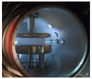

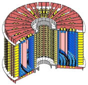

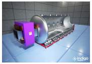

Design of a gaseous beam monitor device using a GPU based code

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Hadrontherapy

Use of heavy ions (^{12}C for example) to treat non-operable and radio-resistant tumors

Advantages

- Localized dose
- Small diffusion in the body
- Biological efficiency

Drawbacks

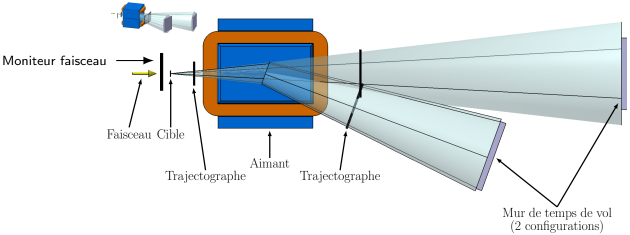
- Fragmentation of heavy ions
- Loss of the ions of the beam
- Production of lighter elements

Aim: To control the dose deposited in the tumor and in the healthy tissues

Knowledge of fragmentation cross-sections of heavy ions (^{12}C) ► FRACAS

FRACAS (FRAgmentation des ions CArbone et Sections efficaces)

Large acceptance mass spectrometer ▶ measure of the fragmentation cross-sections of ^{12}C ions from 100 to 400 MeV/n on targets of medical interest (C, H, N, O)



Charge reconstruction ΔE - ToF

- Beam monitor: time reference and position
- Time of Flight (ToF) wall: energy of the fragments and stop

Mass reconstruction

- Magnet: mass separation of the fragments of same charge
- Up- and downstream trackers: trajectories of the fragments

Beam monitor

Role

- Trajectories of ^{12}C ions before target: monitor the beam
- Time reference: needed for charge reconstruction ΔE - ToF

Characteristics and constraints

- Low material budget
- Coïncidence time resolution $<$ 300 ps FWHM
- Spatial resolution $<$ 100 μm in both directions

Choosen technology:

Gas detector (low material budget)

↓

PPAC (Parallel Plate Avalanche Counter, suitable for detection of heavy ions and good time resolution)

↓

Multi-stages PPAC (one stage for time measurements, two others for trajectory reconstruction)

Simulations: Designing the optimal geometry

Goal: A spatial resolution below 100 μm

Key parameters that affect the spatial resolution:

- Electron cloud transverse size (set by gap size, pressure and gas)
- Strip size and inter-strip size

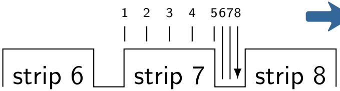
Simulations needed to set those parameters with a code developped in-house: Uroboros

From microscopic simulations to macroscopic results

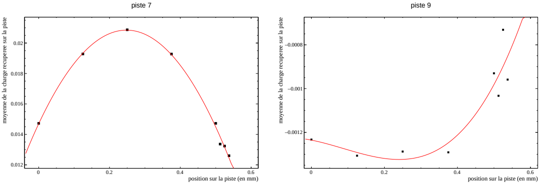
One simulation in Uroboros ∼ 1h: too long to simulate thousands of incident particles

with GPU based code

simulations at 8 different
positions on the central strip
10 simulations by position



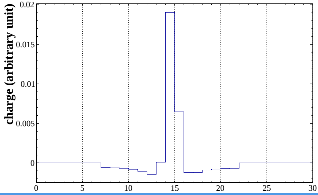
retrieve mean and standard deviation of the charge on each strips



Monte-Carlo code

for the charge on each strip:

a random value is taken from a normal distribution with the mean and standard deviation previously obtained

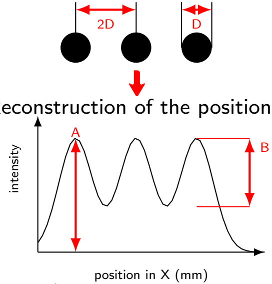


example of values generated
for one incident particle

Evaluating the theoretical resolution of a particular geometry

Derenzo phantoms

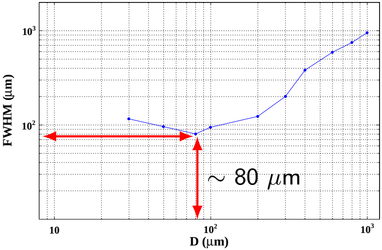
Emission of primary tracks within circles



If B $\geq$ A/2 the peaks are considered separated: the resolution is better than D

Simulated geometry:

- Gap: 4.5 mm
- Strip size: 0.5 mm
- Interstrip size: 0.05 mm
- Gas: isobutane
- Pressure: 25 mbar



Theoretical spatial resolution $\sim$ 80 μm

Experimental tests

Goal: To evaluate the characteristics of the detector with systematic tests

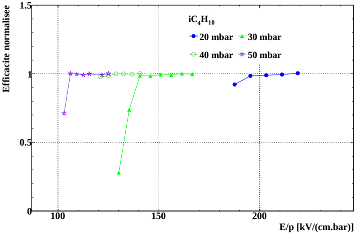
- Finding operating range (pressure and tension)
- Time measurements
- Simple position reconstruction
- Calibrating the detector
- Evaluating its spatial resolution

Operating range

Goal: operate the detector without a loss of counting rate and avoid breakdowns

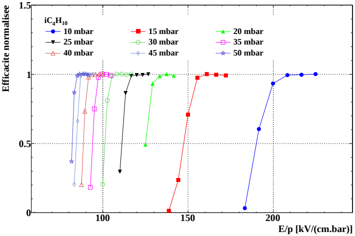
Time reference stage:

gap = 1.6 mm



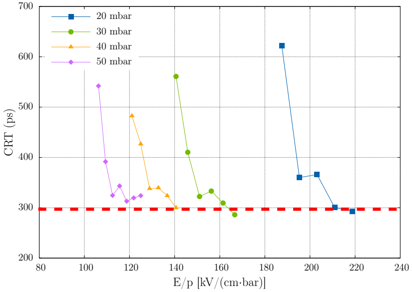
Position measurement stages:

gap = 3.0 mm



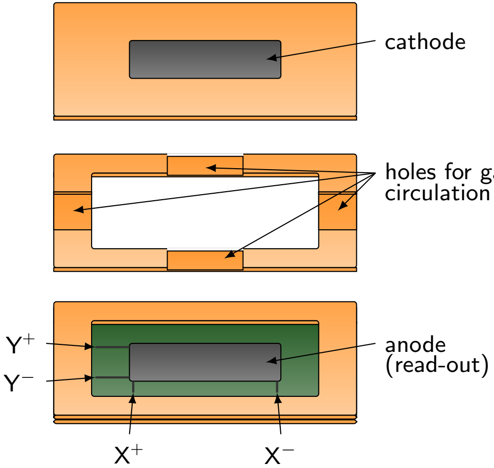
Time measurements

- Coïncidence Resolving Time (CRT)
- Between a 1.6 mm gap PPAC and a ToF wall element
- Source of ^{241}Am: 5.5 MeV α particles

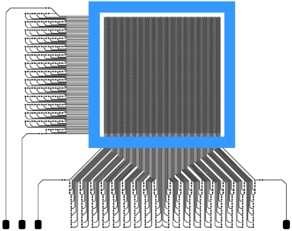


For a pressure of 30 mbar, CRT is under 300 ps FWHM

Position measurement stages: prototype



Resistive read-out



Nb strips X: 127
Nb strips Y: 86
Strip size: 550 μm
Interstrip size: 50 μm
Pad diameter: 350 μm

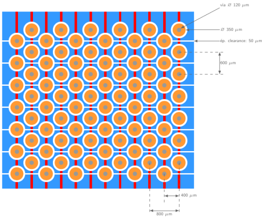
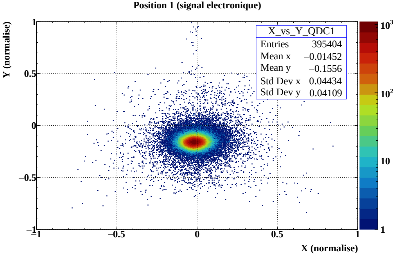
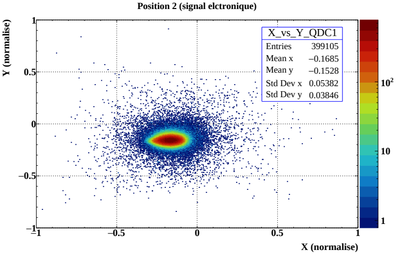


Image reconstruction: preliminary results

Reconstruction of the image of an α source

- gap: 3.0 mm
- gas: isobutane
- pressure: 25 mbar
- ^{241}Am, 5.5 MeV α
- two positions: in the middle, slightly translated to the left
- read-out method: charge division

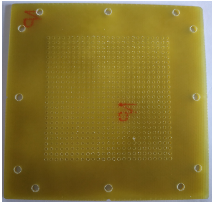




Next steps

Calibration for spatial distorsions

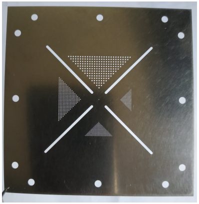
- ∅ 1 mm holes
- Spaced 2 mm apart center to center
- Placed between the source and the cathode



By knowing the exact position of each holes, it is possible to correct the distorsions

Evaluation of the spatial resolution

- Derenzo phantoms: four regions ($D = 500\ \mu$m, $300\ \mu$m, $200\ \mu$m, $100\ \mu$m)
- Placed between the source and the cathode



Same method used as for the simulations

Conclusion

Beam monitor device ▶ Multi-stages PPAC

Simulations (with a GPU based code)

- Design of an optimal geometry with a theoretical spatial resolution $\sim 80\ \mu$m

Experimental tests

- Operating range
- Coïncidence resolving time < 300 ps FWHM
- Image reconstruction

Next steps

- Calibrate spatial distorsions
- Evaluate the spatial resolution

Thank you for your attention !