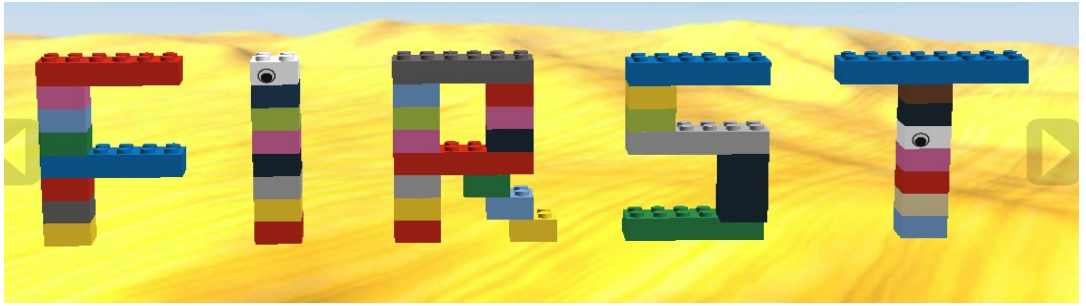

Fragmentation of
Ions
Relevant for
Space and
Therapy

INFN
Istituto Nazionale
di Fisica Nucleare

The Upstream Detectors of the FIRST Experiment at GSI

M. Anelli, E. Iarocci, **A. Paoloni**, V. Patera,
L. Piersanti, V. Patera, A. Sarti, A. Sciubba

TIPP 2011
Technology and Instrumentation in Particle Physics 2011

Instrumentation for Medical, Biological and Materials Research

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Detectors realization:
R. Rosellini, G. Corradi, D. Tagnani, E. Dane', S. Cerioni (LNF)

BTF tests:
A. Mengucci, B. Buonomo, L. Foggetta (LNF)

LNS tests:
C. Agodi, F. Romano (LNS)

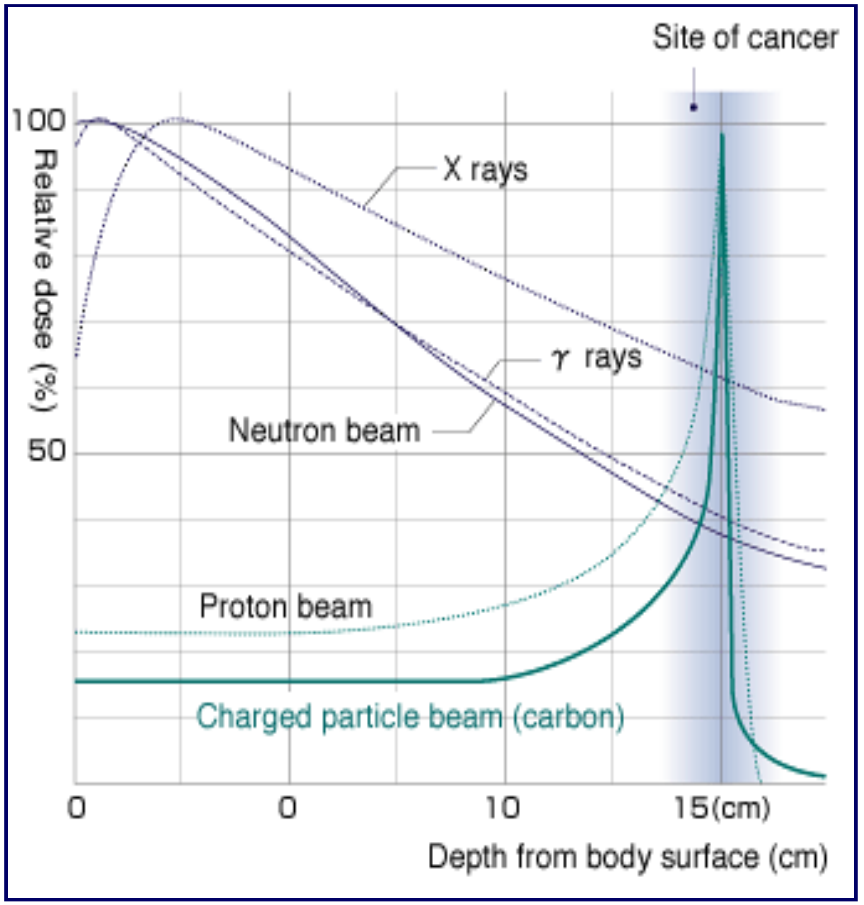
Hadrontherapy with 12C ions

Light ions advantages in radiation treatments of tumor with IMRT:

Better Spatial selectivity in dose deposition

Reduced lateral and longitudinal diffusion

High Biological effectiveness

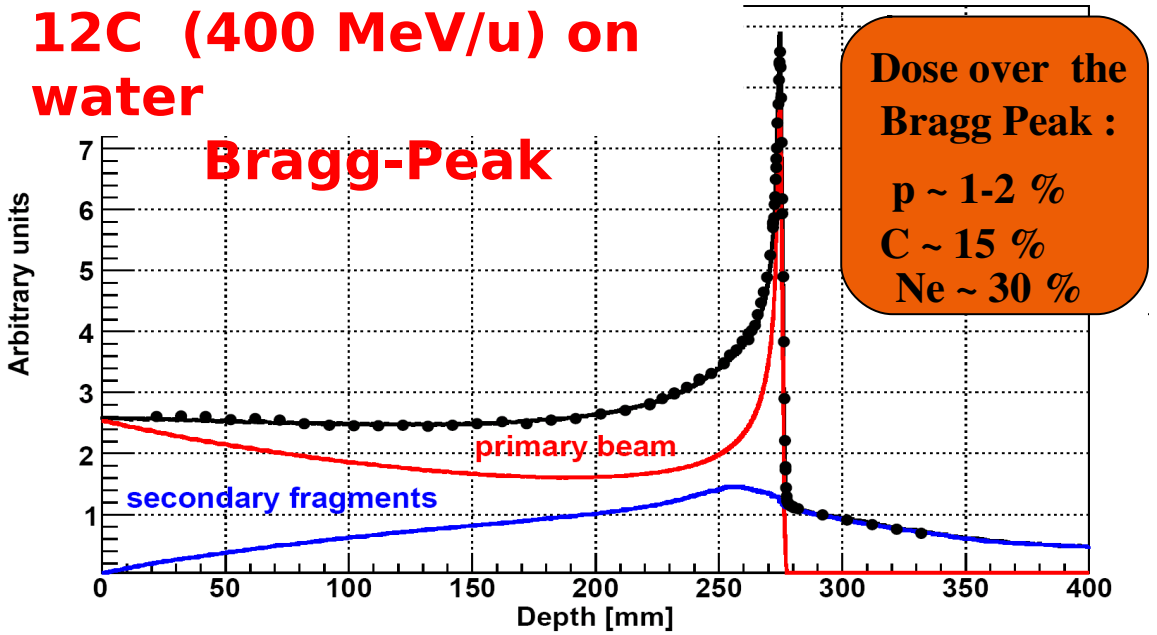


Fragmentation of 12C ions

Production of fragments with higher range and different direction wrt to primary ions;

Attenuation of the primary beam;

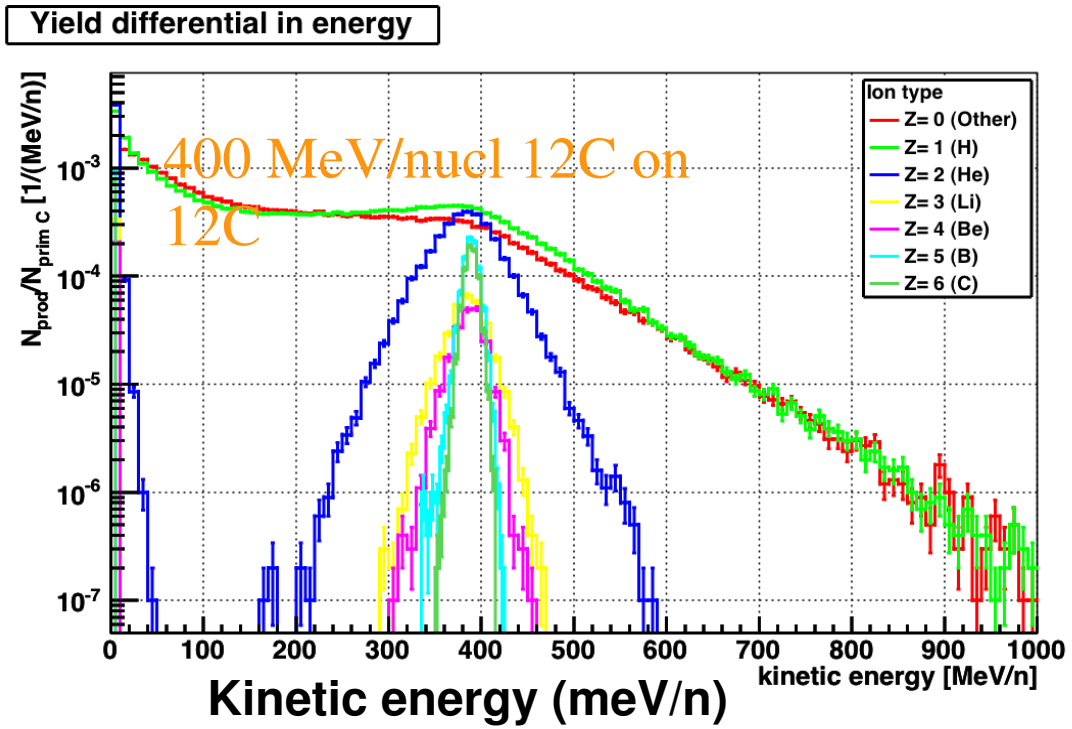
Different biological effectiveness of the fragments wrt to 12C ions.

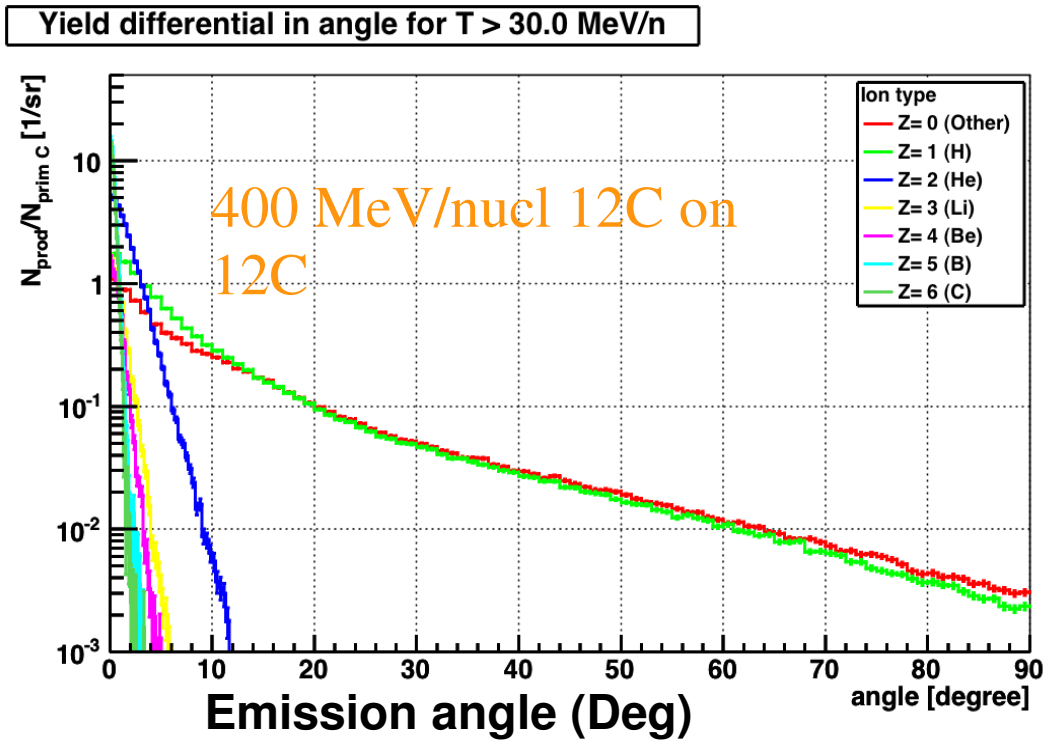


Exp. Data (points) from Haettner et al, Rad. Prot. Dos. 2006
Simulation: A. Mairani PhD Thesis, 2007, Nuovo Cimento C, 31, 2008

A lot of measurements on thin targets, but very few with fragment angular and energy distributions, in the energy range of interest for hadrontherapy.....

Fluka MC Simulation





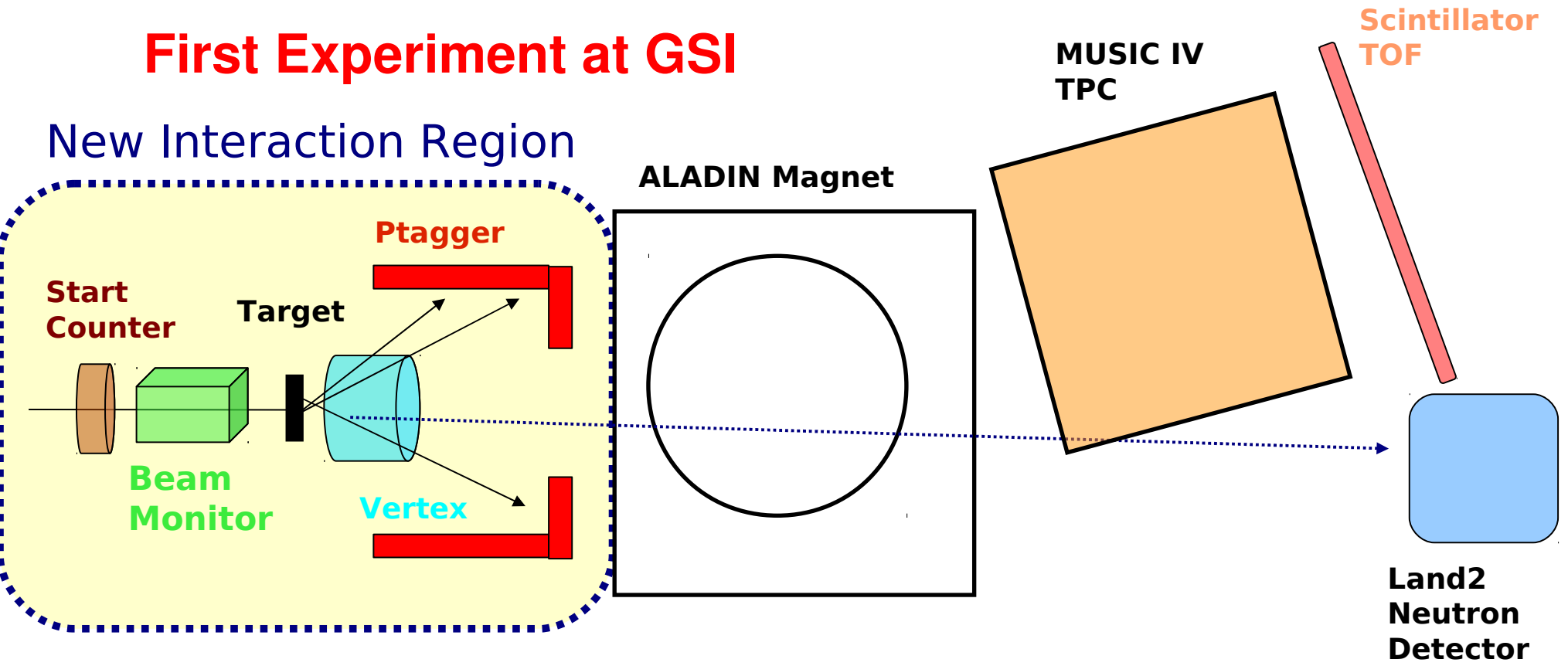
Protons are by far the most abundant fragments with a wide velocity range ($0<\beta<0.6$) with a wide angular distribution.

Z=2 fragments are emitted within 10^{o} around the projectile direction.

Z>2 fragments approximately have the same velocity of 12C beam projectiles and are collimated in the forward direction.

The dE/dX of the fragments spans from ~2 to ~100 m.i.p.

First Experiment at GSI



Run 2011: 12C @ 200-400 MeV/nucleon on carbon target

The FIRST experiment is designed to identify all the fragments (0<Z<6) and to measure their energy and direction.

Scintillator Start Counter: Trigger and T0 for TPC and TOF wall

Beam Monitor: Beam direction and impact point on target

Si pixel vertex detector: fragments emission angle

TPC: Z/p, θ, φ after bending, dE/dX ~ $(Z/\beta)^2$

Scintillator TOF wall: TOF=f(Z,p,θ,φ)/β

Ptagger calorimeter:p(He) detection/discrimination through TOF and dE/dX

BEAM MONITOR

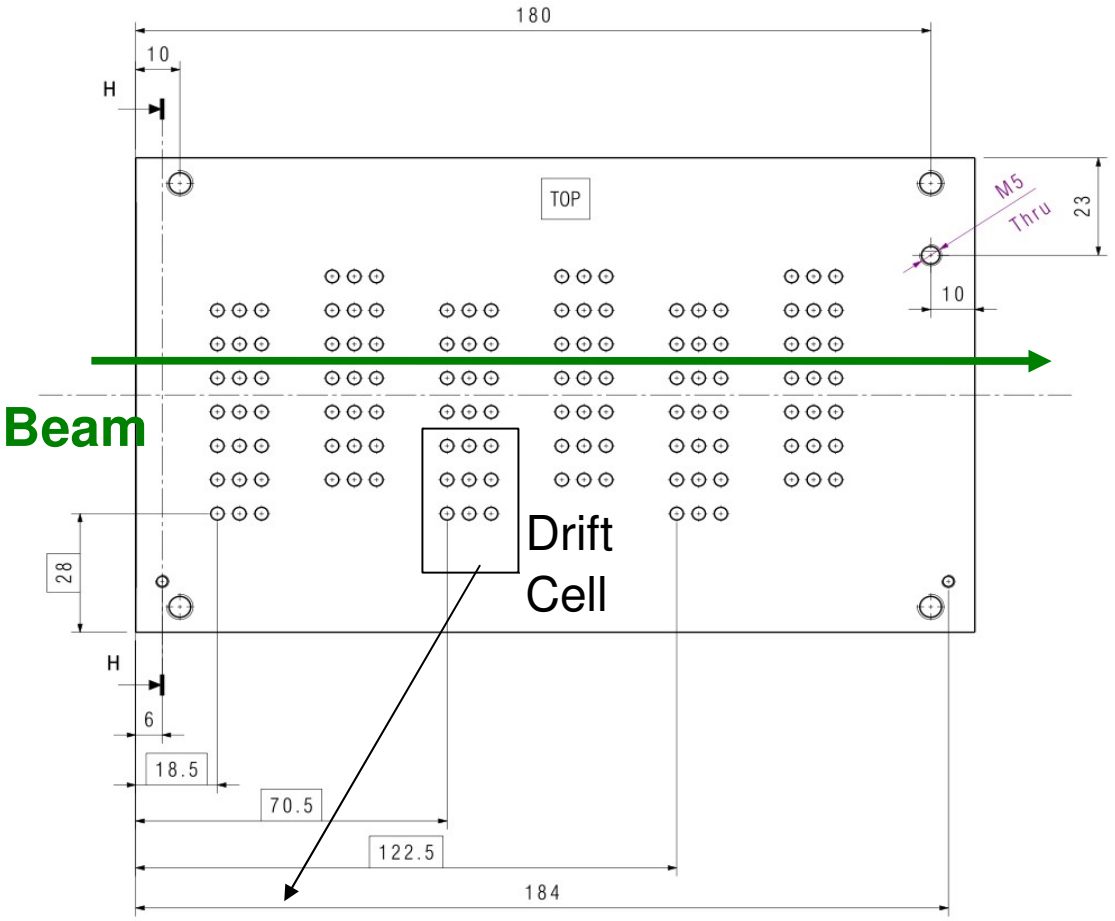
Rectangular Drift Cell (8 mm drift space)

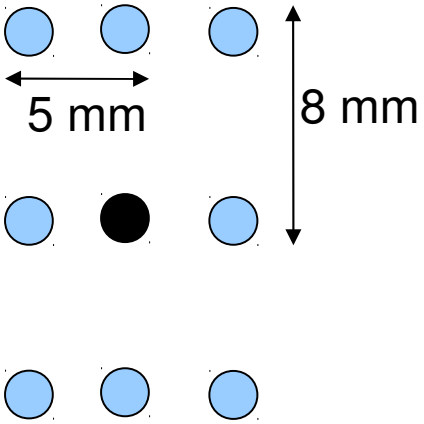
Six staggered planes/view

Less beam interaction with the wires

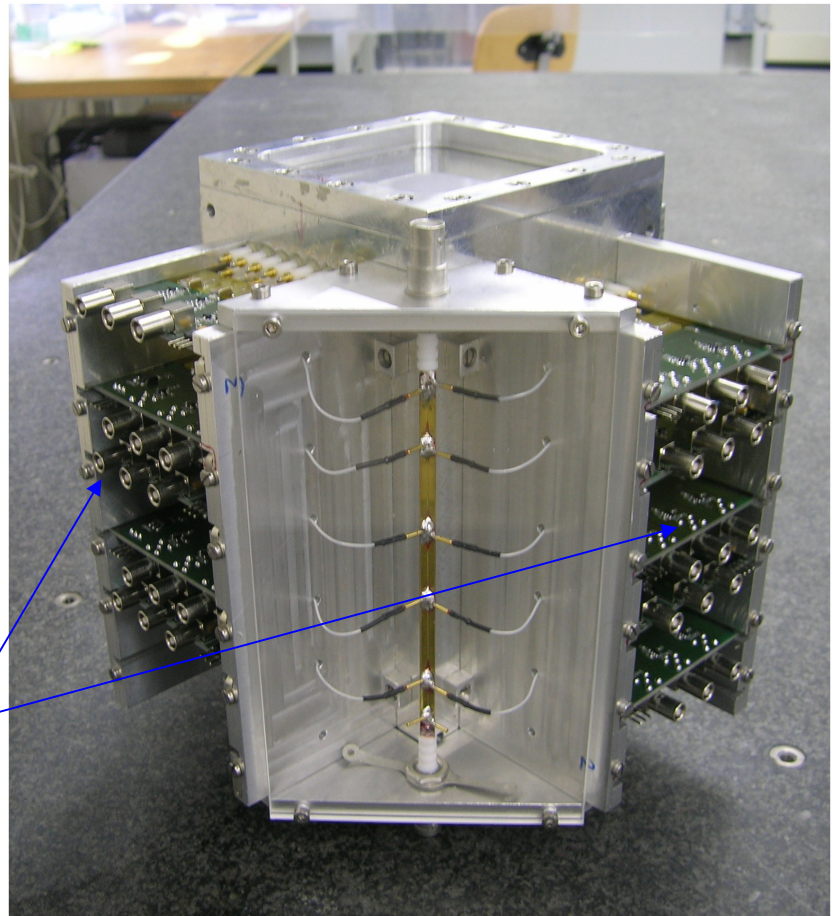
Less border effect in the space-time relations

Tracking redundancy

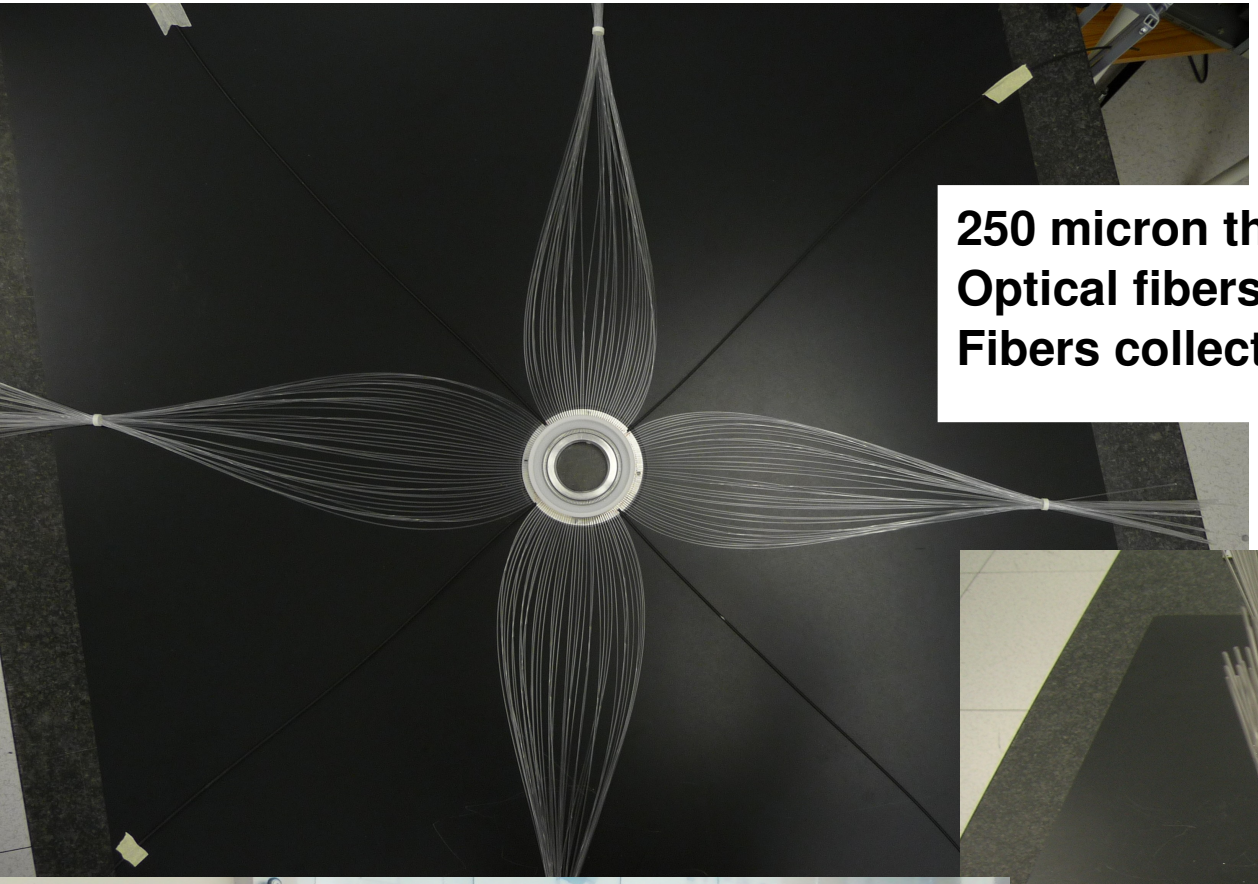




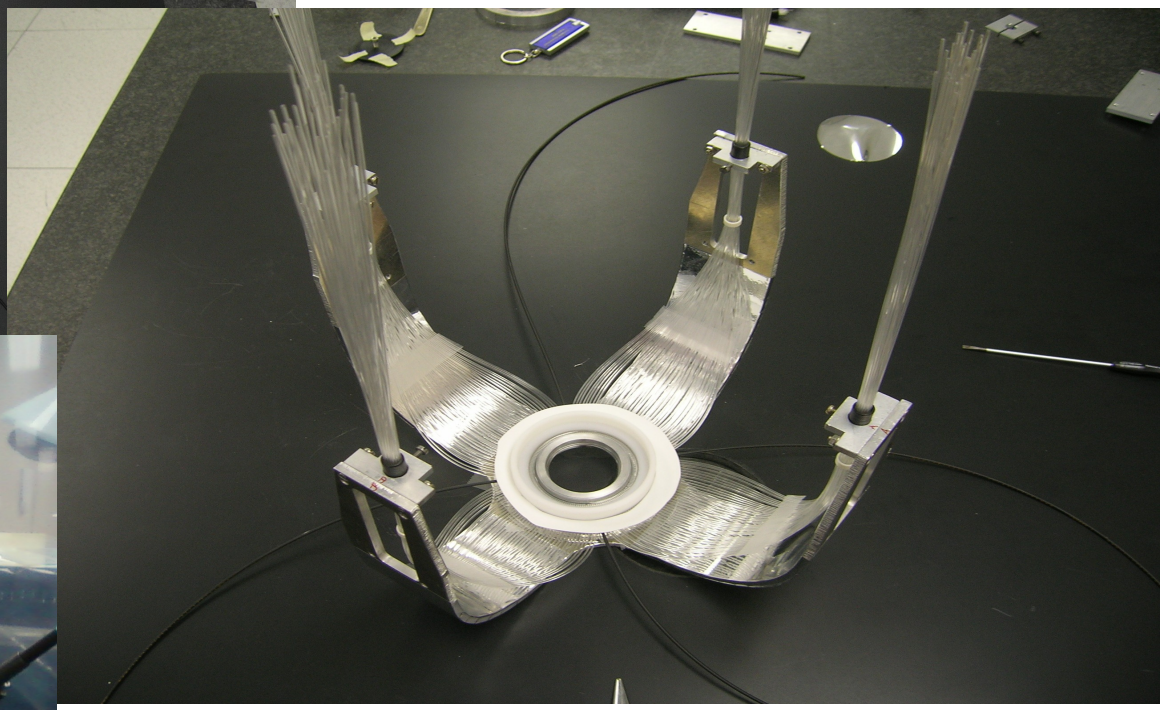
Front-End Electronics (Gain=10)



START COUNTER



250 micron thick scintillator disc (5 cm diameter)
Optical fibers for light transmission
Fibers collected in 4 bundles



Scintillator: EJ-228 (Pilot U)

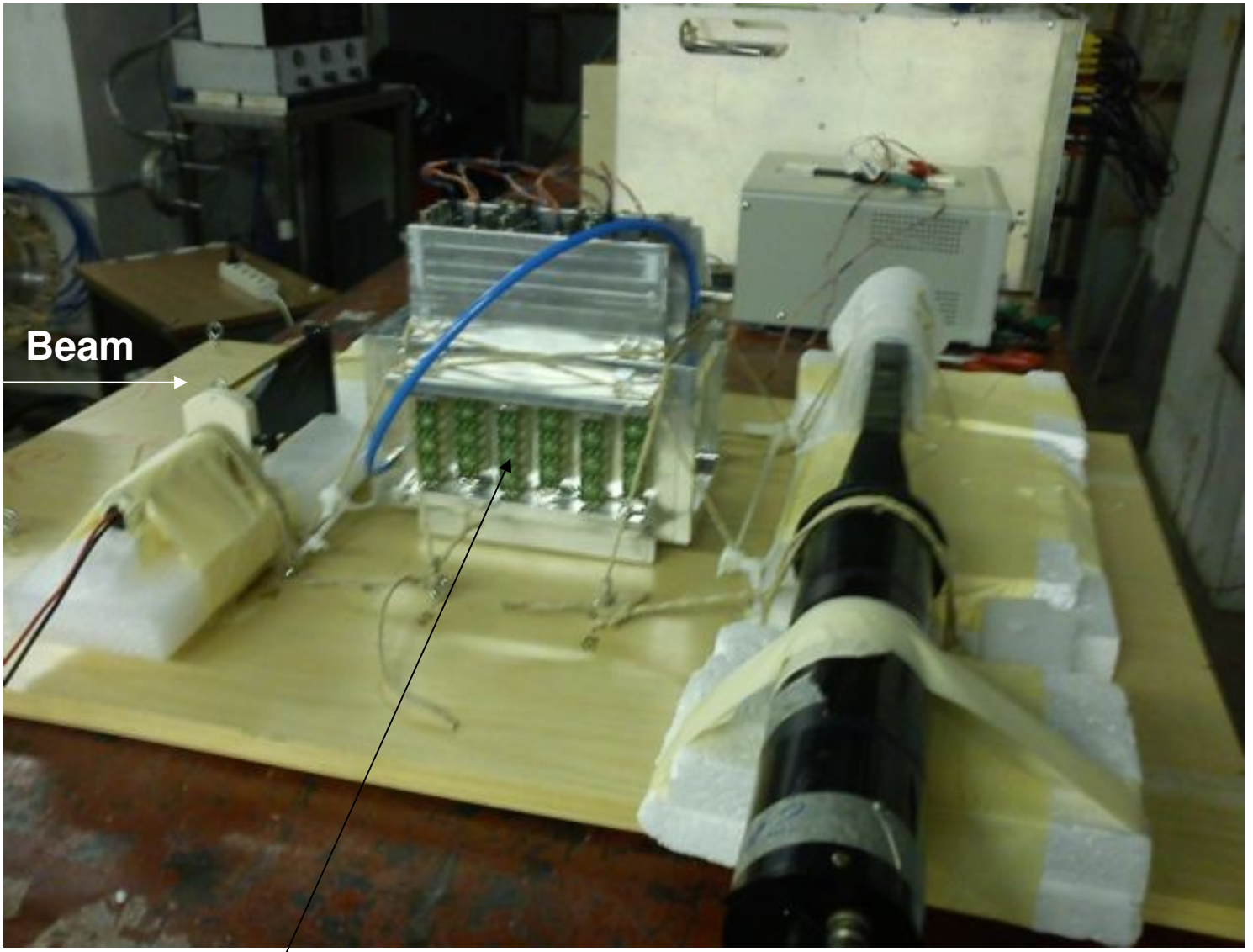
PMTs: Hamamatsu UBA H10721-201

BTF Test Beam at LNF

500 MeV electrons: 10 ns spills at 25 Hz.

$<N_e>=1$, Poisson statistics → Calorimeter for single electron selection.

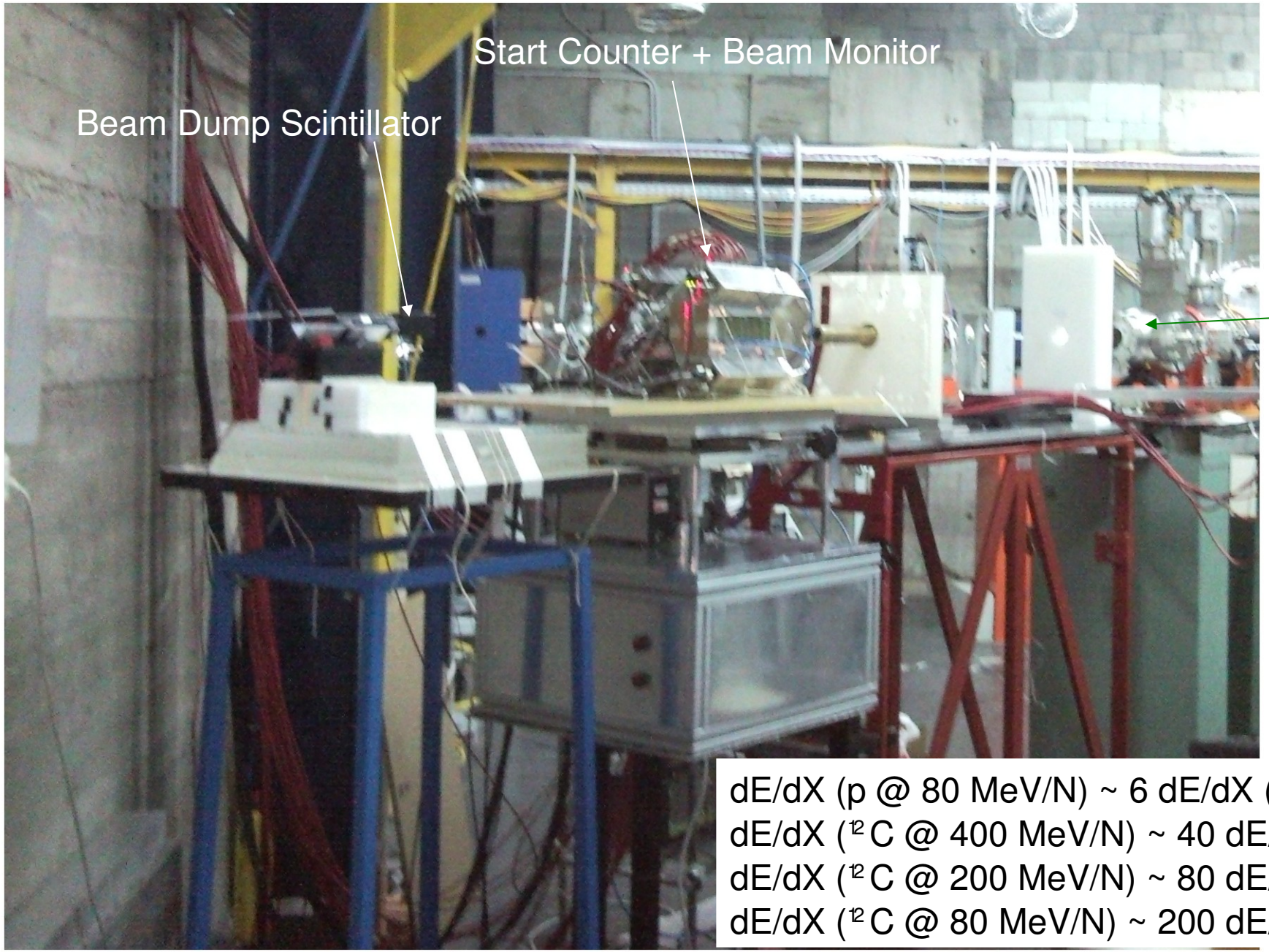
Dedicated to Beam Monitor gas mixture studies



Lead glass
Calorimeter

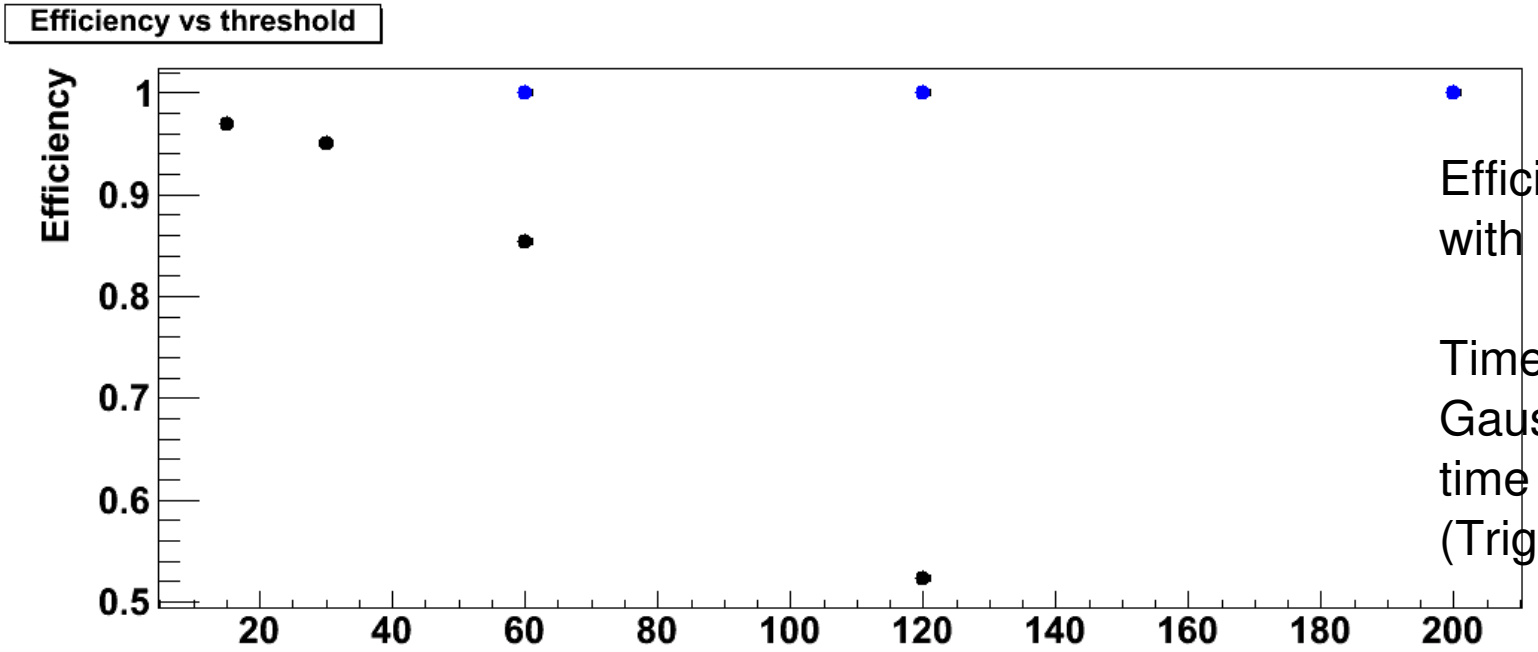
LNS Test Beam @ Catania

Protons and Carbons @ 80 MeV/nucleon ; Rate ~ 1 MHz
Final test of the detectors in GSI-like conditions (high ionization)



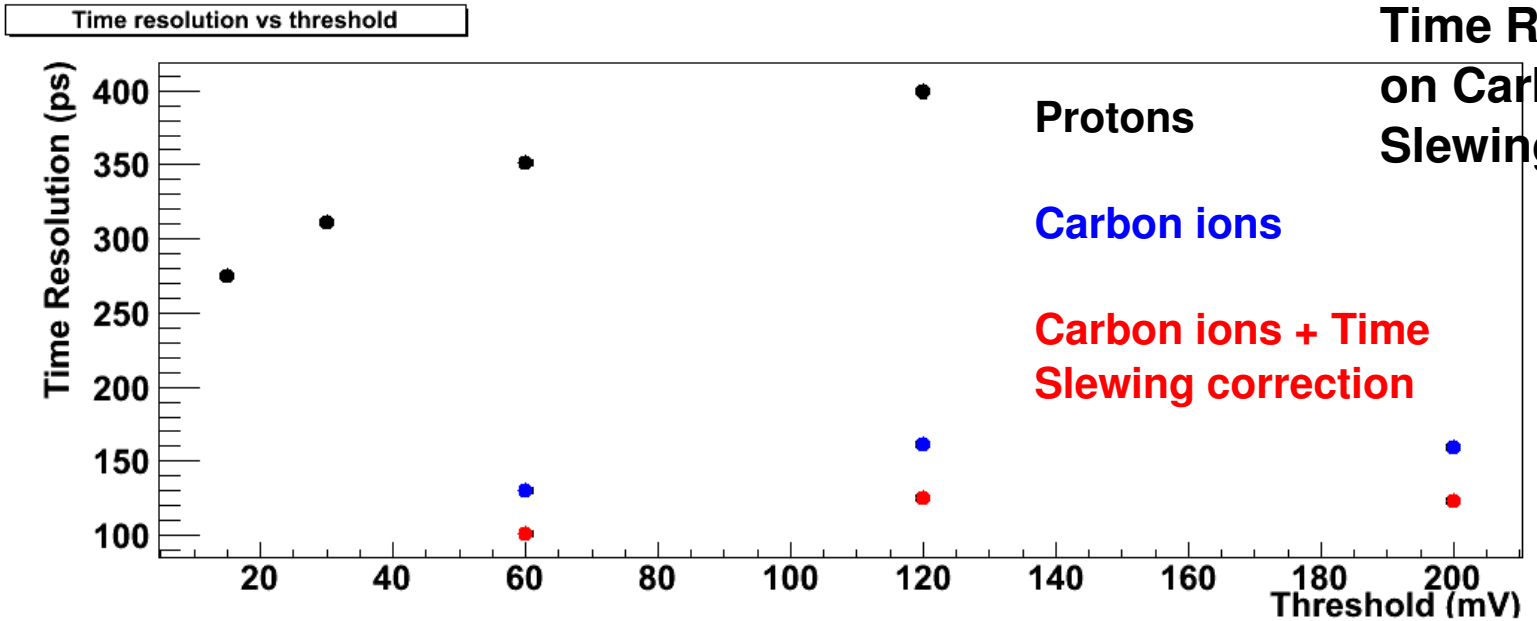
dE/dX (p @ 80 MeV/N) ~ 6 dE/dX (mip)
dE/dX (^{12}C @ 400 MeV/N) ~ 40 dE/dX (mip)
dE/dX (^{12}C @ 200 MeV/N) ~ 80 dE/dX (mip)
dE/dX (^{12}C @ 80 MeV/N) ~ 200 dE/dX (mip)

Start Counter Test Beam Results



Efficiency: fraction of events with at least 3 fired petals.

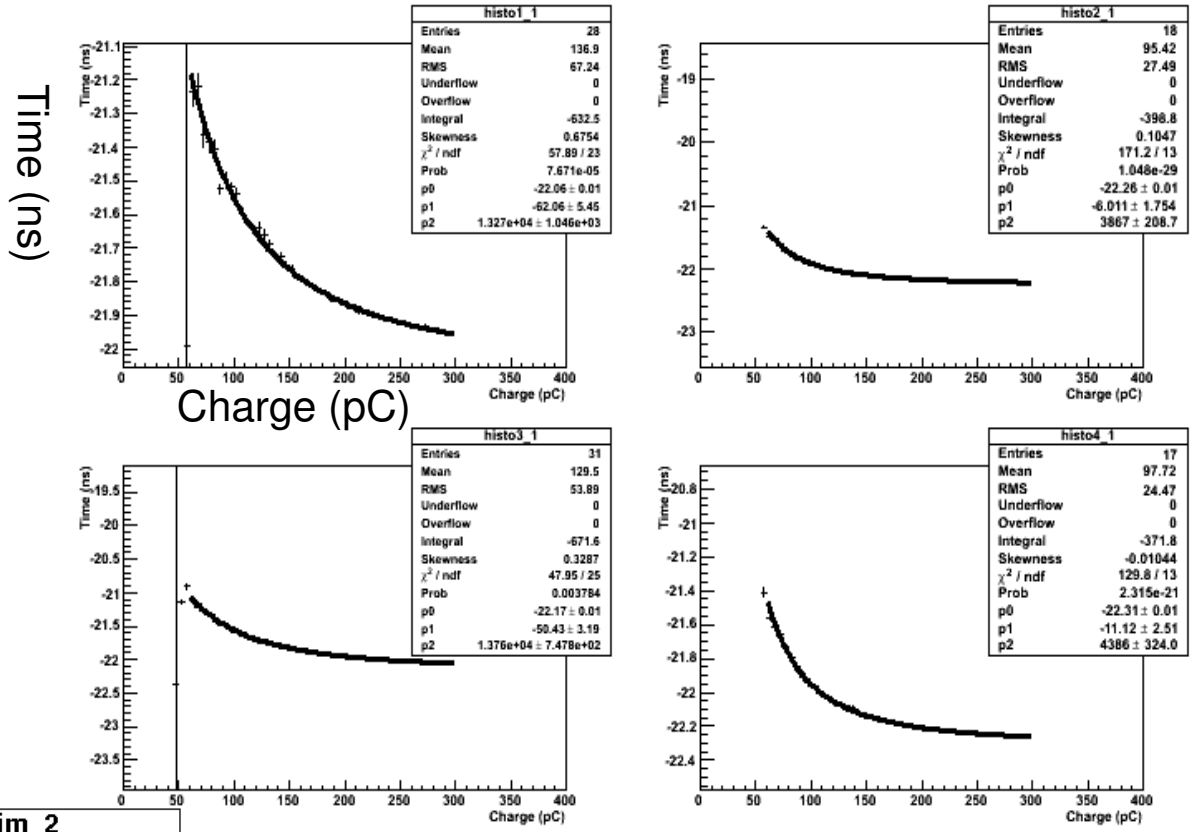
Time resolution estimation: Gaussian fit on first petal time wrt to Beam Dump (Trigger) time.



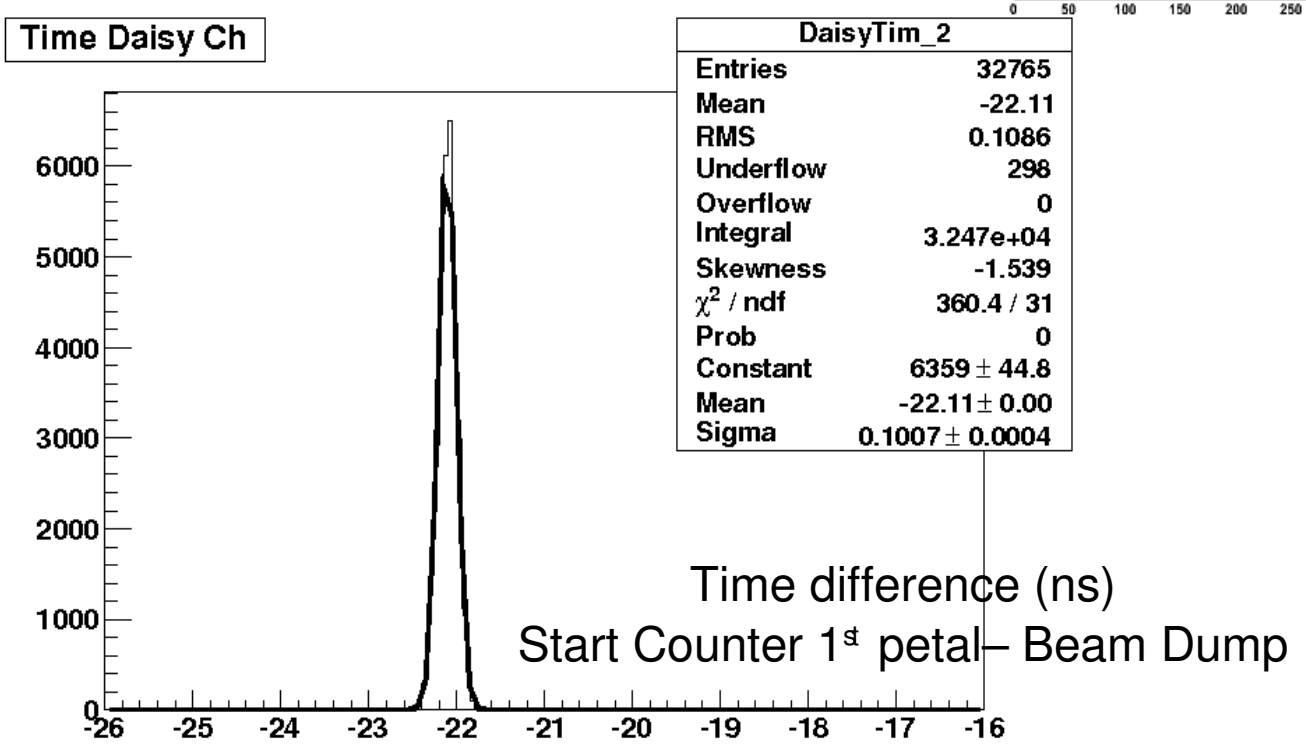
Time Resolution ~ 100 psec on Carbons, after Time Slewing correction.

Time Slewing correction

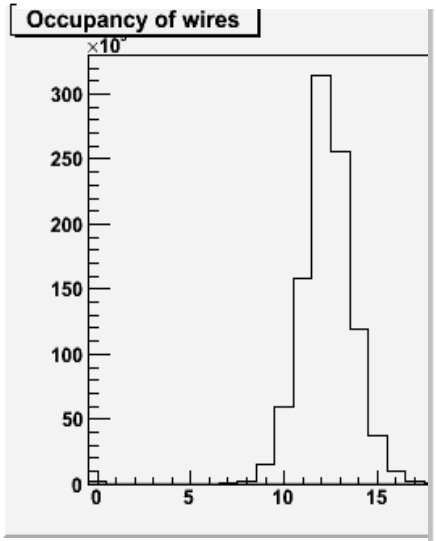
Carbon ions @ 80 MeV/nucleon
Threshold = 60 mV



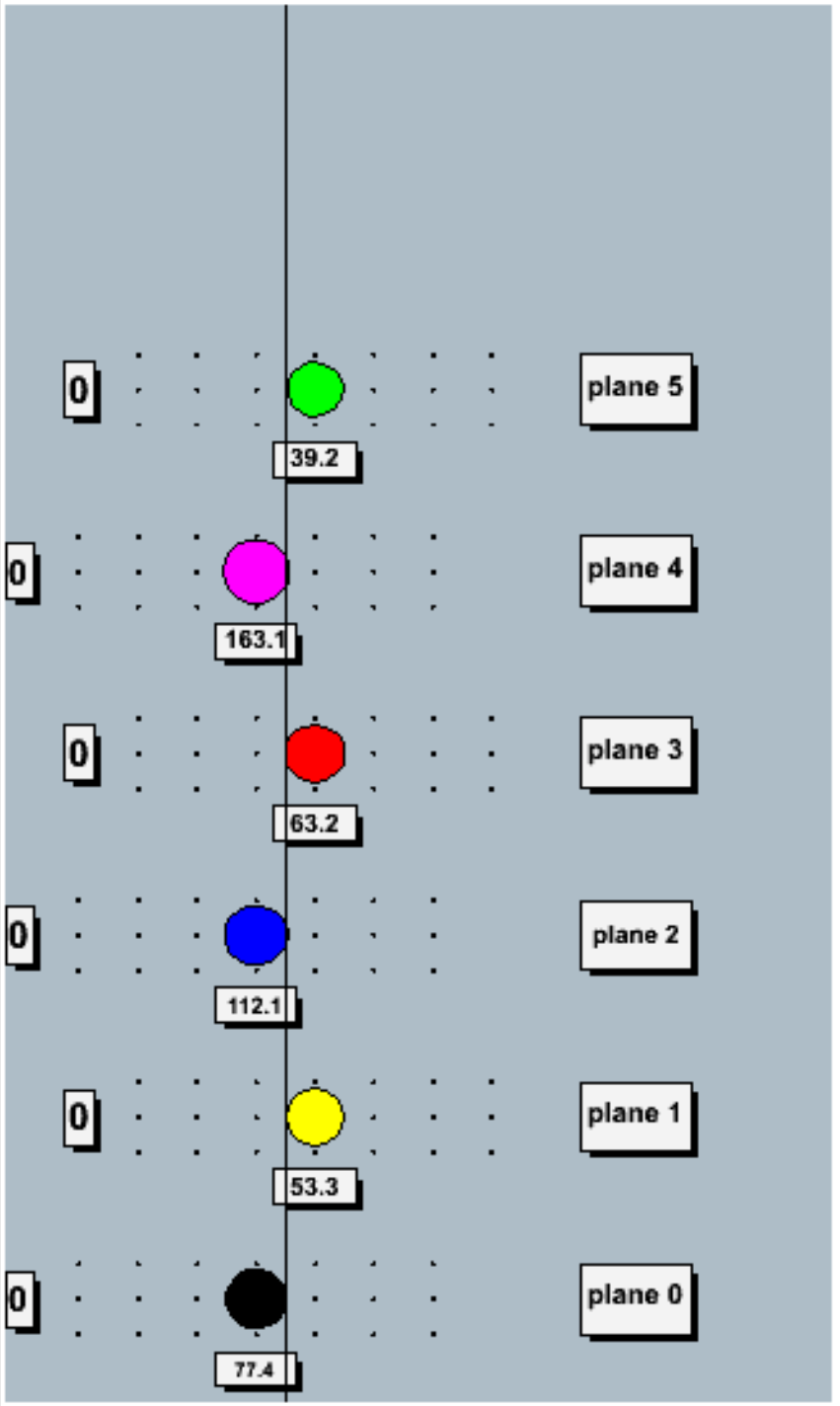
$T = p0 + p2 / (Q-p1)^2$

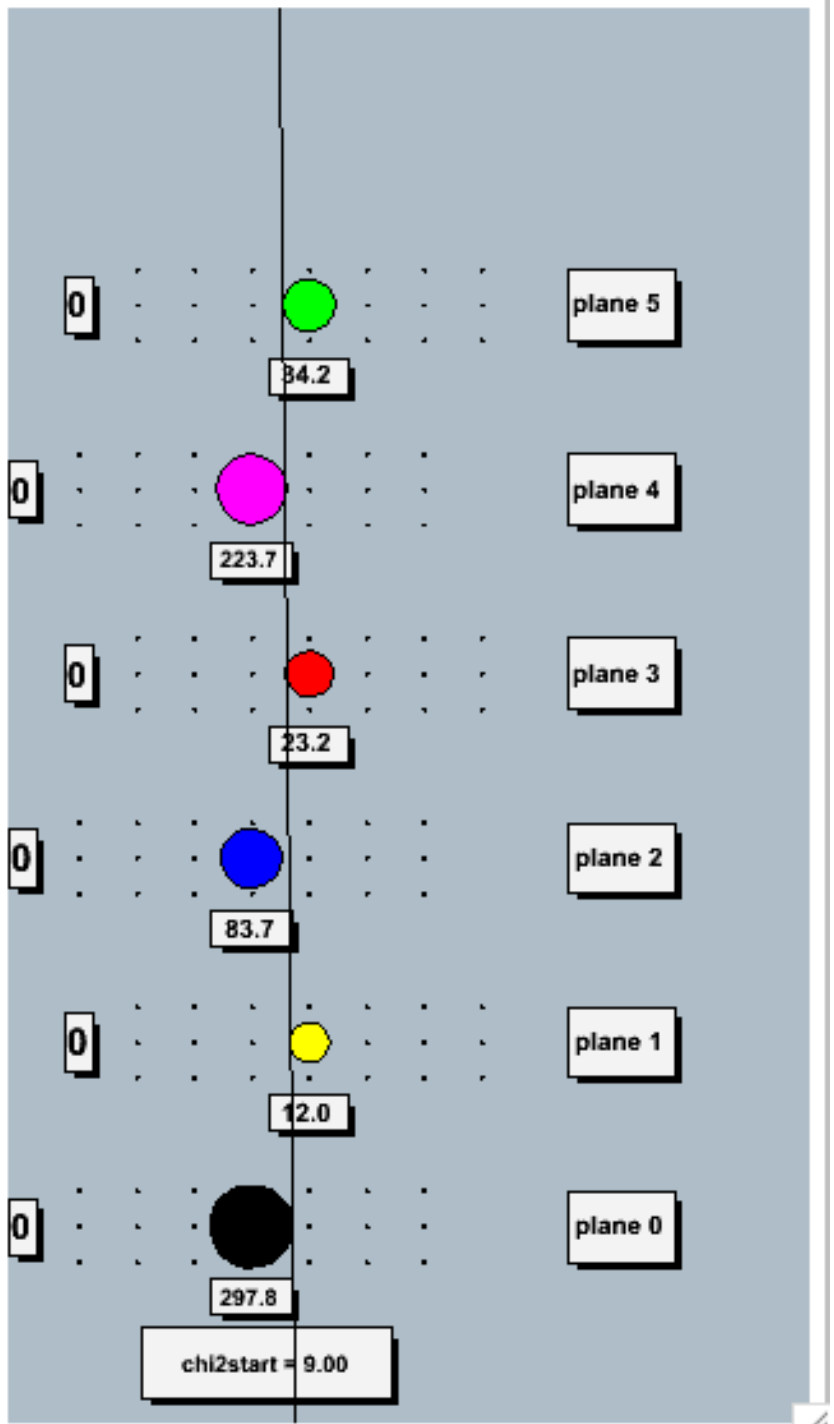


Beam Monitor Test Beam Results

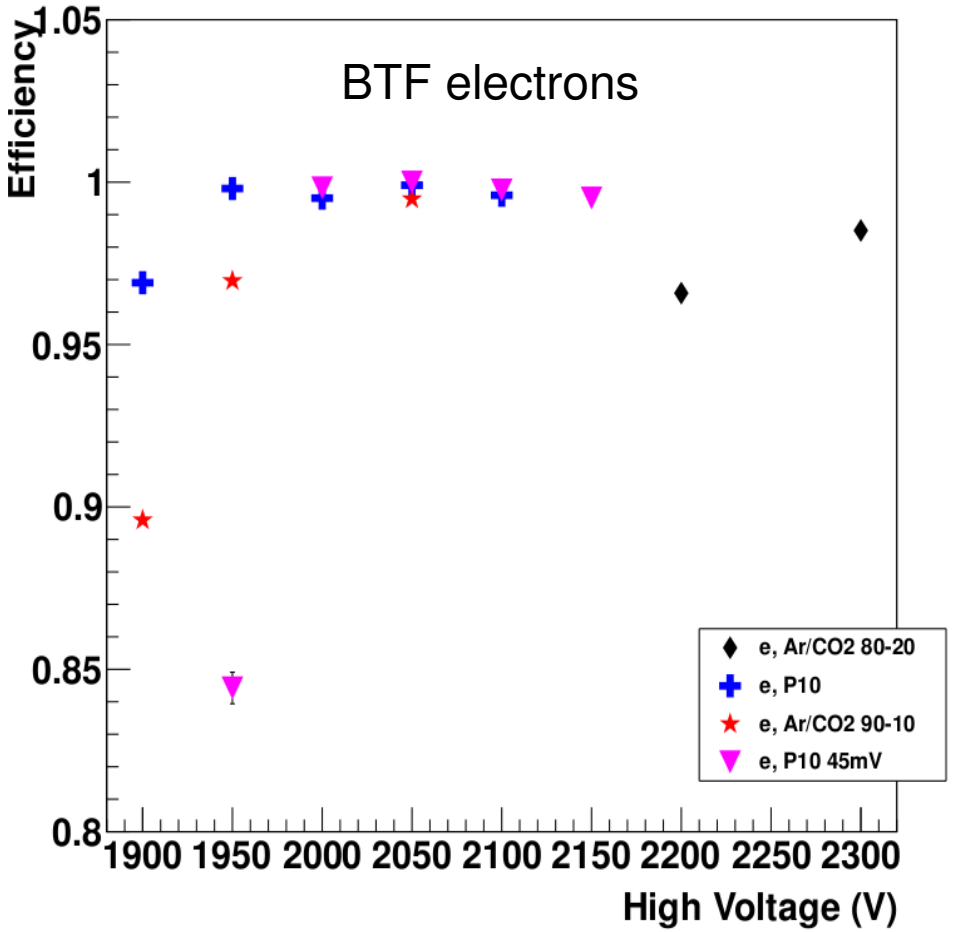


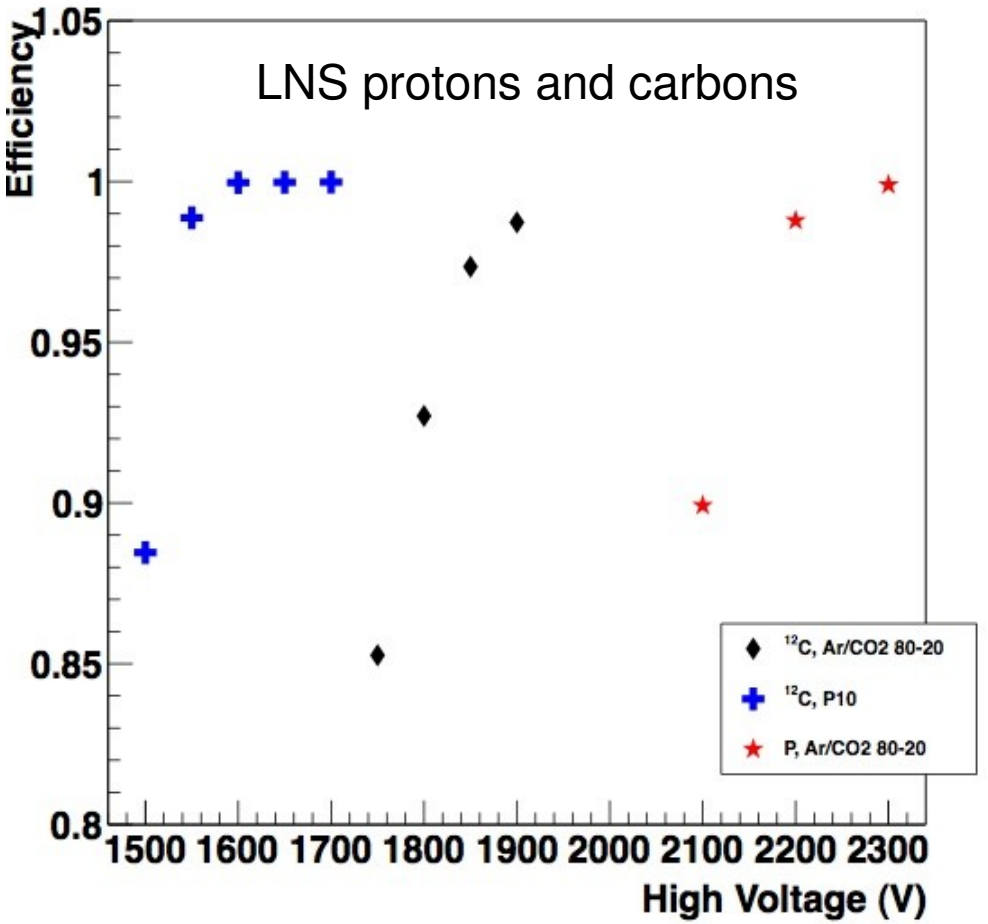
Carbons
@ 1.8 kV
Ar/CO2=80/20





Beam Monitor Test Beam Results: Efficiency





Threshold=15 mV (unless stated otherwise)

Ar/CO_2 mixtures: lower operating voltages at higher Ar concentrations

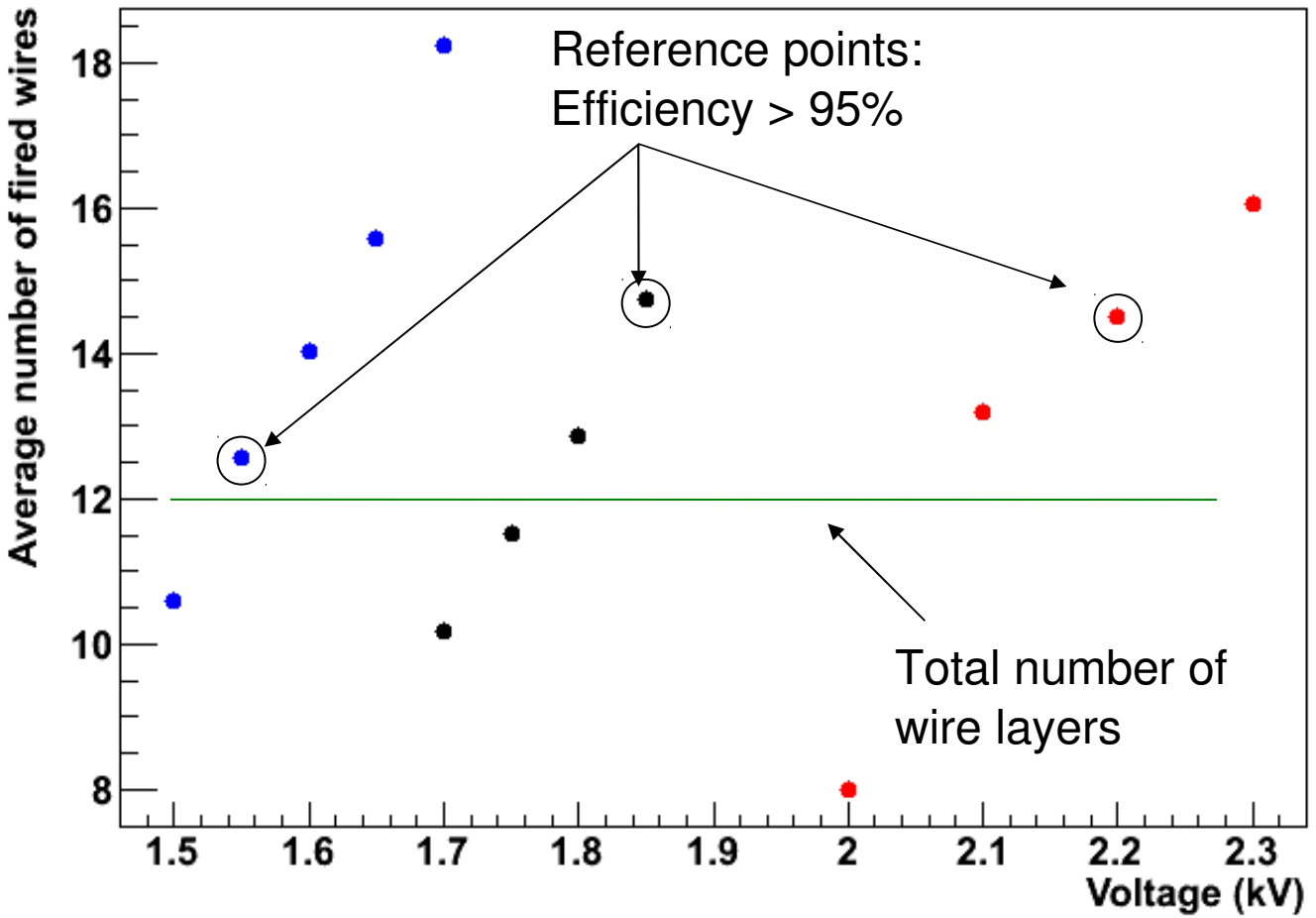
P10 (Ar/CH_4=90/10) operating voltage similar to Ar/CO_2=90/10

Operating voltage on LNS protons similar to BTF electrons

Operating voltage on LNS carbons ~ 300 V lower than on protons.

Beam Monitor Test Beam Results: Occupancy

Average number of fired wires at 15 mV



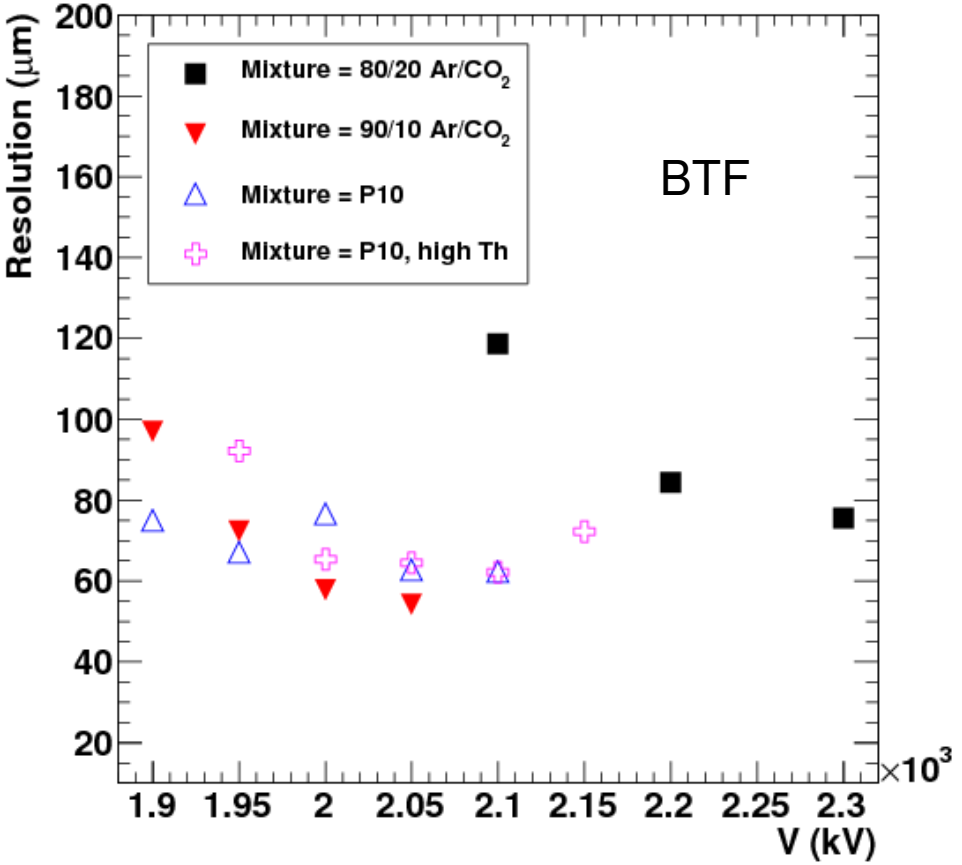
LNS

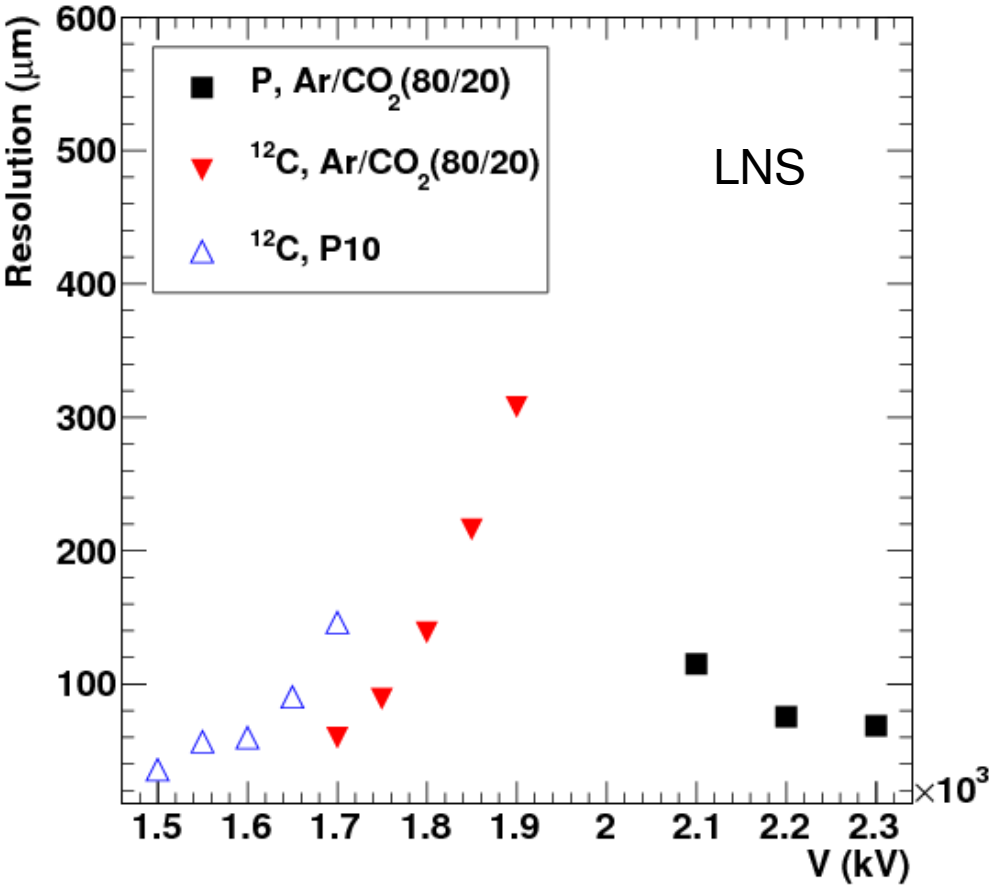
Threshold=15 mV

- Protons Ar/CO_2=80/20
- Carbons Ar/CO_2=80/20
- Carbons P10

A cleaner tracking seems to be obtained with P10 mixture (higher quenching power). Ar/CO_2 mixtures are preferable from a safety point of view. Due to redundancy, the Beam Monitor can be indeed operated at lower (by few %) cell efficiency, fixing the average occupancy.

Beam Monitor Test Beam Results: Resolution

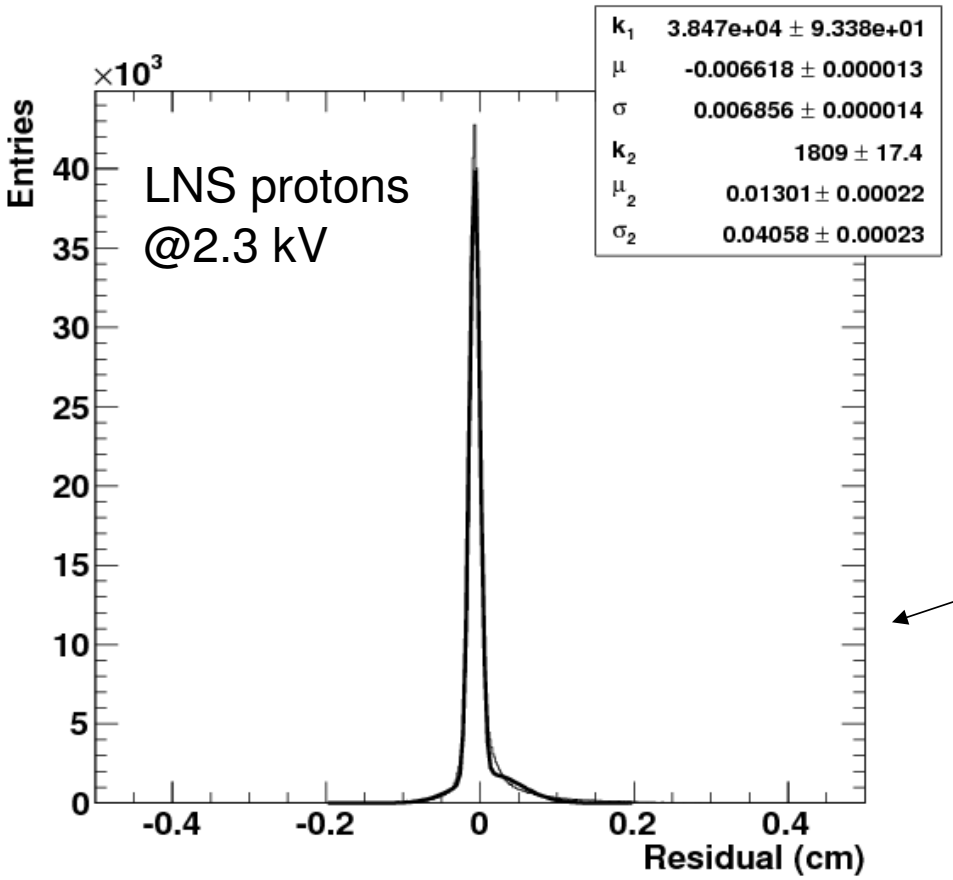


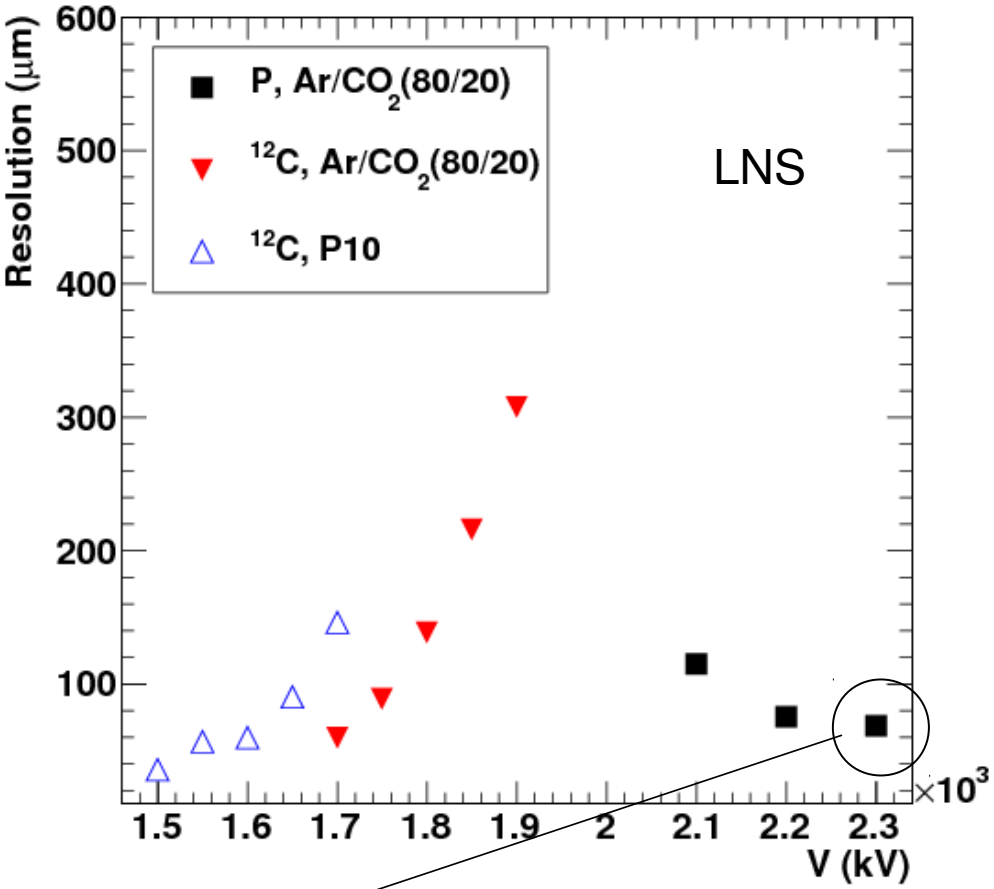


Threshold=15 mV (unless stated otherwise).
R vs t relation parametrized through splines.
Average on all cells. Systematic studies for separate cells to be done.

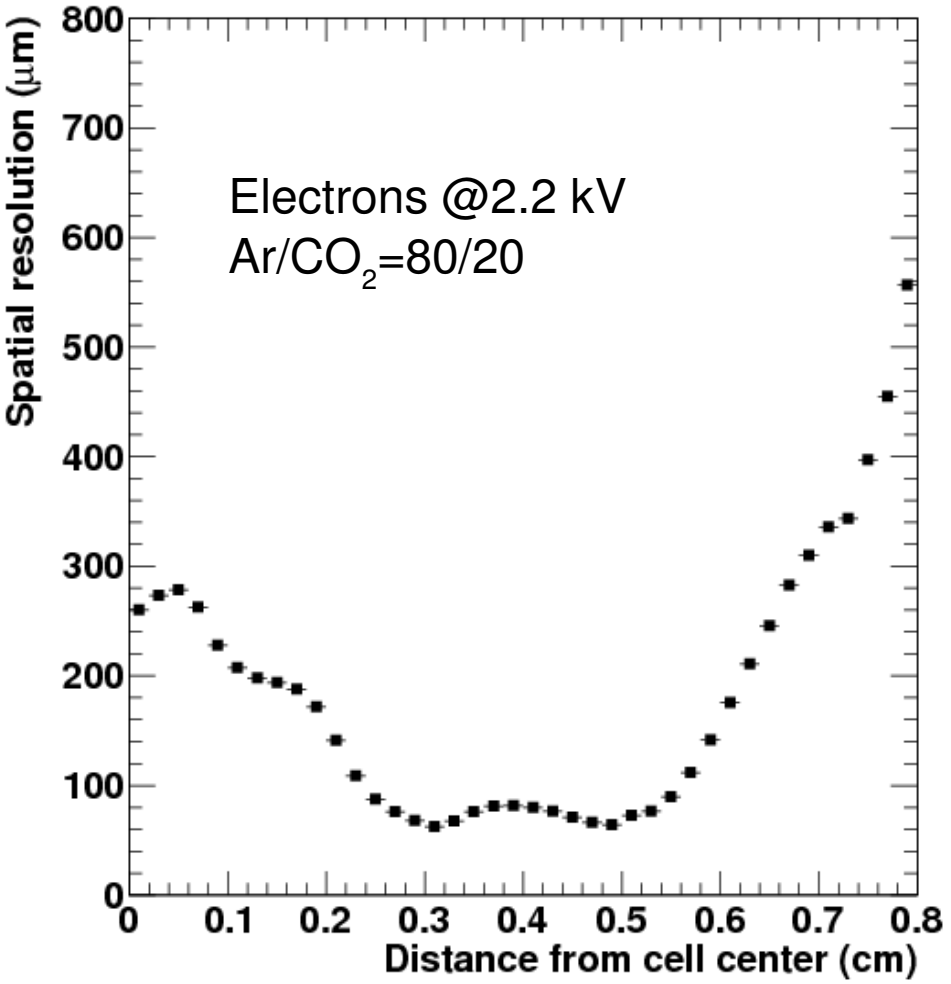
Average Space resolutions better than 100 μm can be obtained for all mixtures and beams.

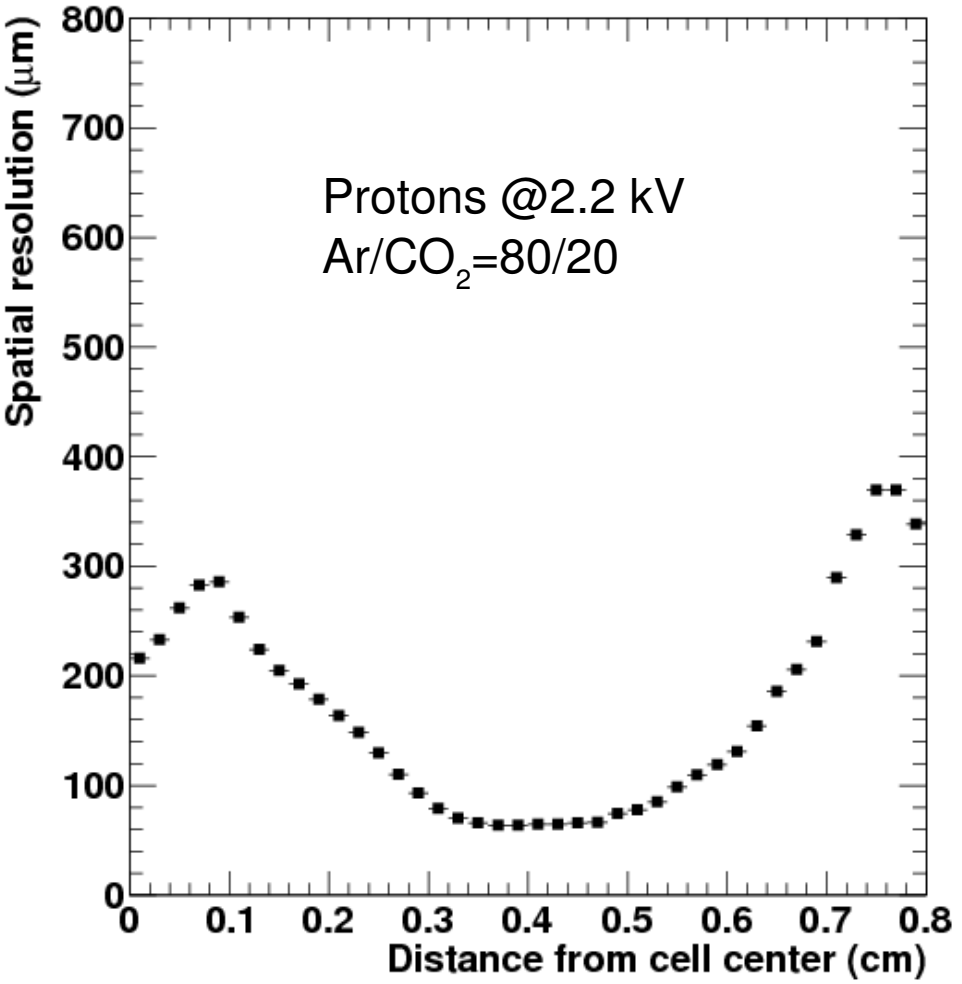
Beam Monitor Test Beam Results: Resolution



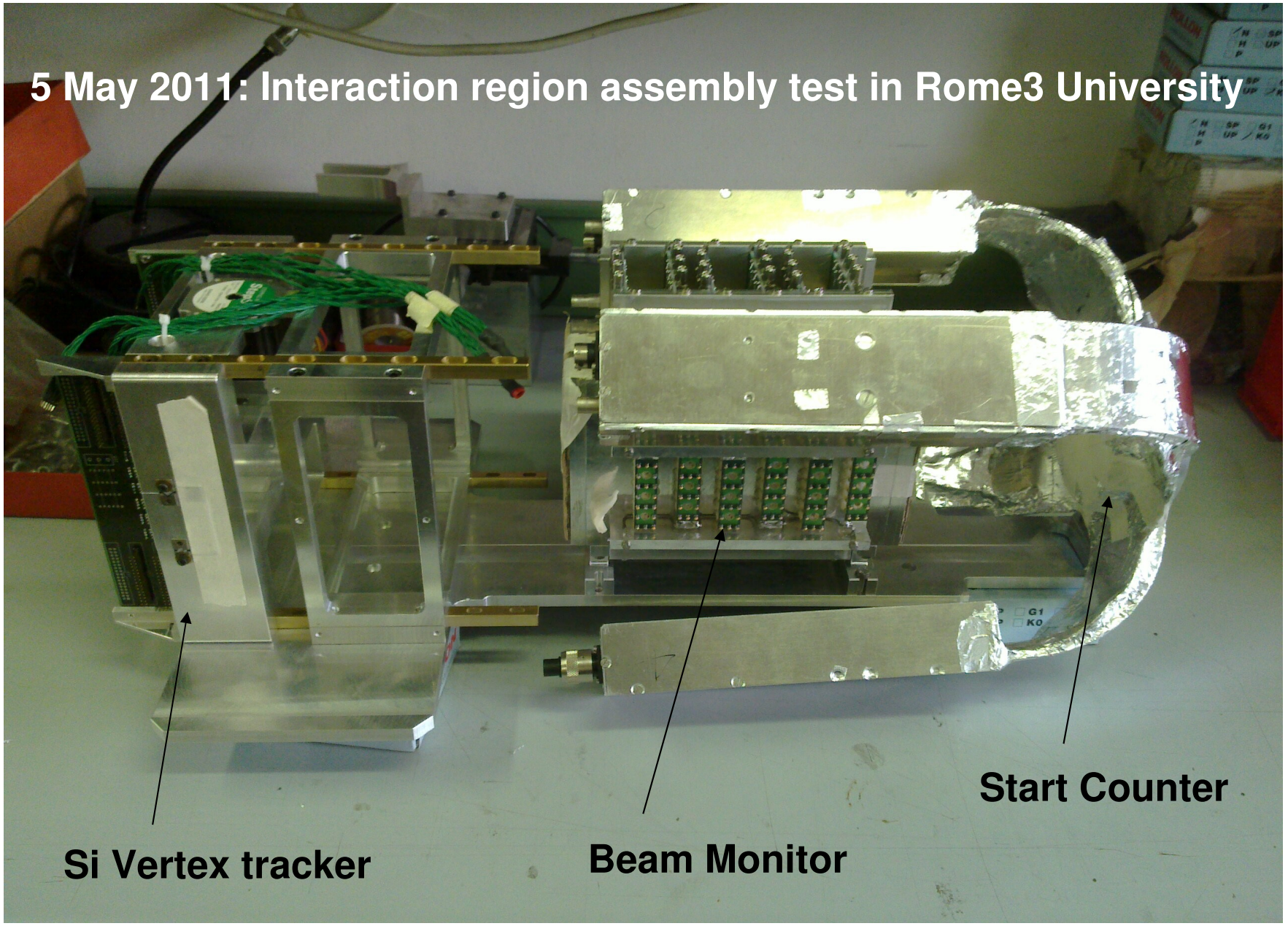


Beam Monitor Test Beam Results: Resolution vs Position





FIRST Schedule



Installation at GSI: July 2011

Data taking: first two weeks of August

Conclusions

The FIRST experiment has been designed to measure the fragmentation of ions relevant for space and hadron-therapy applications.

The 2011 run is dedicated to the study of the fragmentation of ^{12}C ions on a C target.

The experiment is made of detectors already existing at GSI integrated with a newly designed interaction region.

The Beam Monitor and the Start Counter have been completed and tested at LNF and LNS beam facilities.

The analysis of the Test Beams data confirms the good performances of the detectors on ^{12}C ions:
Beam monitor space resolution ~ 100 μm
Start Counter time resolution ~ 100 ps