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

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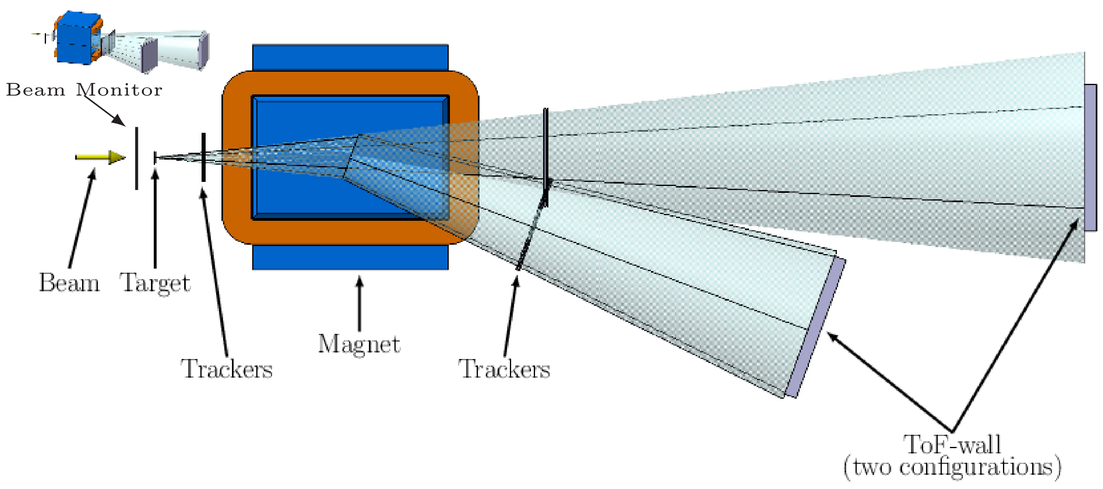
The FRACAS experiment

FRACAS is a large acceptance mass spectrometer designed to measure fragmentation cross-sections of ^{12}C ions on thin targets of medical interest (C, O, H, Ca) for hadrontherapy.



Characteristics and constraints

- **Up- and downstream trackers**
  - Trajectory of the fragments
  - Spatial resolution $\leq 100\ \mu$m
  - Large active area ($\sim 50 \times 50$ cm^2)
- **Magnet**
  - Mass separation of the fragments of same charge
- **Time of Flight (ToF) wall**
  - Energy and time of flight of the fragments to measure their charges
- **Beam monitor (BM)**
  - Trajectory of incident ^{12}C ions
  - Time reference
  - Beam transparent
  - Spatial resolution $\leq 100\ \mu$m

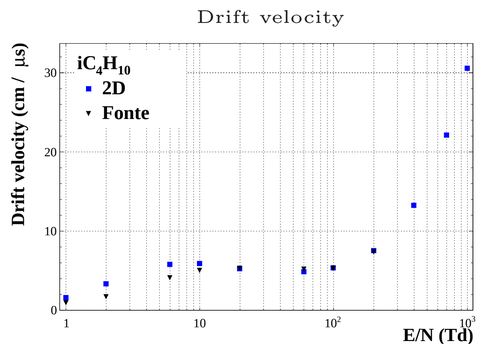
BM: Parallel Plate Avalanche Counter (PPAC) chamber

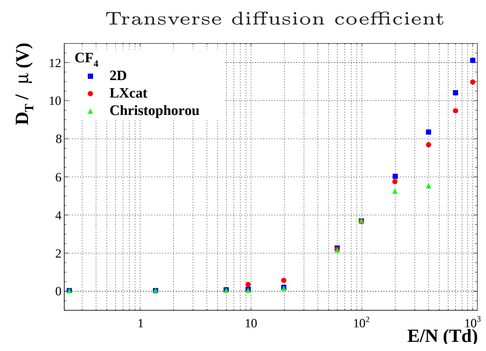
➜ **Need to simulate the performances of the detector at the design stage: GPU based simulation code**

GPU based simulation code in 2D and 3D

Simulation of the drift of charged particles in a gas mixture in an electro-magnetic field

- Based on **CUDA** (NVIDIA GPU language)
- **Scattering cross-sections** used to evaluate electron interactions
- Extraction of the **swarm parameters (drift velocity, diffusion cœfficients, ...)**





Comparisons of swarm parameters between simulation data (■), LXcat data (●), and experimental data, Fonte *et al.* (▼) [3] and Christophorou *et al.* (▲) [4]

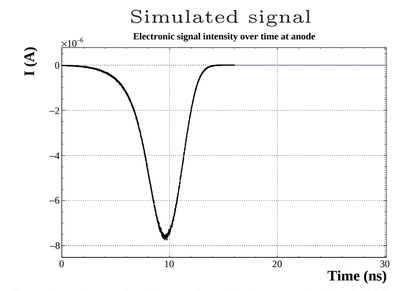
LXcat: website hosting a solver of the Boltzmann equation (bolsig+) [1], and databases of scattering cross-sections [2]

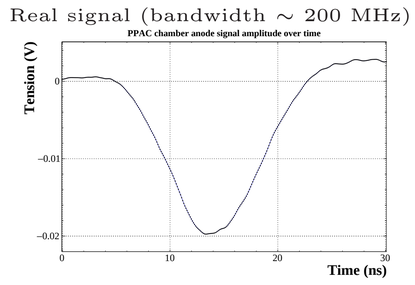
➜ **Design a geometry meeting the constraints put on the beam monitor performances**

Use of Ramo field maps

Simulation of the **signal induced on electrodes** by the drifting particles

- HV: -800 V
- Gap: 1.6 mm
- Gas: iC_4H_{10}
- Pressure: 50 mbar

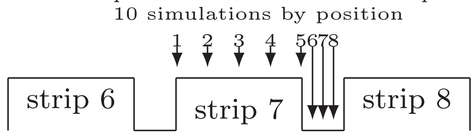


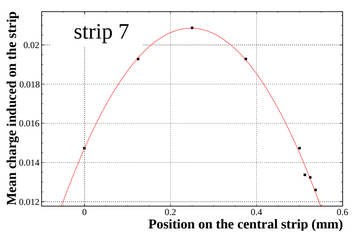


Monte-Carlo simulation

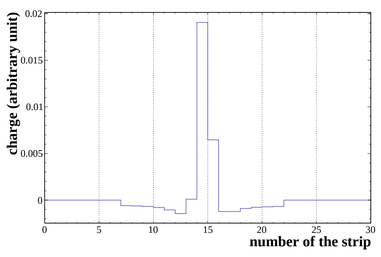
Simulation of **thousands of incident particles**: one simulation (one incident particle) in the GPU based code takes 1h ⟹ use of **pattern responses**

with GPU based code
simulations at 8 different positions on the central strip
10 simulations by position





patterns
mean and sigma of the charge induced on each strip



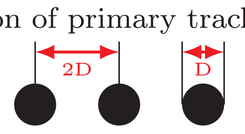
➜ **with Monte-Carlo code**

using patterns to simulate the response to multiple incident particles

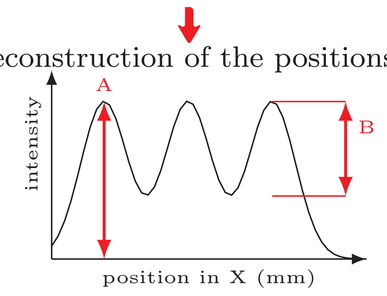
Design of the geometry

Evaluation of the simulated **resolution**: **Derenzo phantoms**

Emission of primary tracks within circles

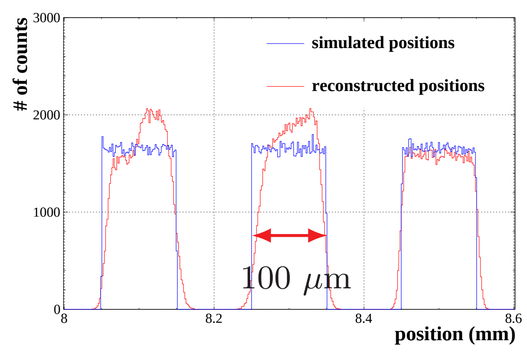


Reconstruction of the positions



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

Simulated geometry:
- Gap: 7 mm
- Strip size: 0.5 mm
- Interstrip size: 0.05 mm

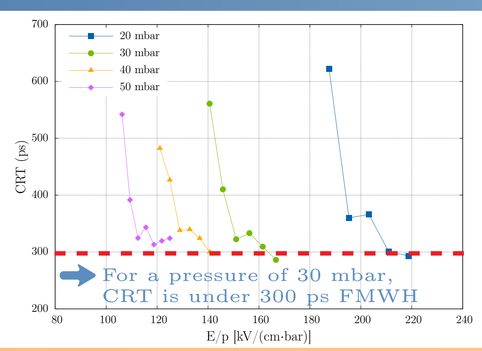


The simulated spatial resolution is of the order of 50 μm

Tests with prototypes: time measurements and position reconstruction

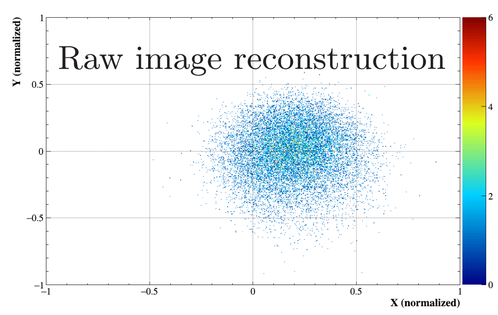
Time measurements

- **Coïncidence Resolving Time** (CRT)
- Between a **1.6 mm gap PPAC chamber (iC_4H_{10})** and a **ToF wall element**
- Source of ^{241}Am of **5.5 MeV α particles**



Position reconstruction

- Image of an ^{241}Am source of **5.5 MeV α particles**
- Source placed **in front of the cathode** of the stripped PPAC chamber
- Gap: **4.75 mm** , Strip size: **1.3 mm** in 50 mbar iC_4H_{10}



More tests on the position reconstruction will be made with the prototype with the designed geometry

Bibliography

[1] G. J. M. Hagelaar and L. C. Pitchford, "Solving the Boltzmann equation to obtain electron transport coefficients and rate coefficients for fluid models", Plasma Sci Sources and Tech 14, 722 (2005).

[2] Bordage database, www.lxcat.net, retrieved on June , 2017.

[3] P. Fonte *et al.* Nuclear Instruments and Methods in Physics Research A 613 (2010) 40-45.

[4] L. G. Christophorou, J. K. Olthoff, et M. V. V. S. Rao, J. Phys. Chem. Ref. Data 25, 1341 (1996).