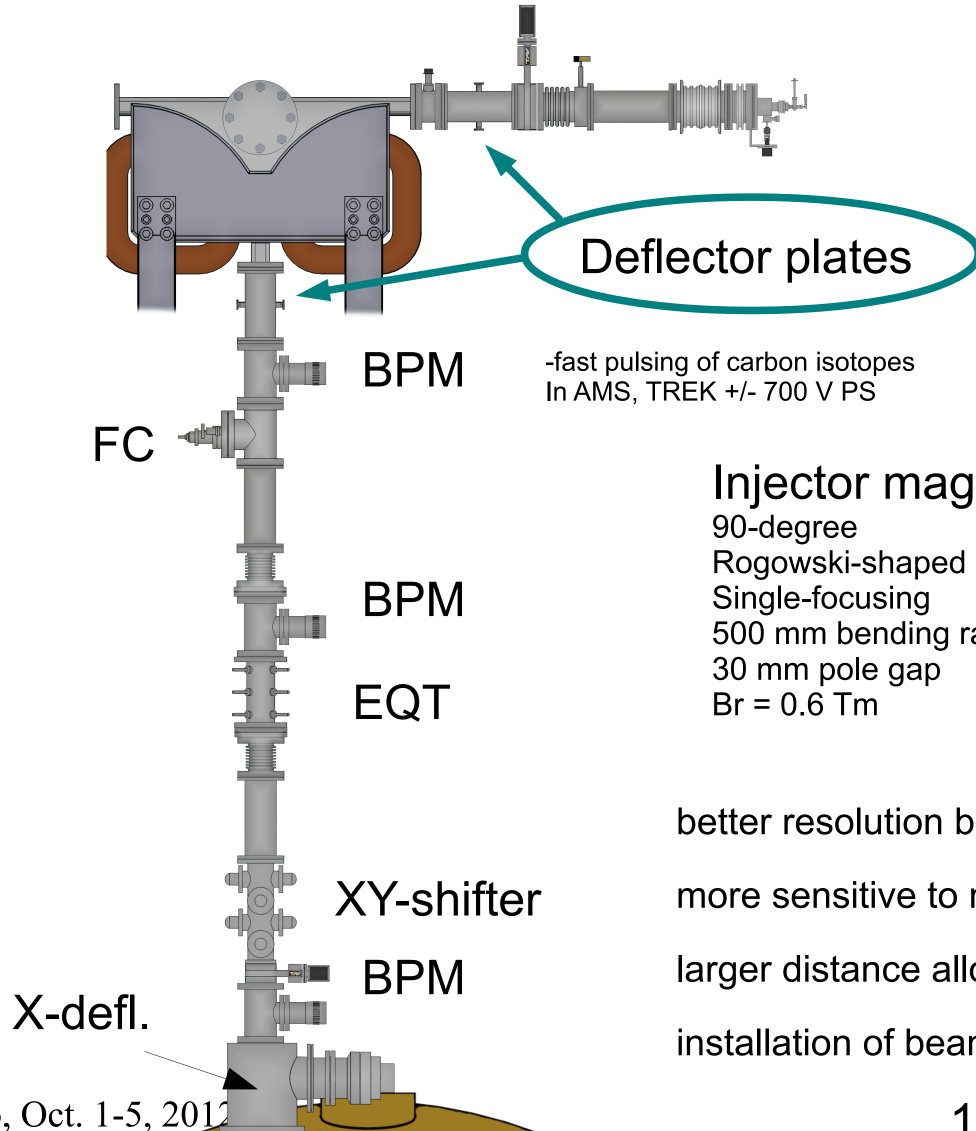
Ion sources room & injector platform



- ESD, electrostatic deflector (cylindrical)
  - Rotatable to choose beams from either the 40-sample MC-SNICS for AMS (hybride) or the Alphatross for He ions
  - Moved up to allow beam straight from the fourth ion source
  - Manually operated, but stepper motor easy to install
  - Directs the beam through EQT, BPM, and deflector to
- Two-sided 90-degree injector magnet
  - Allows installation of several ion sources
  - Single-focusing, resolution could be better
  - Ions from a single-cathode Cs-sputtering IS on the other side, beams from other three IS chosen in the ESD
  - Stray field resulted in turbopump failure

Injection to Tandem





-fast pulsing of carbon isotopes
In AMS, TREK +/- 700 V PS

Injector magnet

90-degree
Rogowski-shaped poles
Single-focusing
500 mm bending radius
30 mm pole gap
Br = 0.6 Tm

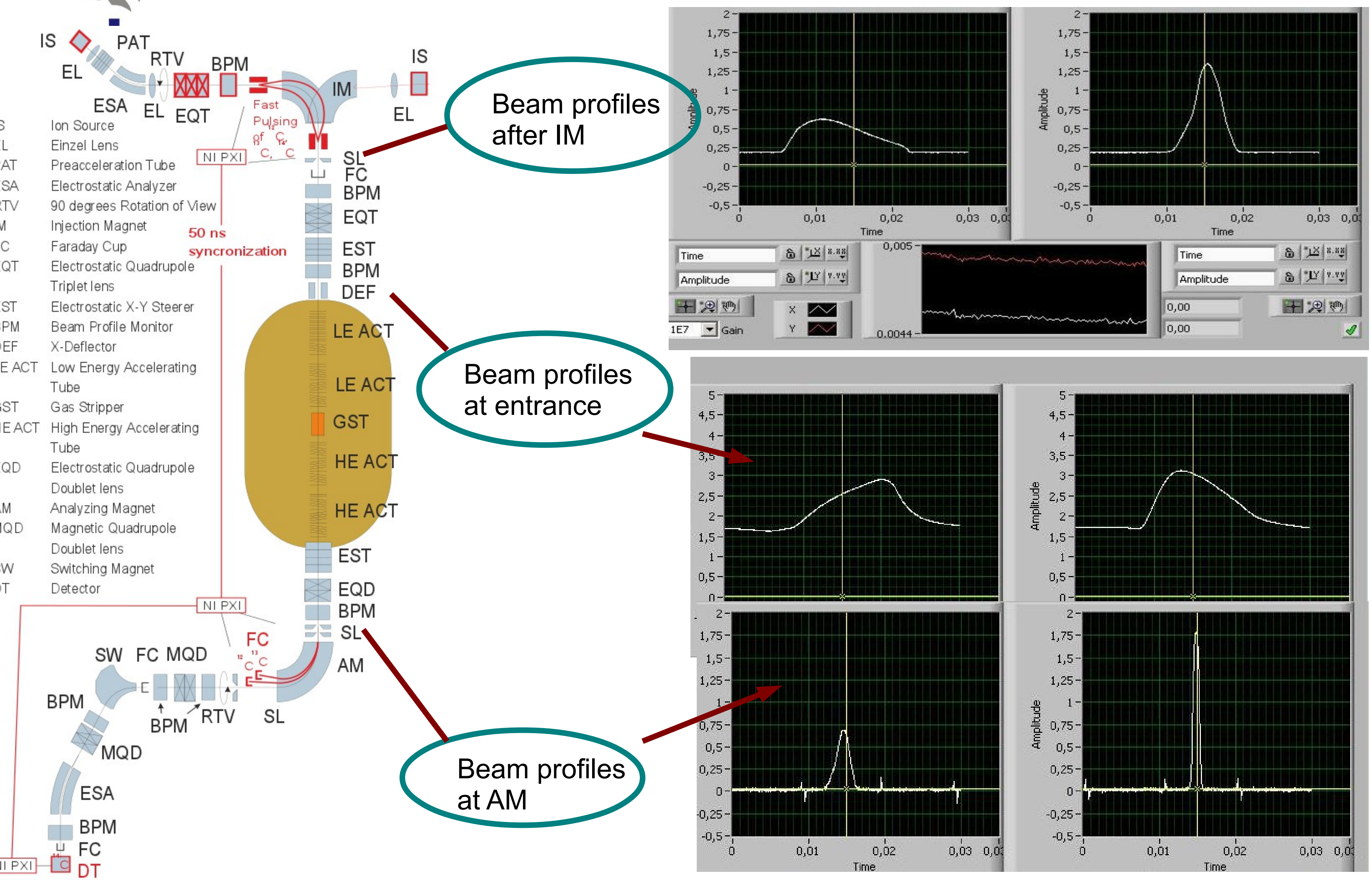
better resolution but:

more sensitive to misalignments,

larger distance allow

installation of beam diagnostics

First tests: low-energy $^{16}O^{-}$ through tandem



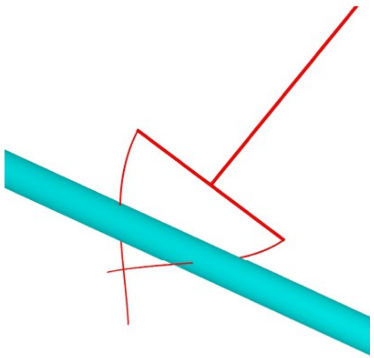
Low-Energy Ion beams through tandem

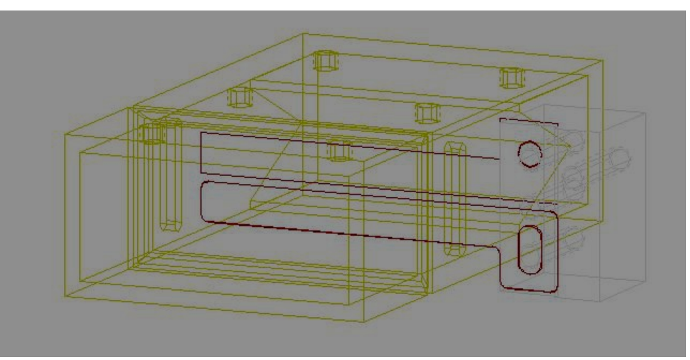
- Any ion from IS can be run
  - Tested ions from carbon to copper
  - Some instability at high beam currents
  - No terminal voltage
  - If AM polarity reversed, can be run to target (not tested)
  - But note Br = 0.10 to 2.25 Tm (900 keV p to 80 MeV 238U)
- Allows mutual calibration of
  - Injector magnet and analyzing magnet
  - At keV energies
- Instabilties at higher beam currents
  - Seen at BPM after tandem
  - Charging of some parts somewhere (broken resistor?)

Inside tank

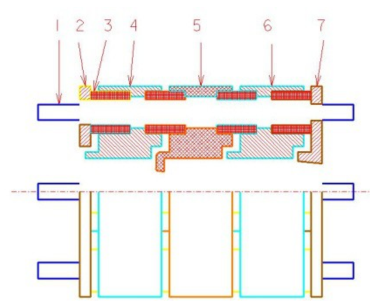
- Terminal-voltage stabilization
  - New electric feedthrough for corona needles (must be low impedance?)
  - New stabilization electronics (NEC)
  - GVM, slit, CPU
  - new resistors to be installed in 2013
- New GVM/amplifier (NEC, Oct. 2011)
  - Adapter flange & feedthrougs
- Terminal recirculation installed 10 yrs ago, NI CRI/O working well
- gas stripper, two bottles, CO_2 or Ar, the latter for AMS to reduce background
- pumping tube, allows monitoring stripper gas composition remotely (RGA)

Beam diagnostics





- Beam profile:
  - Transversal intensity cross-section (XY) of beam
  - Beam transport, focusing/scanning
  - Fast digitizing & readout of BPM signals
- Benefits
  - Storage of quantitative data for later use
  - Allows automation
  - Reconstruction of XY profile
- Faraday cups
  - Slow AC-motor manipulators replaced with
  - pneumatic ON/OFF control



DAQ and control

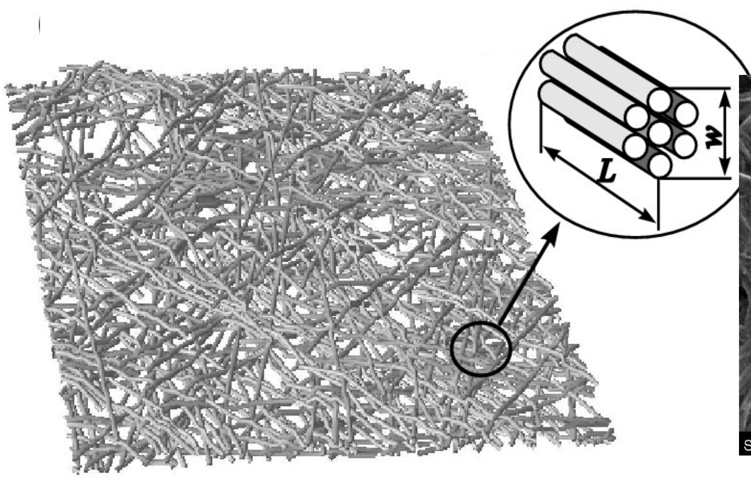
- NI CompactRIO & PXI + LabVIEW
  - Event counting
  - Ion current measurement (multiplexed DMM)
  - Automatic conditioning of electrostatic analyzer
  - Monitoring of HV terminal (active control in future)
  - Will eventually replace lucite control rods
- Fast Comtec GmbH MPA
  - Multiparameter detector data
- SQL database
  - Playback of beam parameters

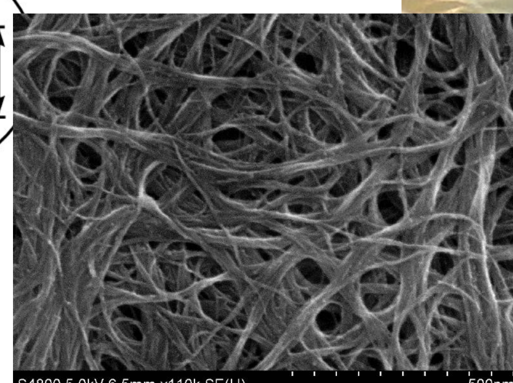
Current application projects

- AMS
  - Hybrid-MC-SNICS is being installed (fall 2012)
  - Bayesian data analysis
- IBA of multilayer structures
  - TOF-ERDA
  - RBS, NRA
- Modification of materials, detector tests
  - Proton irradiation
    - Probed by PAS (positron annihilation spectroscopy), microwaves, laser, CV&IV
  - Temperatures from 10 K to 300 K
  - Calibration of solar wind detectors (ESA)

Modification of Materials (cont'd)

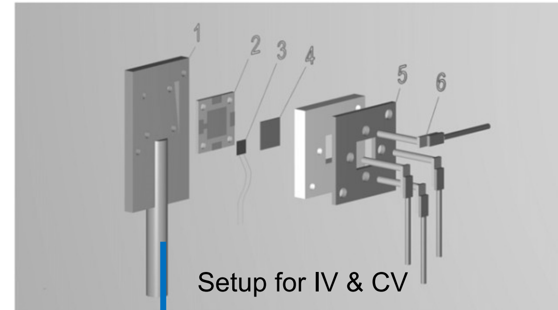
- Study of irradiation effects
  - Heavy-ion irradiation (20 MeV ^{12}C)
    - Buckypaper (carbon nanotube fibers)
    - Graphene
  - Probed with ultrasound, TEM, AFM
  - MD simulations

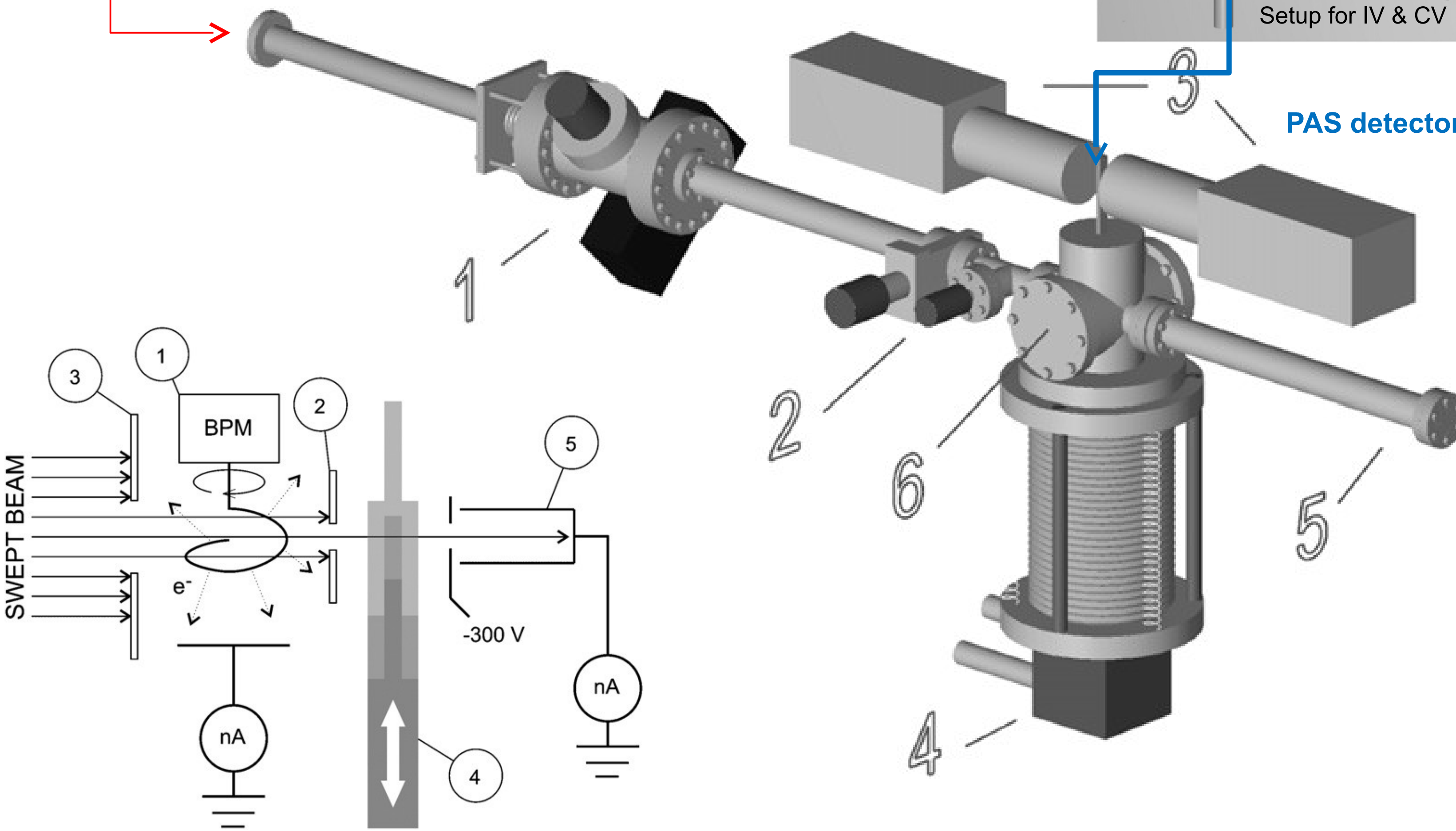




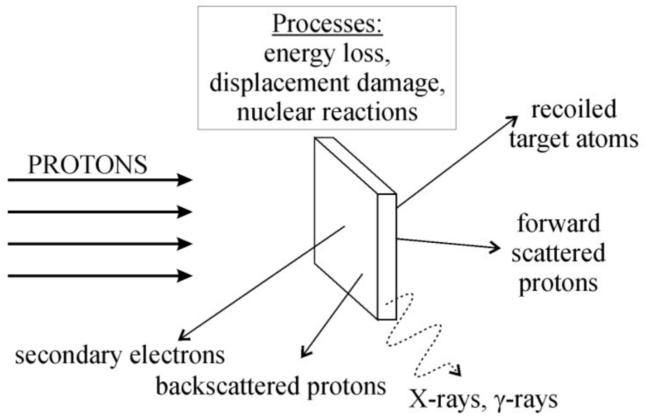
Irradiation and characterization at cryogenic temperatures

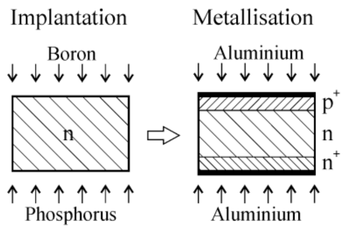
S. Väyrynen et al, Nucl. Instrum. Meth. Phys. Res. A 572 (2007) 978–984

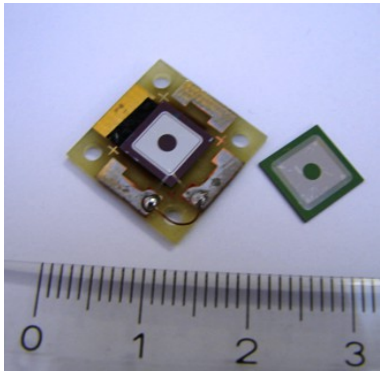




Effects of activation by proton irradiation on silicon particle detector electric characteristics



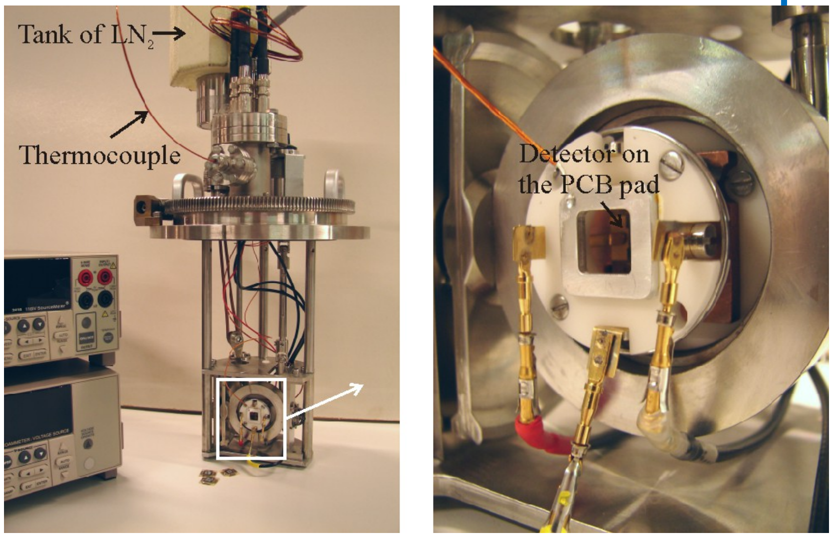




Processing (left) and mounting of silicon detector (right)

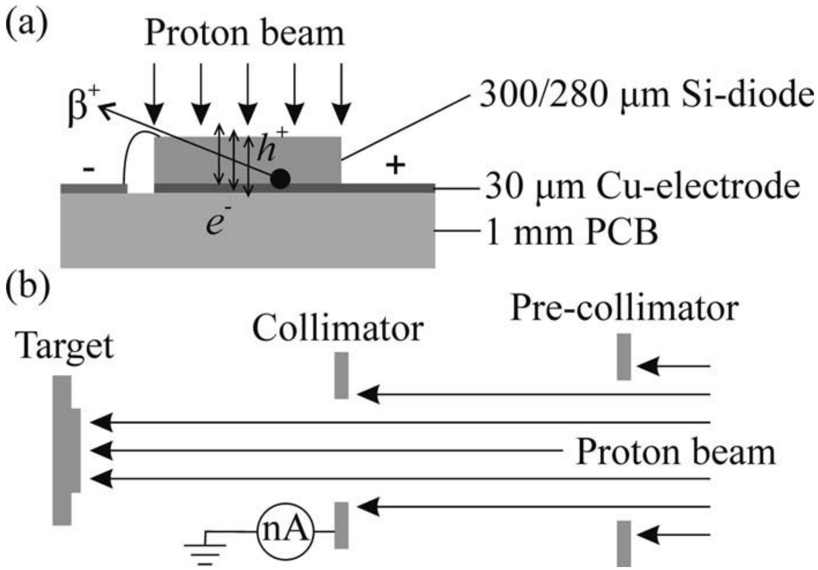
Proton irradiations in developing radiation hard detectors:

- defects in silicon similar to pions,
- more efficient compared to neutron and electron irradiations

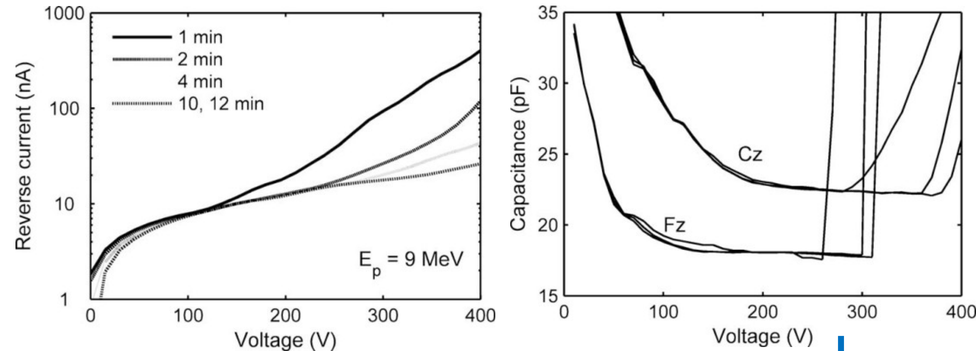


LN2-cooled goniometer for detector irradiation

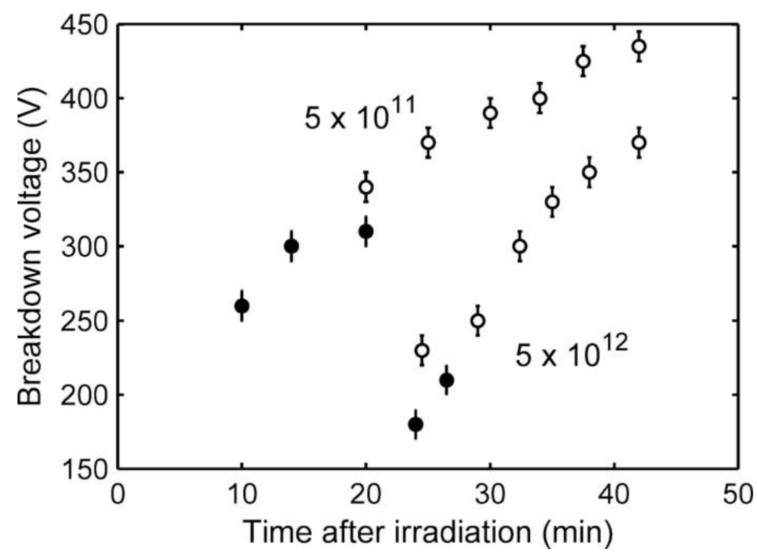
Effects of activation by proton irradiation on silicon particle detector electric characteristics



S. Väyrynen et al,JOURNAL OF APPLIED PHYSICS **106, 024908 2009**



Characteristics of detectors at various times after 9 MeV proton irradiation: Cz (left), Cz & Fz (right)

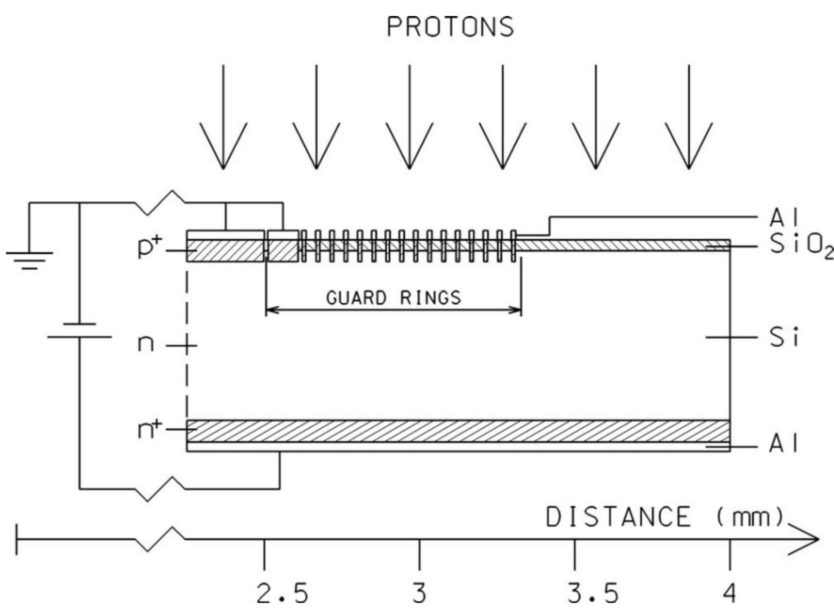


Wait at least 15 min after irradiation before starting electrical measurements to avoid effects of silicon activation

Recovery of breakdown voltage of the Fz detector

Breakdown of silicon particle detectors under proton irradiation

- Detectors made on Czochralski and float zone silicon materials irradiated with
  - 7 and 9 MeV protons at 220 K.
  - Biased up to the operating voltage.
- At specific values of the fluence and flux of the irradiation
  - a sudden breakdown in the detectors occurs
  - the breakdown is an edge effect
  - the buildup of an oxide charge lead to an increased localized electric field, which in turn triggers a charge carrier multiplication

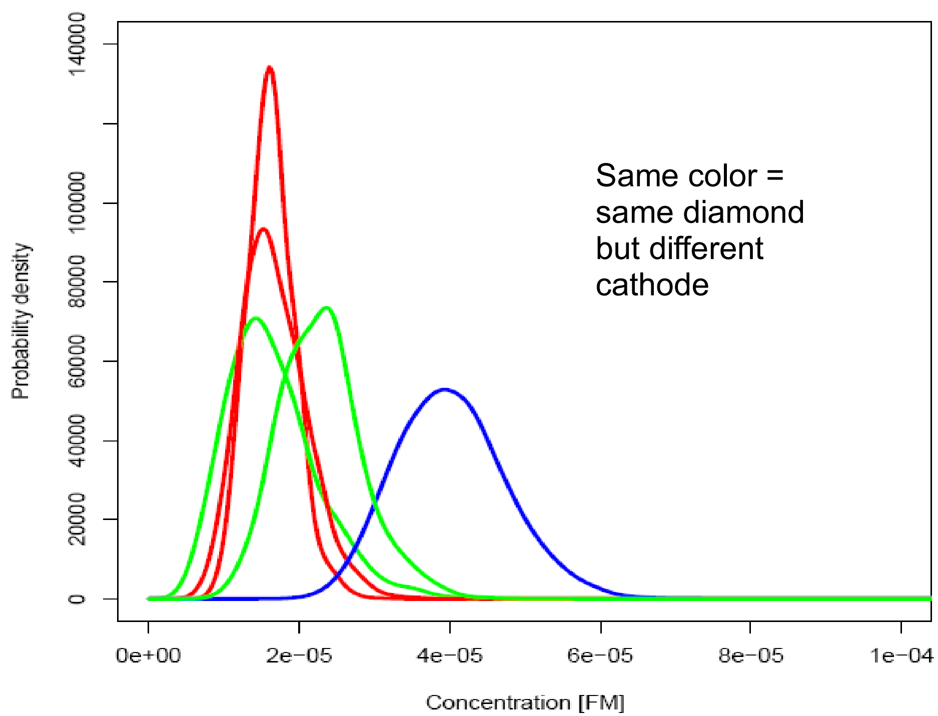


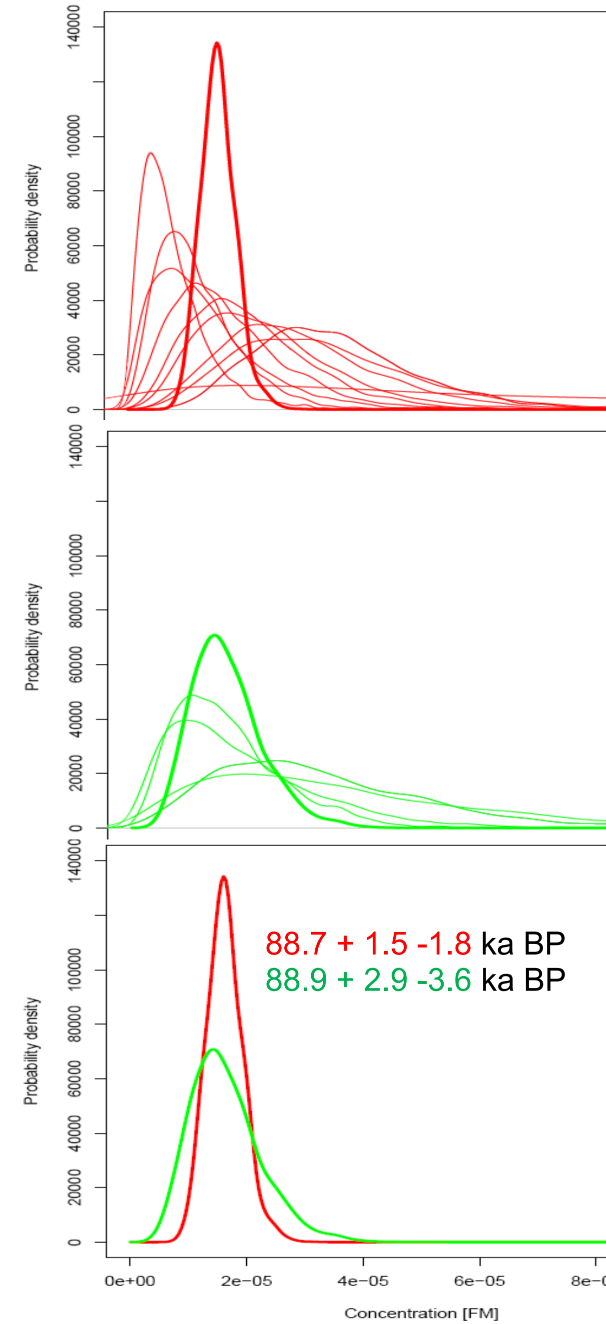
AMS as an example of the performance

- Good transmission
  - Not 100% but almost (for protons > 50%)
- Very low machine background
  - Natural diamond, hammered in cathode holder (no chemistry!)
  - Reasonable 13C current, but only a few 14C counts in 200 s
  - Requires Bayesian data analysis
- Fraction modern (FM of 1950 14C)
  - Converted to radiocarbon age (in years BP) by
  - Age = -8033*log(FM)
  - Examples:
    - Age11: 88700 +1500/-1800 years
    - Age22 : 88900 +2900/-3600 years

AMS performance

- Radiocarbon blanks (white diamond):
  - Thin lines = separate measurements for the same cathode
  - Thick lines = combined results
  - Results of the two cathodes combined
  - Three different diamonds (shown here in red, green, blue)



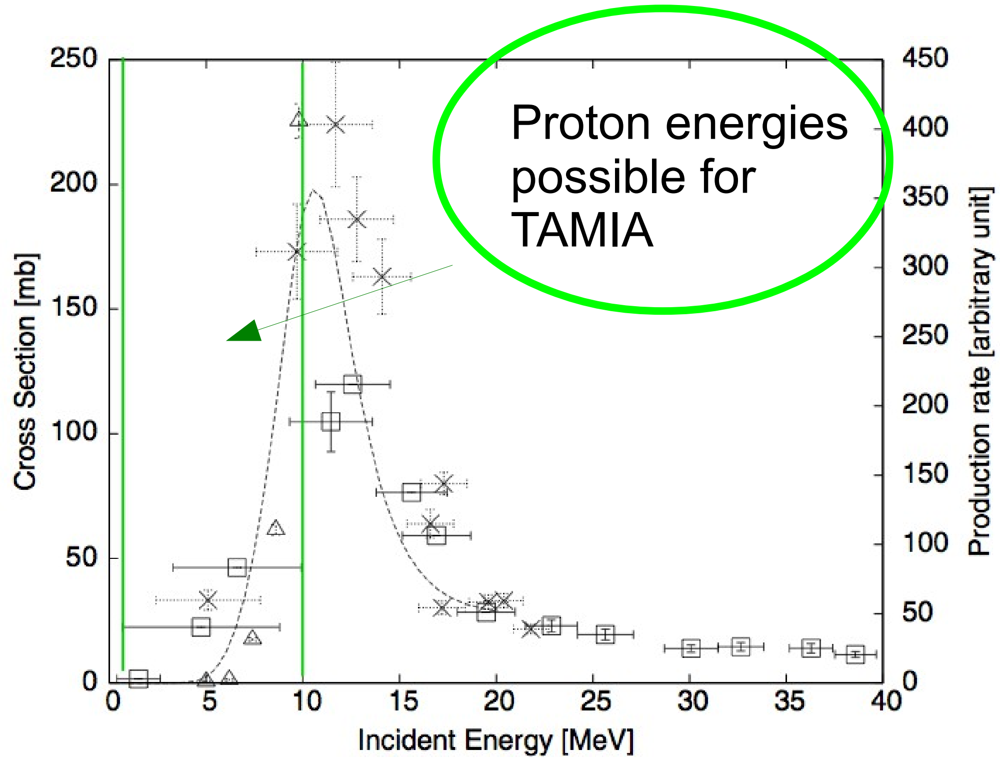


Back to the 60's: low-energy nuclear physics with 5-MeV tandem

- Measurement of excitation curves of reactions
  - Target preparation techniques advanced from the “early days”
  - Implanted targets, nitride/carbide composites
  - Compounds readily available in various form

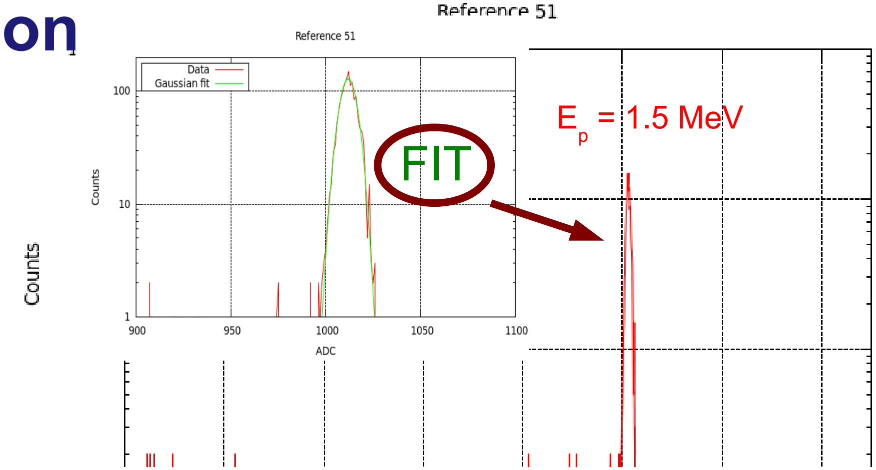
Example:
$^{133}Cs(p,n)^{133}Ba$, using CsI target

J. Granholm et al, J. Phys. G: Nucl. Part. Phys. **38** (2011) 015101

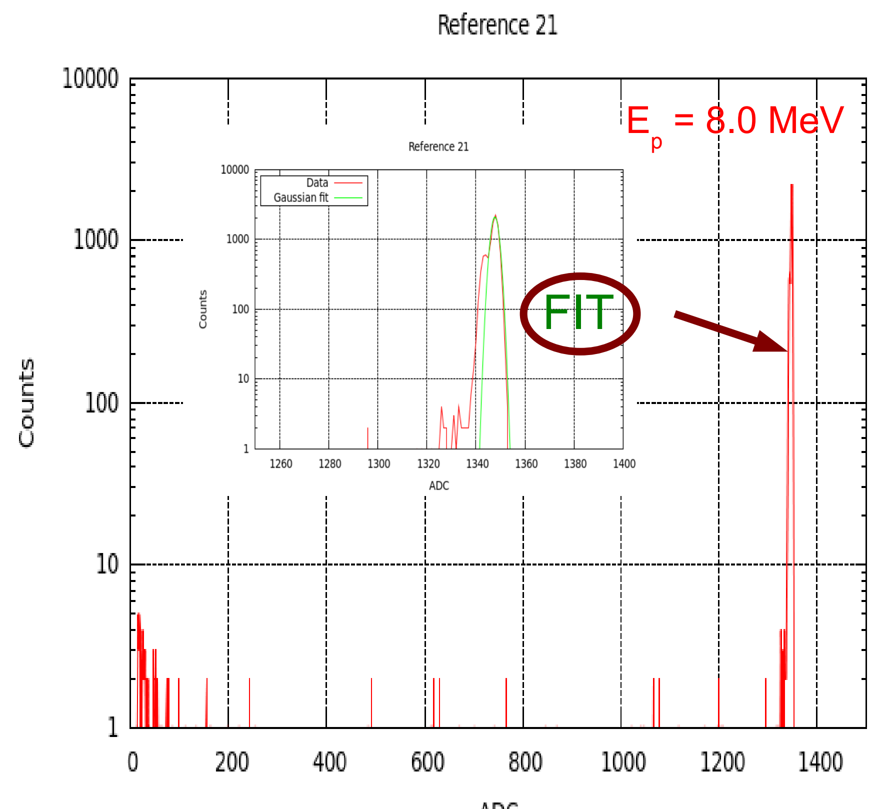


Low-intensity beams from MISS for detector calibration

- Aim of the experiment:
  - Energy calibration of particle detector
  - Detector will be launched to solar orbit
  - Very low intensity on target required:
  - 100 to 1000 protons at 1.5 to 10 MeV



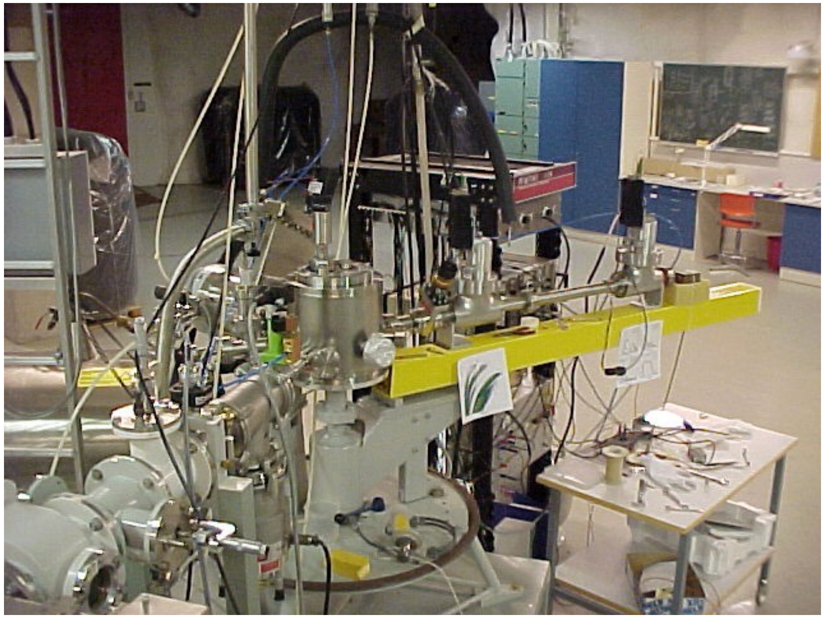
- Challenges:
  - Slit stabilization not possible
  - Need to rely on GVM
  - No signal from BPM

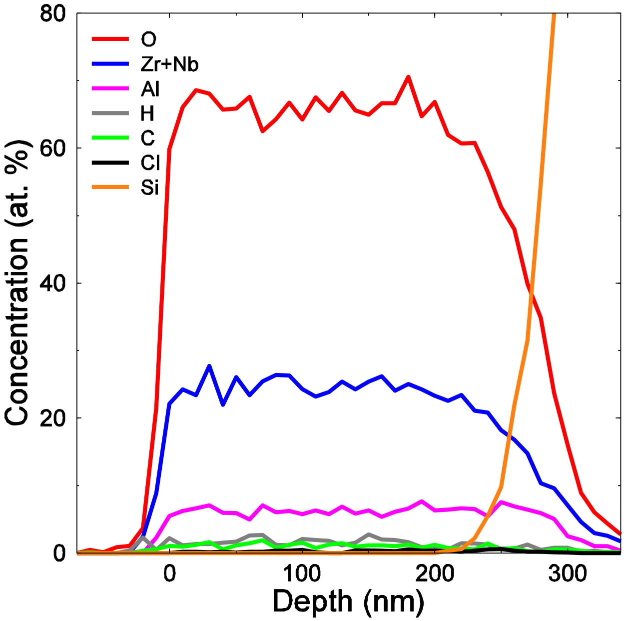


- Observed
  - Energies measured by particle detector and given by accelerator differ
  - Which one is correct?

TOF-ERDA of multilayers

- 35 to 60 MeV ions of Cl, Br, or I (the easiest!)
- Heaviest ion used: 197Au
- Two timing detectors (300 ps) + Si for total energy
- Replaced 15N NRA hydrogen profiling since 1995





Summary

- Modifications (before the shut-down in April 2010)
  - Easier/faster tune-up
  - Error diagnostics
  - Data stored for further use
  - Expandable by other tasks and devices
  - Modular, off-the-shelf components → flexibility
  - Encourage to further improvement
- Results after renovation
  - The accelerator building itself ready February 2011
  - Tandem in use from April 2012
  - Robust & reliable operation
  - No big mistakes, yet!
  - Development on-going

Thanks for the team

- Harri Tyrväinen (electrical engineer, automation & control design+software)
- Pasi Siiki (senior technician, electronics design+software)
- Raimo Ingren (technician, tandem operation, AMS runs)
- Pietari Kienanen (technician, tandem operation, AMS runs)
- Mikko Mannermaa (technician, electronics, CAD design)
- Sisko Vikberg (computer support)
- + mechanical workshop (3 persons)
- + researchers (mostly grad. students)
- + personnel of the Dating Laboratory (AMS sample prep.)