Horizontal light ion microbeam facility for individual mammalian cell irradiation at the 7MV VdG accelerator of the INFN-LNL

Silvia Gerardi, Giuseppe Galeazzi, Roberto Cherubini

Main elements of the LNL single-ion microbeam apparatus

(S. Gerardi et al, Rad. Res. 161(2004)93-94)

- Different light ions ($^{1}H^{+}$, $^{2}H^{+}$, $^{3}He^{++}$, $^{4}He^{++}$) and enegies available (0.8 – 14MeV, in air)
- Pinhole Microcollimator in air (and its alignment system)
- A fast beam deflection system: electrostatic deflector
- Particle detectors:
  - high efficiency single-ion counter
  - spatial particle in air distribution monitor
  - track detector
- Semi-automatic Cell visualization and localization system
- Automatic Cell micropositioning and revisiting system
- Especially designed Petri dish

...peculiar characteristics

(Ref.:S. Gerardi et al, Rad. Res. 161(2004)93-94)

- Pinhole microcollimator installed in air
- Inverted phase contrast optical microscope

+

Software for cell image acquisition and coordinates logging (semi-automatically)

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NO FLUORESCENT CELL STAINING ✶ NO UV LIGHT

- Precision micropositioning stages (Physik Instrumente, D):
  - 0.1μm positioning resolution and unidirectional repeatability
  - 0.1μm minimum step
  - No backlash

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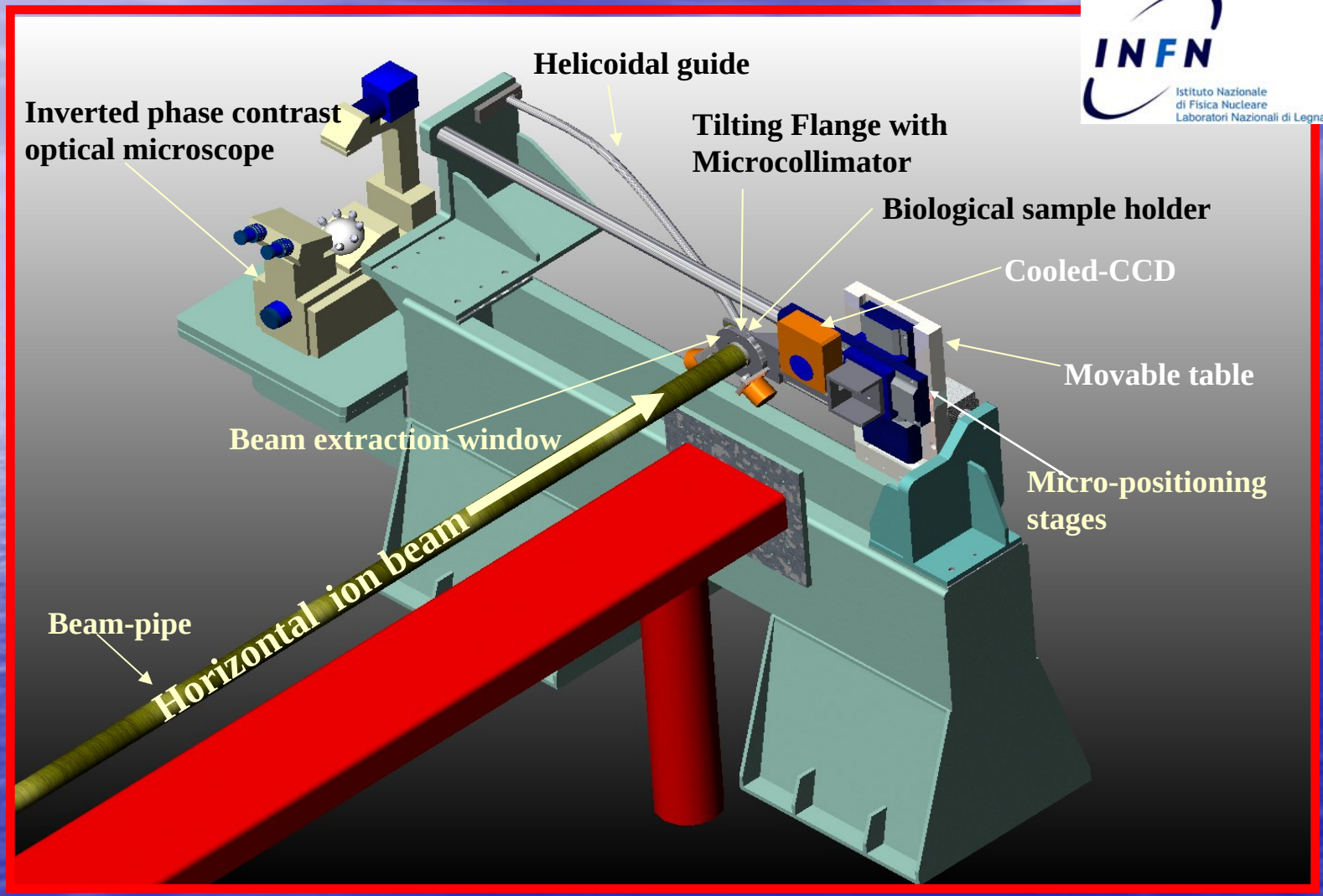
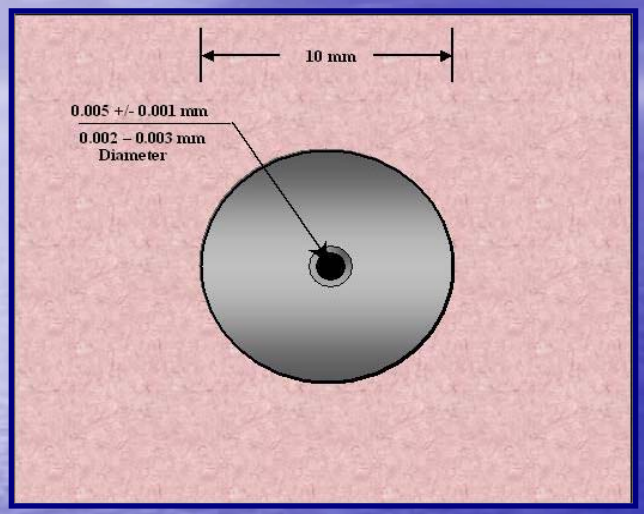
- Overall positioning precision under microscope: < 1 μm

- Counting rate: < 1 ion / second

3D scheme of the Single-ion Single-cell microbeam facility

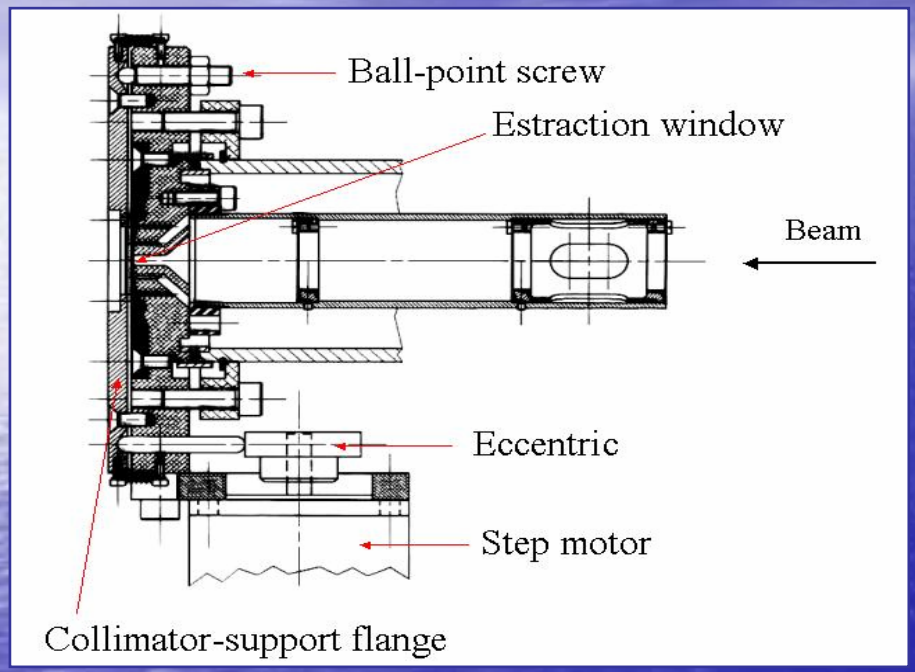


Pinhole microcollimator



- Material: tantalum
- Thickness: 200μm
- Hole diameter: 2÷3μm or 5μm

In air ion beam extraction flange and microcollimator alignment system



Technical drawing: lateral section

Photo: front view

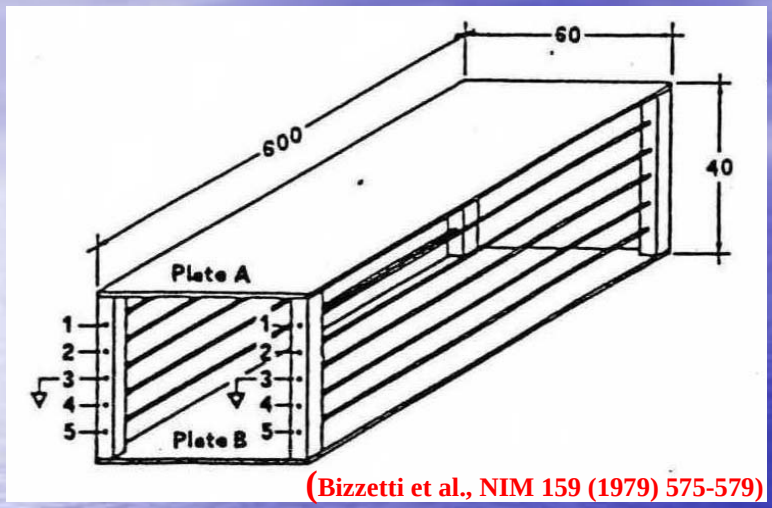
Beam monitor and single ion spatial distribution in air

Ultrathin window for particle detection

Custom-made cooled CCD camera:

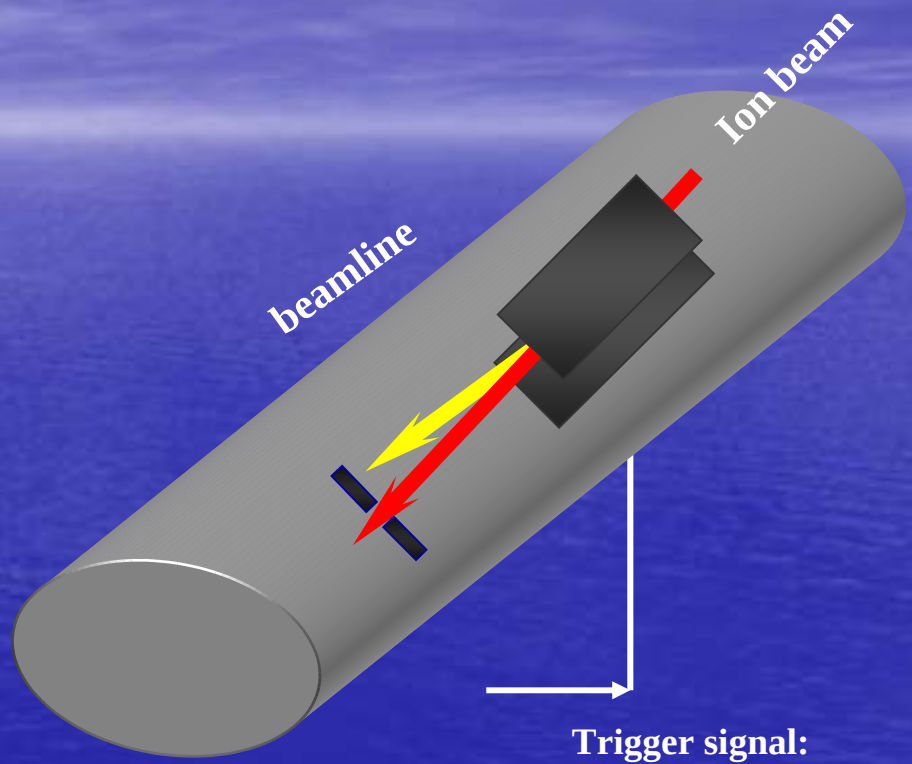
- no optical lens
- no shutter
- 3.0 μm Havar window
- pixel : 6.8 x 6.8 μm^2
- array : 2184 x 1472

Electrostatic beam deflector



(Bizzetti et al., NIM 159 (1979) 575-579)

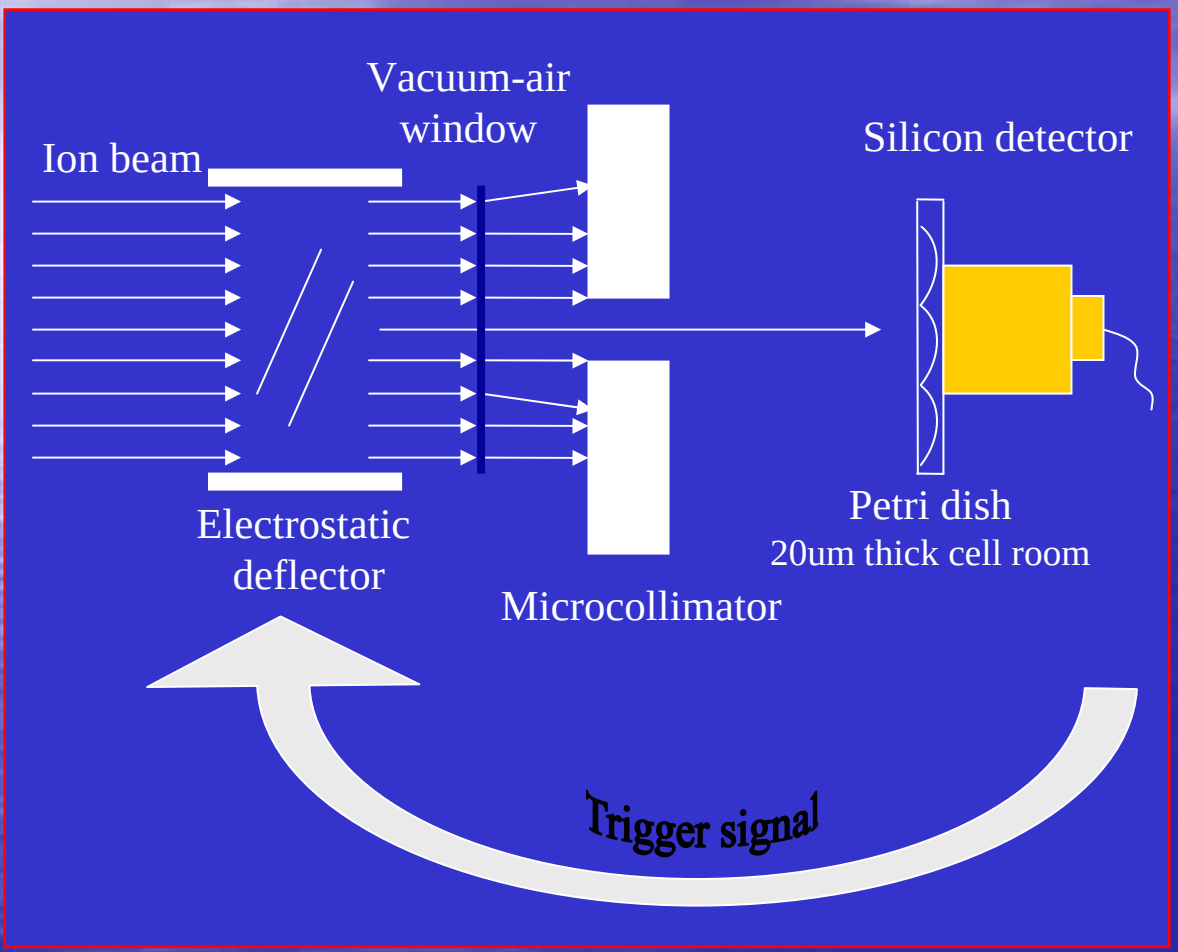
Plate A	$3V_0$ (Volt)
Wires 1-1	$2V_0$ (Volt)
Wires 2-2	V_0 (Volt)
Wires 3-3	0
Wires 4-4	$-V_0$ (Volt)
Wires 5-5	$-2V_0$ (Volt)
Plate B	$-3V_0$ (Volt)



Trigger signal:
Beam on / Beam off

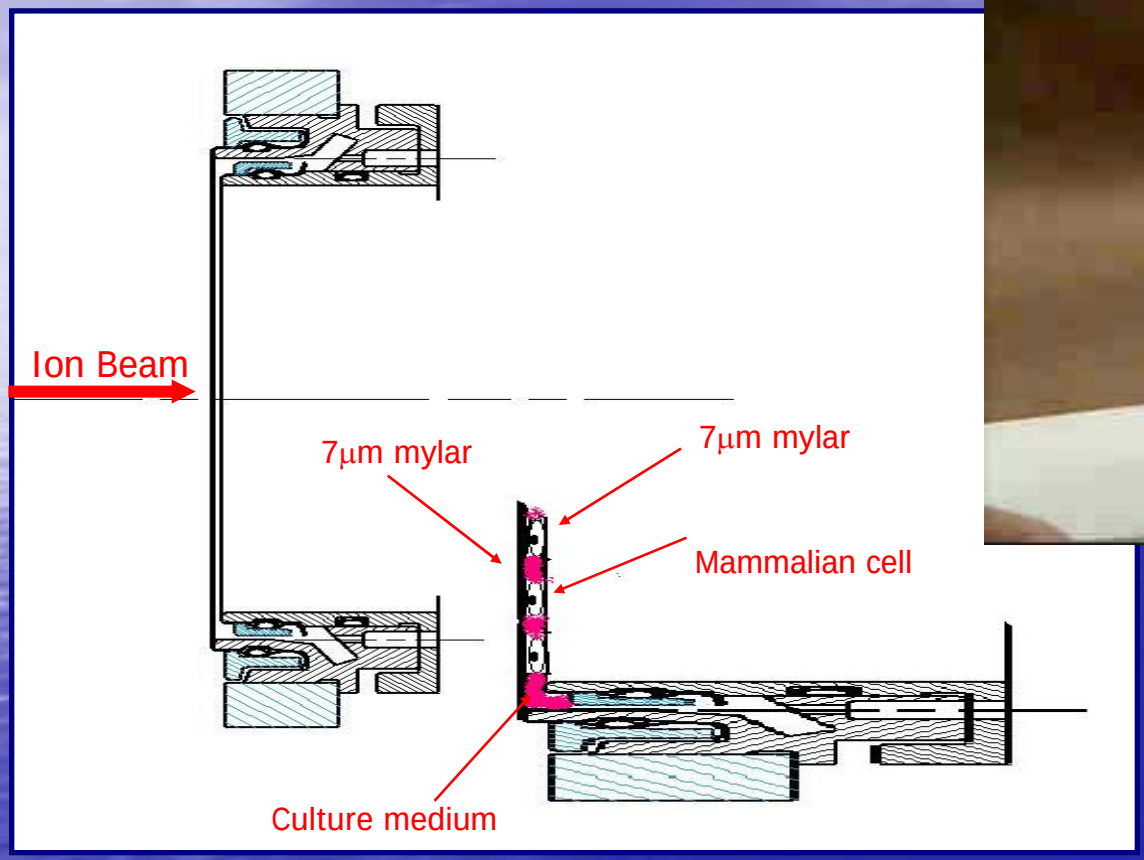
V_0 = 200 V, during deflection stage
Response time = 150 ns

Single Particle Detection



- Active detection
  - silicon detector
    - ⇒ spectrometer
    - ⇒ deflector trigger
- Passive detection
  - track detector (CR39)
    - ⇒ ion impact points
    - ⇒ overlapping with cell map

Especially designed Petri dish



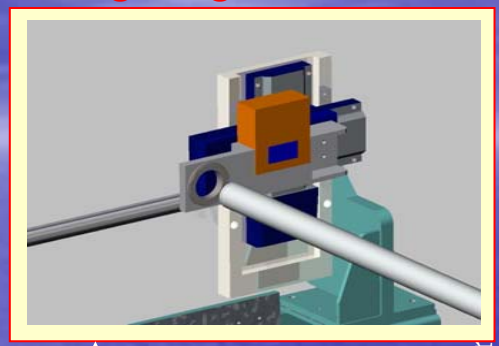
Ext. Diam.: 100mm
Int. Diam.: 75mm
Cell room thickn.: 20μm

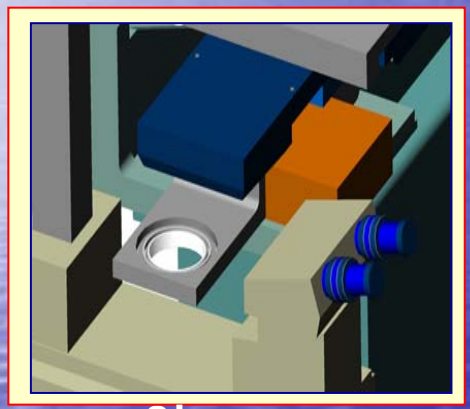
Cell visualization, micropositioning and revisiting system

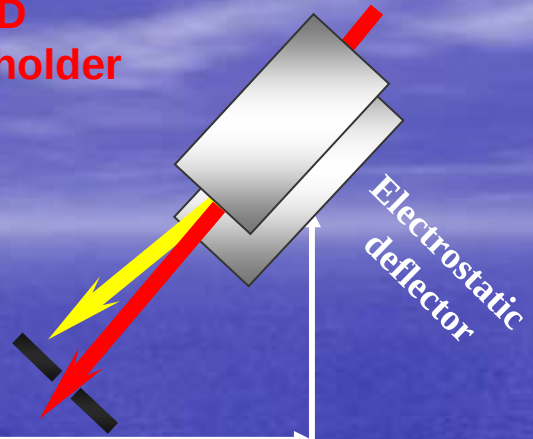
Single-ion cell irradiation protocol

Single ion hit position by cooled CCD
Micropositioning stages and Petri dish holder

Semi-automatic cell recognition and fiducial marks





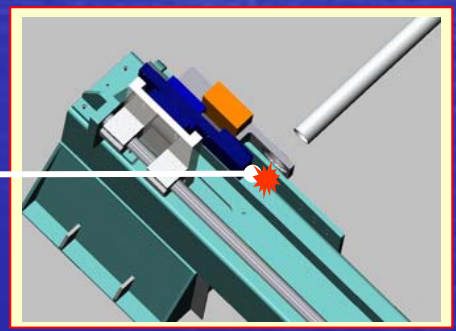


Trigger signal

Cell and Ion position data

Particle detector

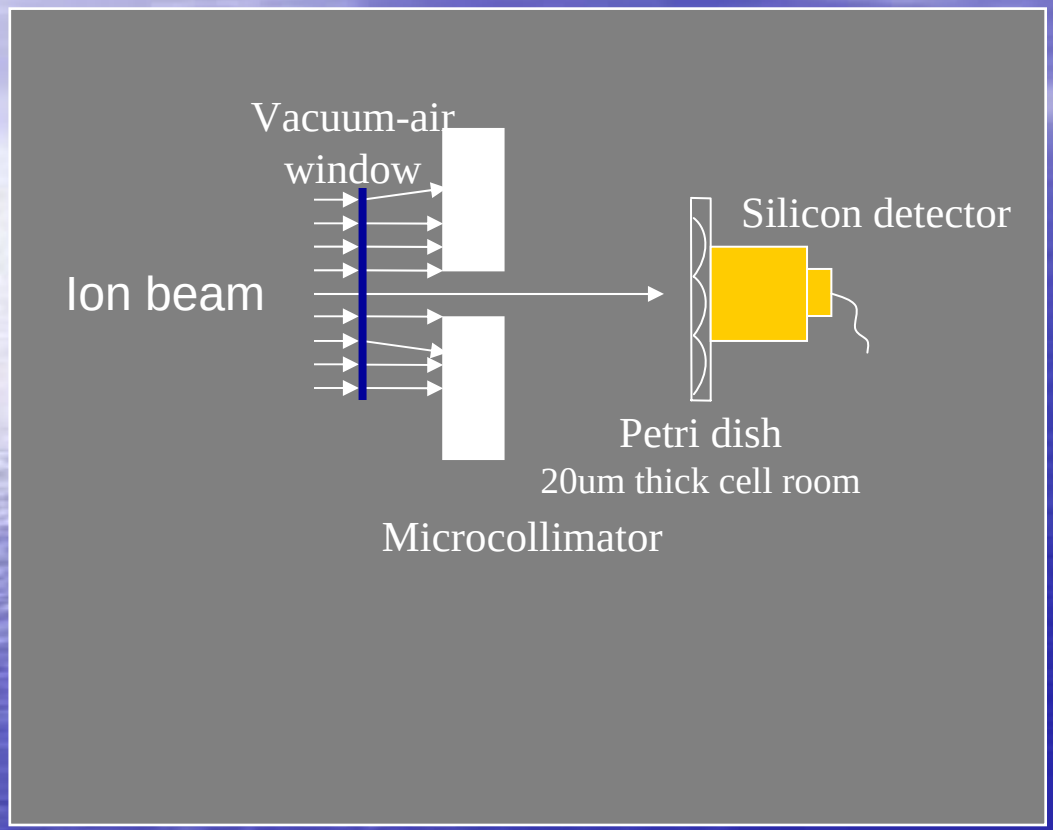
Single Ion data

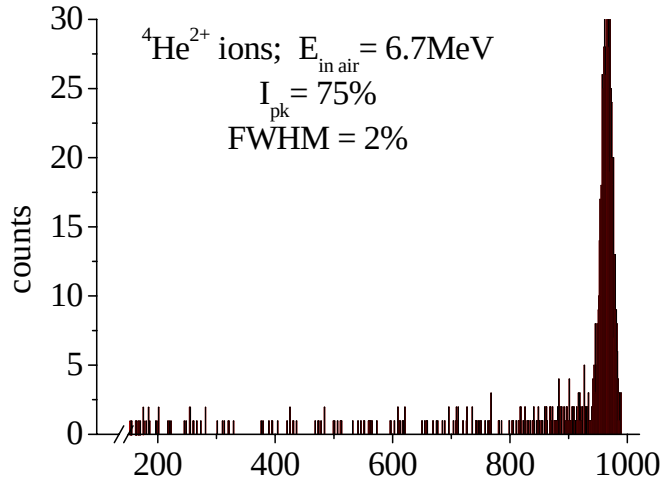


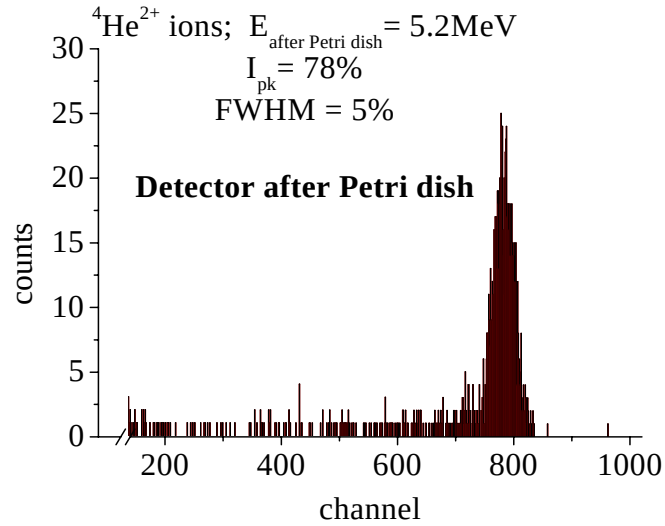
Cell co-ordinates

Image Analysis System and micropositioning stages controller

Ion beam monitoring and spectrometry during cell irradiation







.....Perspectives...

- Radiobiological studies (cell survival, micronuclei induction, chromosomal aberrations, DNA damage, protein expression) ... “bystander effect”
- Sub-micrometric collimator in silicon wafer (etching /micromachining technique)

- ...twin microbeam facility for heavy ions ($6 \leq A \leq 20$) at TANDEM-ALPI accelerator

….people who have participated …

Physics and technological development

R.C. , INFN – LNL

Silvia Gerardi, INFN – LNL, ***in charge for LNL microbeam facilities R&D***

Giuseppe Galeazzi, INFN – LNL & Padova Univ.

Biological aspects:

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Alessandro Bertoldo, INFN – LNL

Maria Cavinato, INFN – LNL

Selena Gomirato, INFN – LNL

Technical drawings: **Marco Rigato, INFN – LNL**

CN VdG Accelerator operation: **Stefano Contran, INFN – LNL**

LNL mechanical and electronic workshops staff

...related references:

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M. Conzato, R. Cherubini, G. Galeazzi, S. Gerardi, L. Read
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