Proposal for an irradiation facility at the TAEK SANAEM Proton Accelerator Facility

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21st RD50 Workshop, CERN
14th November 2012

TURKISH ATOMIC ENERGY AUTHORITY

- Founded in 1956
- In charge of CERN relations since 2006
- Talks towards Turkish associate and eventual full membership at CERN are continuing.

SANAEM: Saraykoy Nuclear Research and Training Center
Just 40km from center of Ankara and METU

Google maps

Our Goal

This project aims to demonstrate

- *Technology transfer from CERN*
- *Industrial partnership between CERN and Turkish companies*
    - *Initial interest for an irradiation facility came from TAI (Turkish Aerospace Industries, Inc.) for space-qualified electronics research*
    - *The magnets for this facility are planned to be produced in Turkey, qualifying the company for future CERN contracts*
- *A facility in Turkey, useful for researchers from particle physics community*

SANAEM Proton Accelerator Facility

The purpose of TAEK SANAEM PAF is radioisotope production of

- ^{11}C, ^{13}N, ^{15}O, ^{18}F for PET (positron emission tomography)
- ^{201}Tl, ^{67}Ga, ^{111}In for SPECT (single photon emission computed tomography)
- ^{123}I

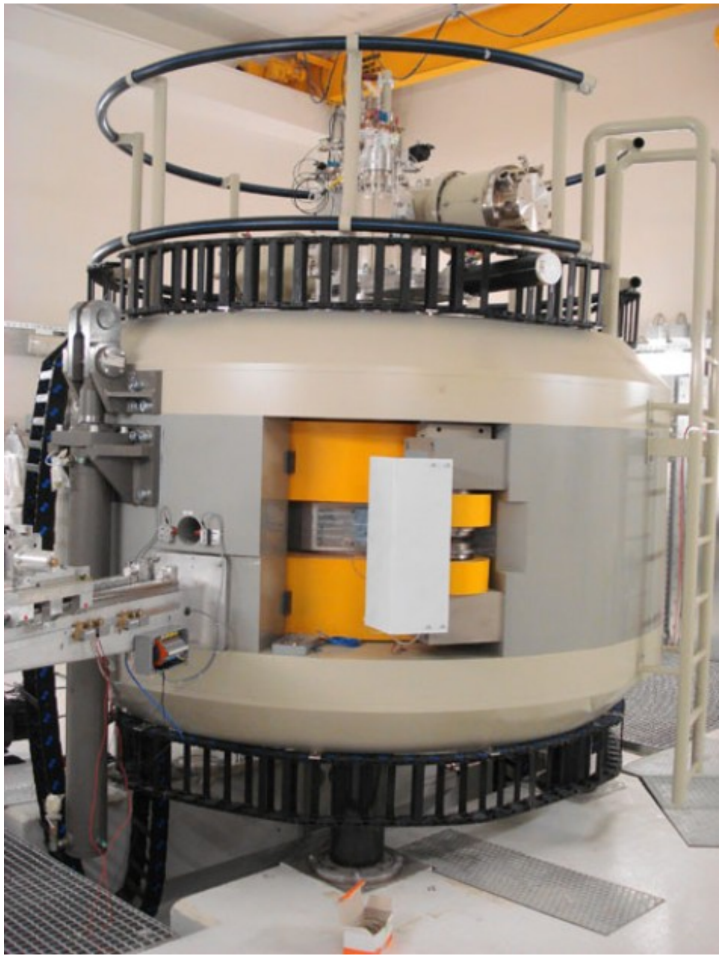
using 2 interoperable beam lines.

- Commissioned in 2011-2012
- Inaugurated on May 10th, 2012
- Ready to produce radioisotopes after the certification process which is ongoing

Photos from TAEK SANAEM PAF booklet

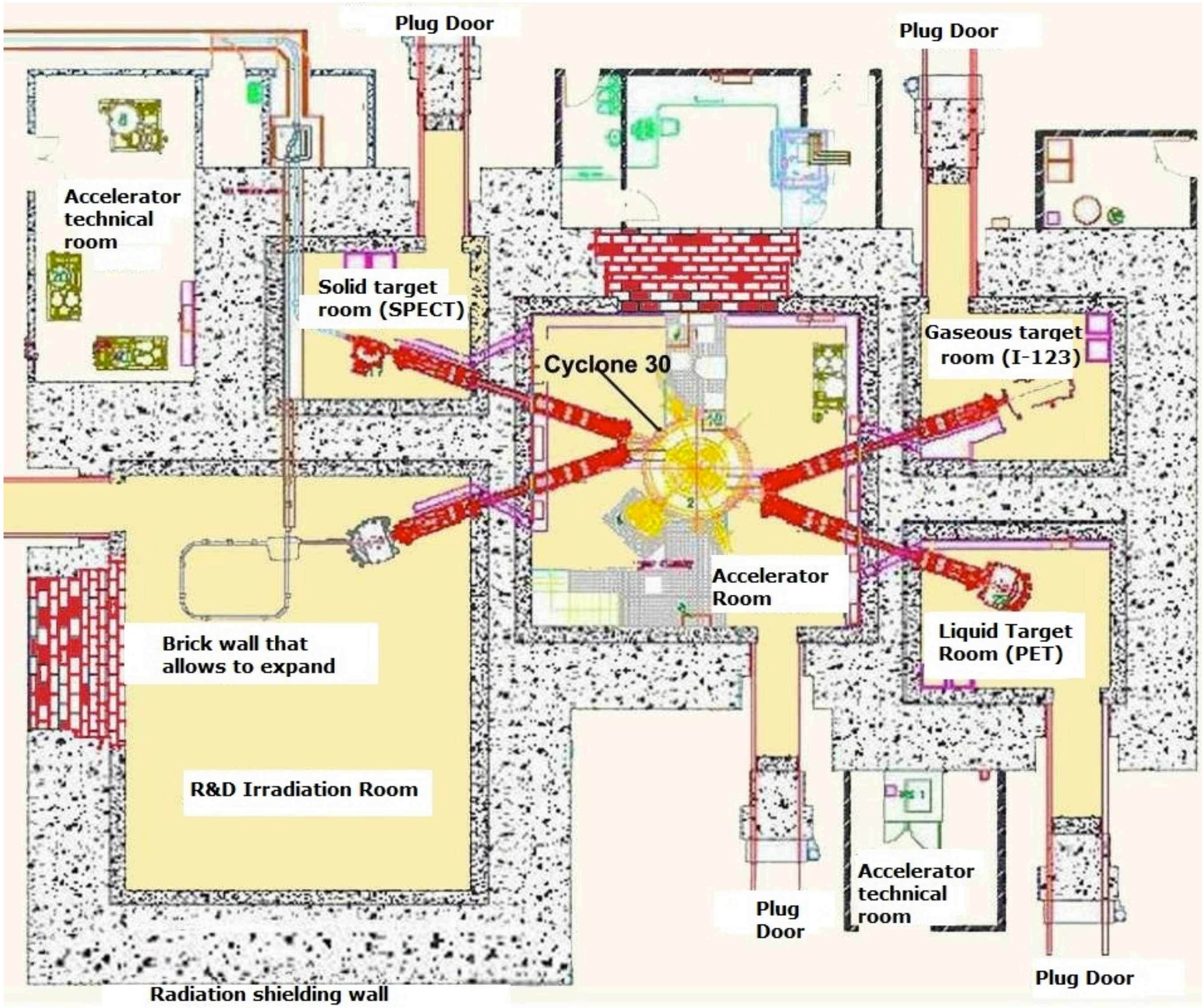
Cyclotron from IBA

Type - Model - Designer company	Circular - Cyclone30 - IBA (Belgium)
The total number of beam lines	4
Number of lines in the output of a single bundle	2
Number of simultaneous output beams	2
Accelerating ion type / Generated ion type	H^{-}/ H^{+} (proton)
Proton beam energy	15-30 MeV, variable With energy spread < 1%
Proton beam current	12 µA - 1.2 mA
Extractor	Carbon foil
Normalized beam spread	Horizontal <15mm.mrad Vertical <10mm.mrad
Magnetic field – magnet type	0.12 – 1.7 tesla – Deep Valley
Magnet mass	About 50 tons
Ion source system	External negative (multicusp)
Main vacuum system	Cyrogenic pump (4 units) <10^{-7} mbar
RF system	4 harmonic modes 65.5 MHz frequency
Maximum power consuption	150 – 180 kW(for 30 MeV and 1.2 mA)



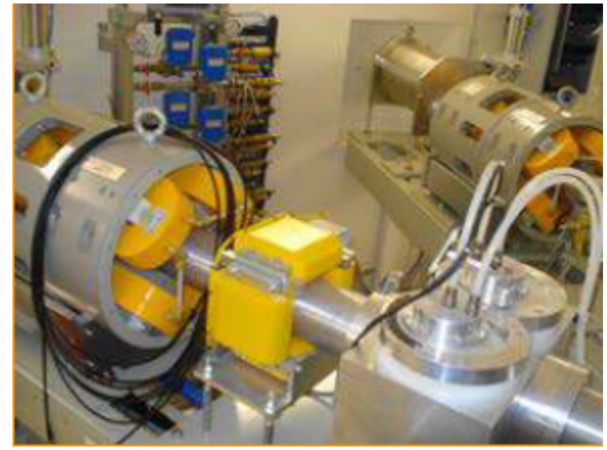
from TAEK SANAEM PAF booklet

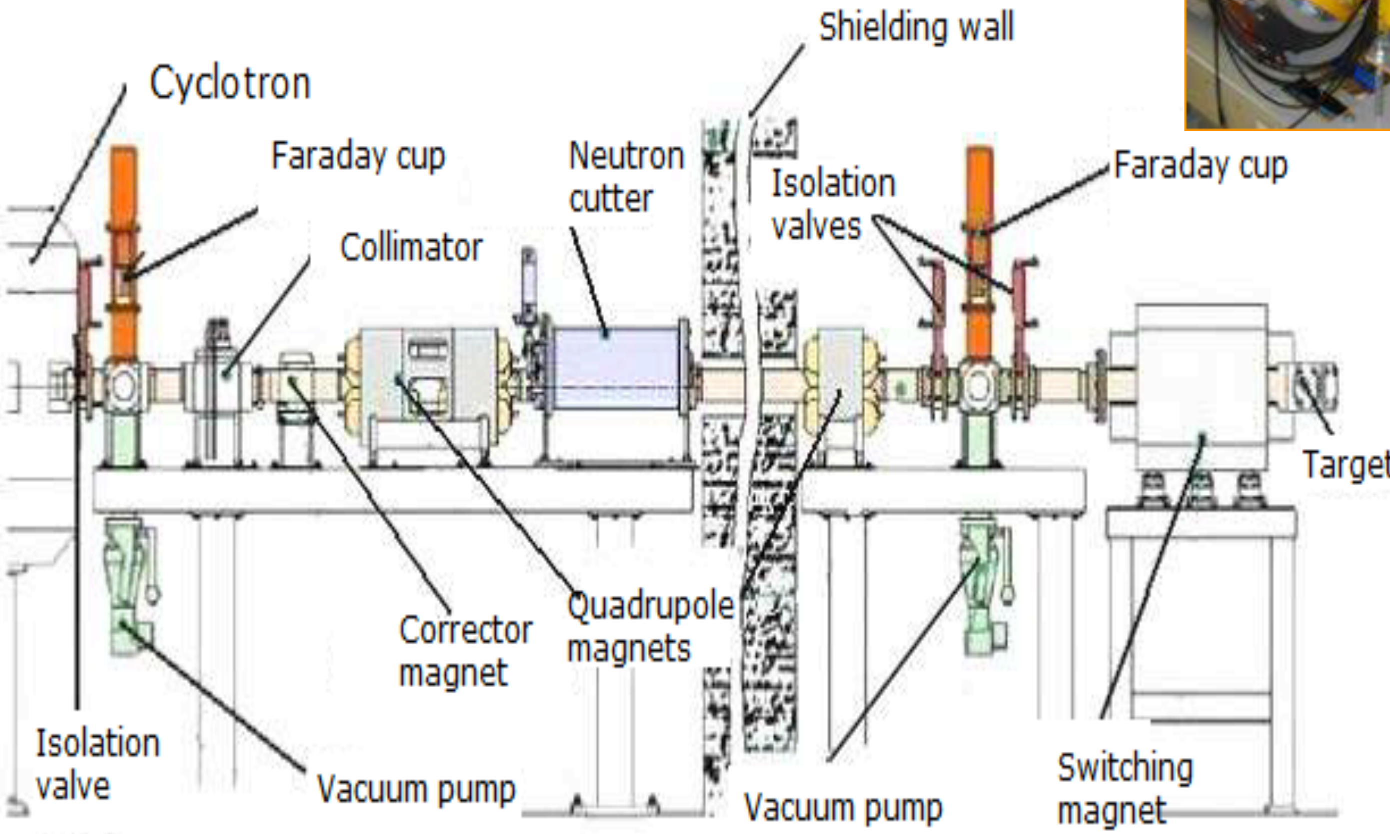
SANAEM PAF(Proton Accelerator Facility)



from TAEK SANAEM PAF booklet

Typical Transfer Line from the Cyclotron





Currently, there is no switching magnet in the R&D room but this is being planned by TAEK.

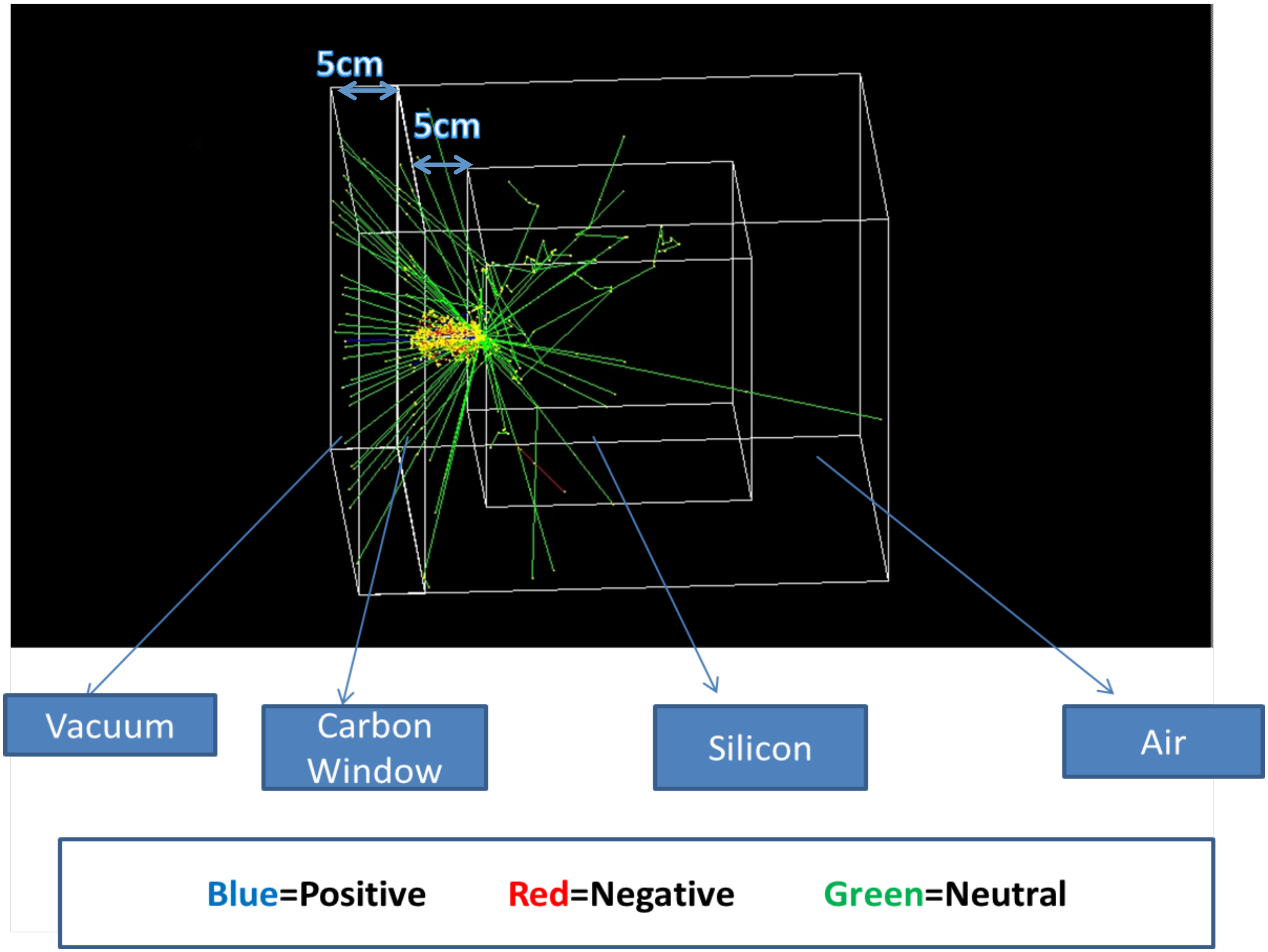
modified from TAEK SANAEM PAF booklet

Irradiation Facility

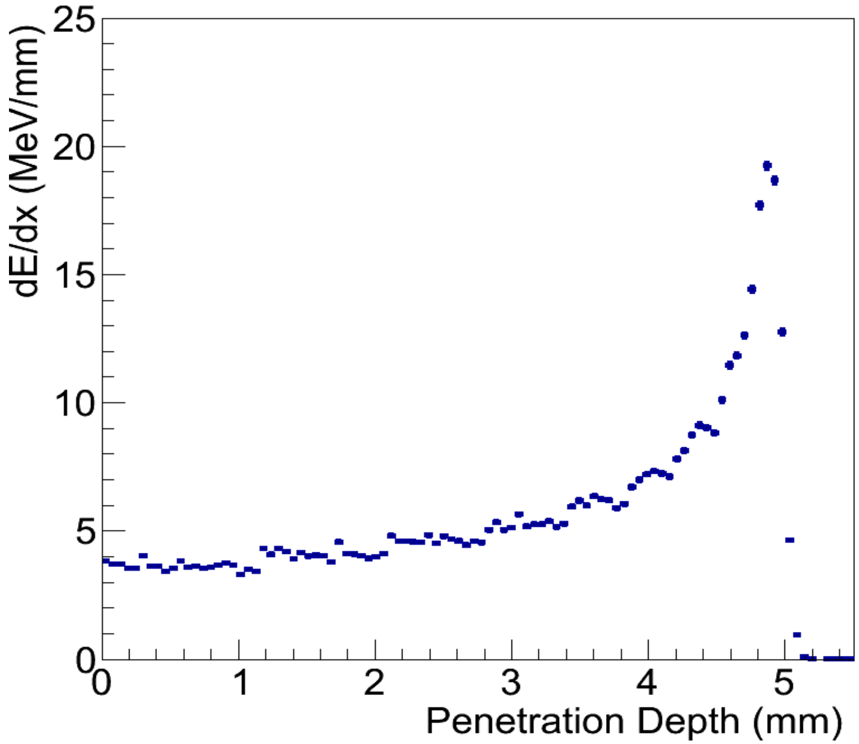
- Main interest: irradiating electronics cards, semi-conductor detectors
- 30MeV protons can penetrate 5mm of silicon
  - Can only test 1 layer at a time (maybe 2 or 3 if very thin!)
  - A robot to switch in/out the layers after required beam time
- Maximum current (12mA) is high→use lowest setting of 12μA
  - Max beam size of 1cm, corresponds to 2.5×10^{13} proton/cm^2/s
  - This is similar to Karlsruhe Proton Cyclotron KAZ facility
  - Hardness factor of approx 2** for 30MeV protons, 5×10^{13} n_{eq}/cm^2/s
- Blow up the beam to reduce the fluence and larger test area
  - Will still need cooling even if beam size is 5cm
- We have used
  - Geant4 to study the radiation parameters
  - MADx and Mathematica to study the necessary beam optics to blow up the beam

***A.Dierlamm, 16th RD50 workshop, 01/06/2010*

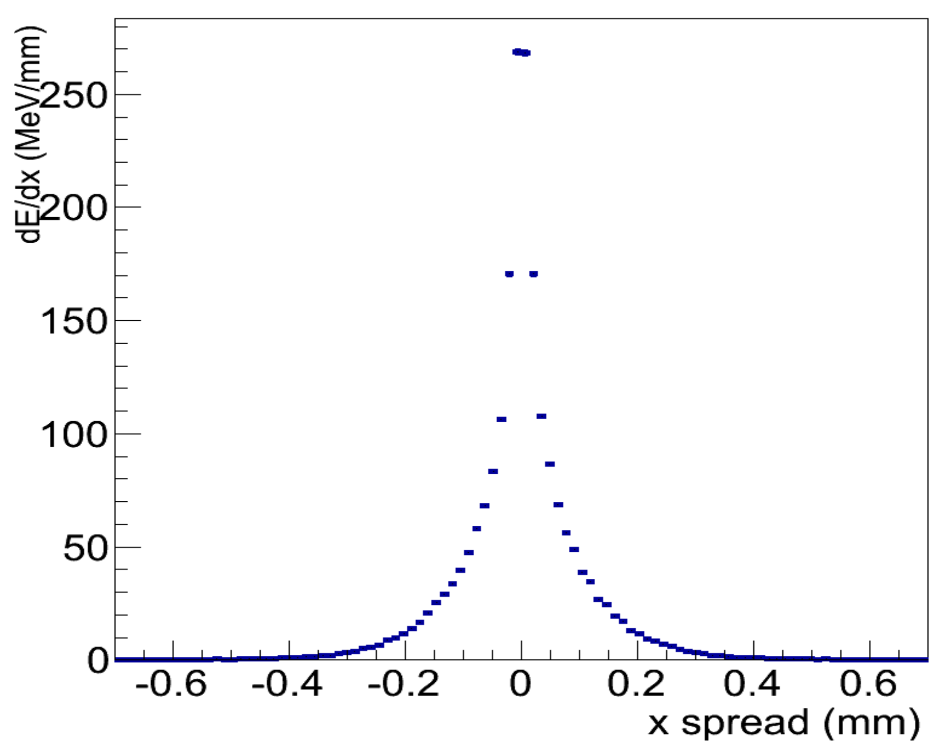
Geant4 simulation of 30 MeV protons hitting silicon target



Bragg peak for 30 MeV protons in Silicon

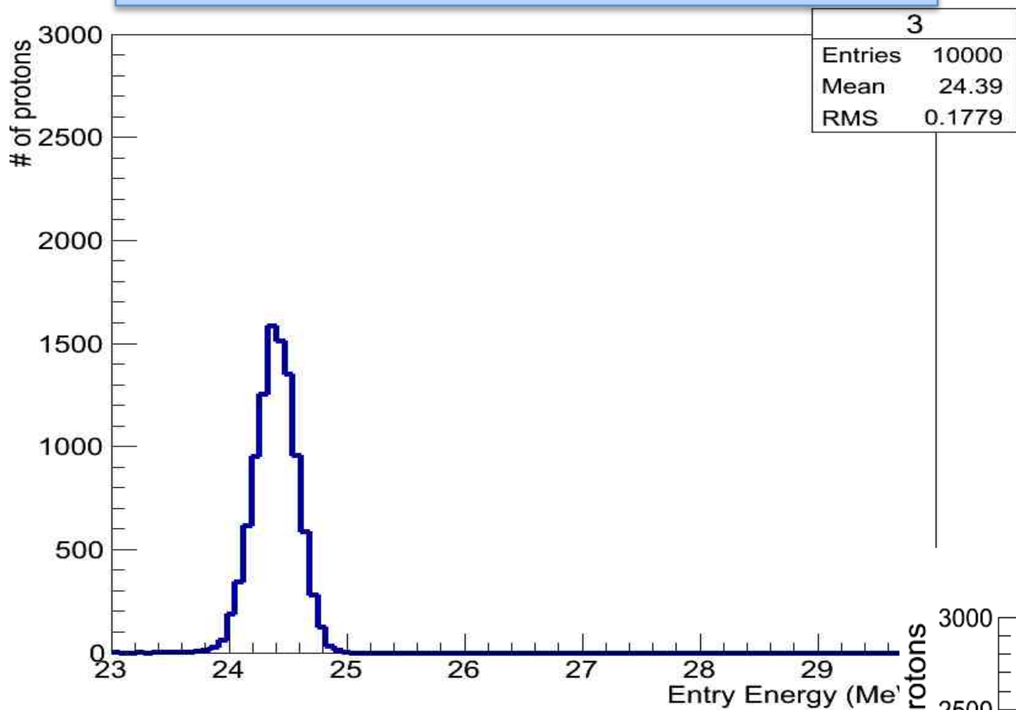


Transverse spread for 30 MeV protons in Silicon



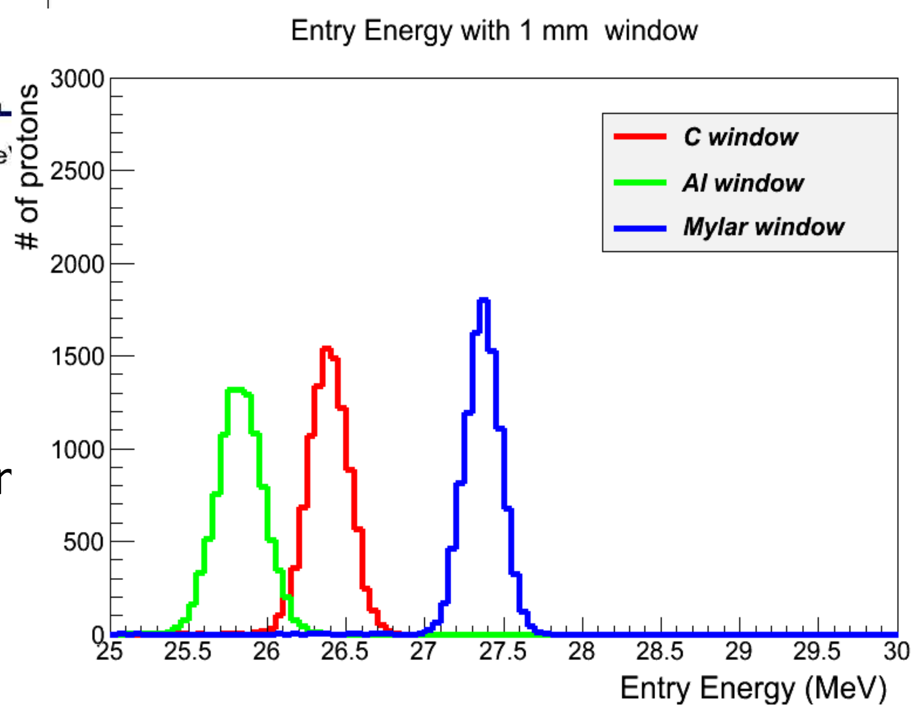
30MeV protons can penetrate 5mm of silicon and have a very small transverse position spread

Energy loss of 30MeV beam in 3m of air



Transfer line is foreseen to be about 3m long after switching magnet to give enough space between the other experimental stations and room for shielding

Energy loss in 3m of air is >5 MeV
→ Use beam pipe with vacuum and then a thin window to extract the beam
Current plan is to use Mylar with 1mr
Beam entry energy would be 27MeV and the window introduces minimal transverse spread in the beam

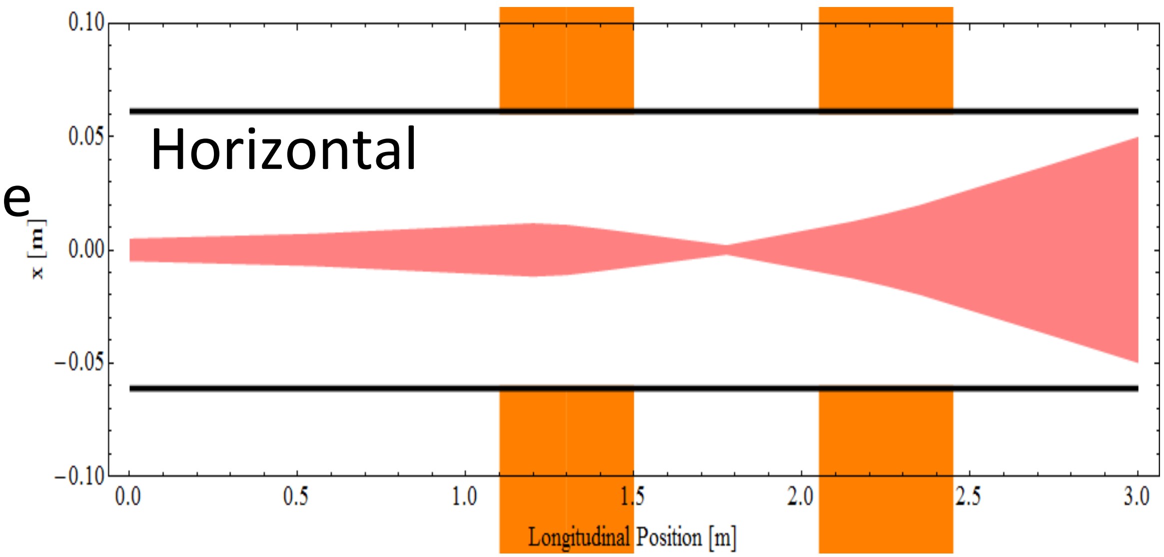


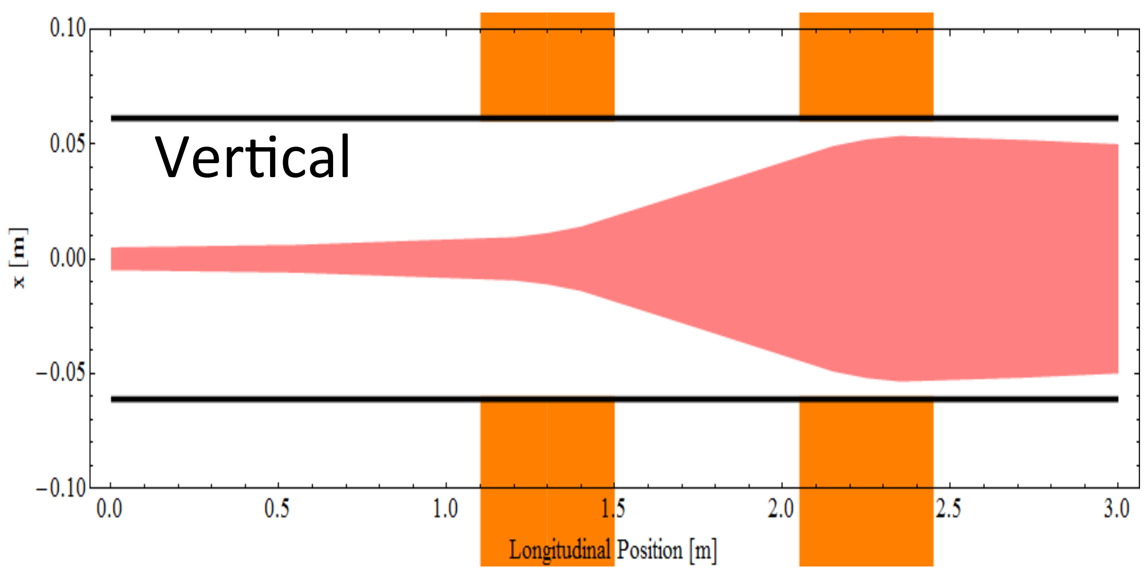
Beam line design

- Employ MADx to optimise the beam optics
- Input:
  - 2 quadrupole magnets and locations
  - Initial beam parameters (Twiss parameters)
    - emittance (in x and y)
    - beta and alpha (in x and y)
  - Final beam parameters
    - beta(in x and y)
- Output:
  - quadrupole coefficients
  - all beam parameters at exit

Constraint:
Beam size of 10cm at the irradiation location

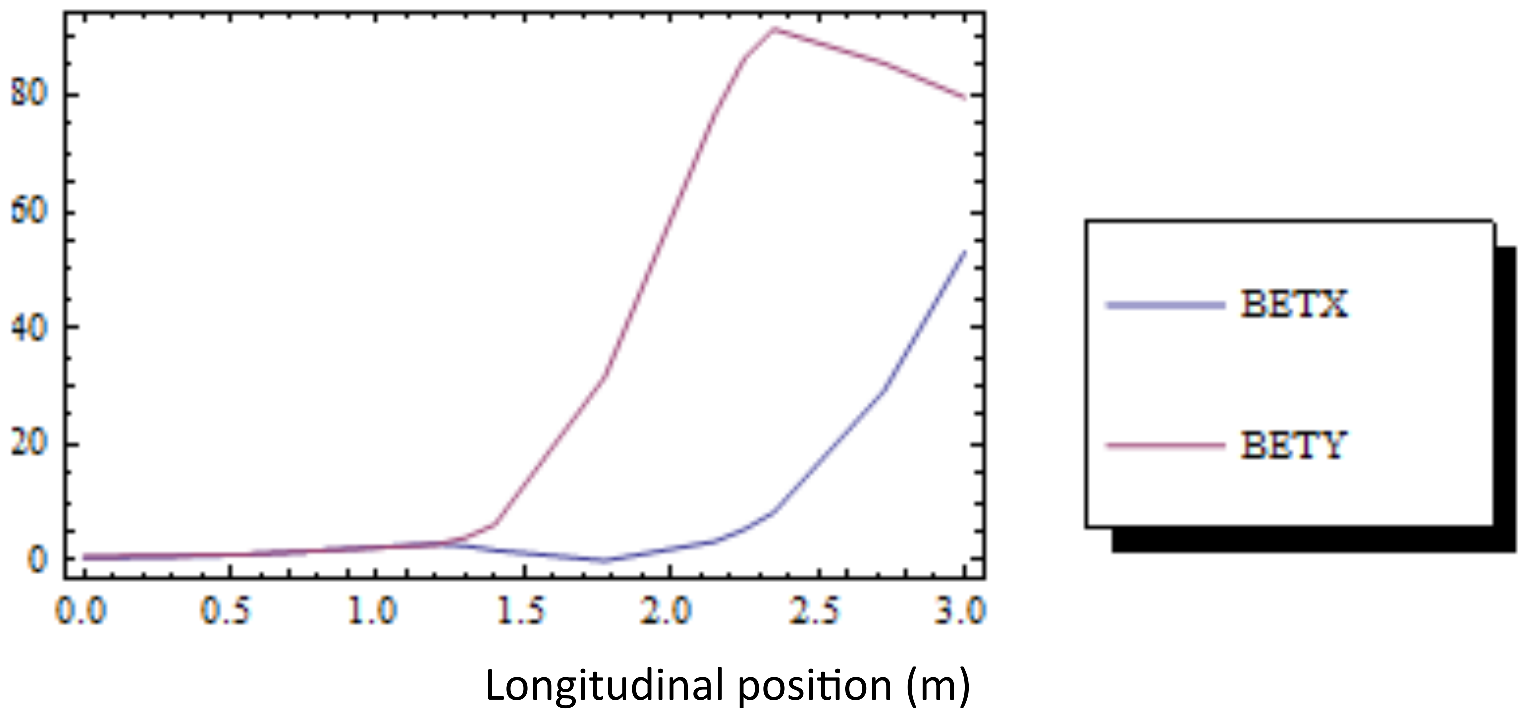
Quadrupole magnets shown in orange





Quadrupole coefficients
Q1: 9.05 m^{-2}
Q2: -2.70 m^{-2}

Twiss parameter beta for x and y axis for 10 cm beam size



What else?

- Collimator for the beam
  - Possibly right after the switching magnet
- Corrector magnets (dipoles) to make minor adjustments to the trajectory
- Faraday cup for assessing beam current
- Dosimeter for the irradiation dose
- Beam position monitors (BPM)
- Beam loss monitors (BLM)
- Robot
  - for moving the beam, in case larger irradiation area is required
  - Switching the component being tested
- Shielding from other experiments and for radiation sensitive test equipment

Conclusions

- Current design is flexible: beam energy from 15MeV to 30 MeV and beam size from 2cm to 10cm.
- Planning to file proposal in February to the Ministry of Industry, Science and Technology
- 3-year project: Sept 2013-Sept 2016
- At the end of which the facility would be available for use to the particle physics community

- *Special thanks to Dr. Ali Tanrikut and Alper Nazmi Yuksel from SANAEM PAF*