the ActarSim simulation package

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Outline

1. ActarSim: Overview
   - Main features
   - Status of the code development
2. ActarSim: examples of applications
   - Particle identification
   - Position resolution
   - Number of pads with charge
3. What is missing

Developers: H. Alvarez Pol, E. Benjamim, D.Y. Pang, B. Fernández Domínguez, E. Estévez Aguado

Consultants: D. Cortina, P. Roussel-Chomaz, H. Savajols, W. Mittig

ActarSim: basic features

- Uses **Geant4** and **ROOT** for the production and ***tracking*** of primaries and most energetic secondaries ($E_{cut} > 1$ keV). Uses ROOT for further simulation and analysis.
- Stores the ***position*** and the ***energy*** deposited for each track.
- Calculates the ***drift*** and ***diffusion*** of the electronic clouds (external macro).
- Calculates the ***induction*** in the pads plane.
- ***Modular*** and ***configurable*** for testing geometry, gas parameters, amplification, reconstruction algorithms, ...

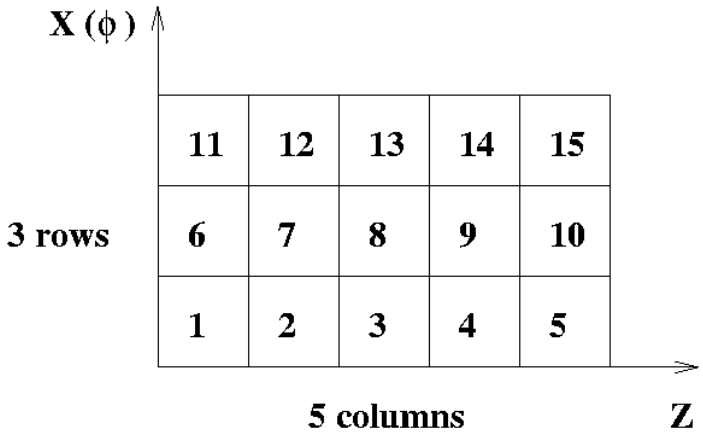
ActarSim: main features

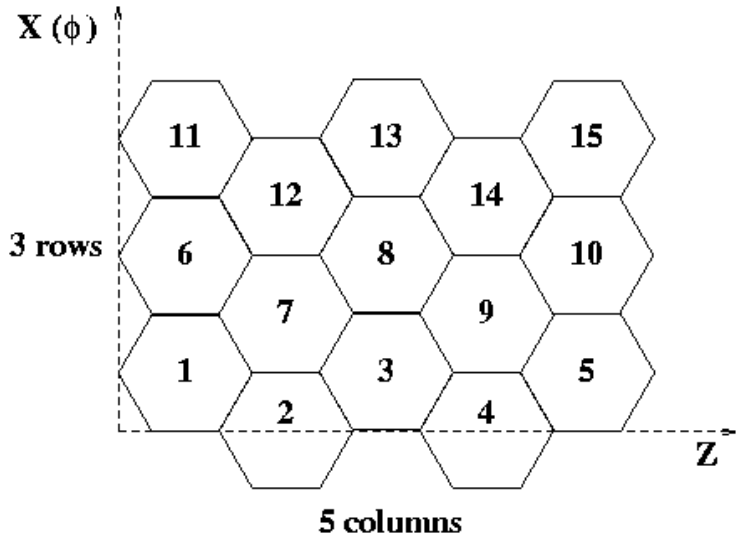
- User-selected ***geometries*** (tube, box) and sizes.
- Possibility of defining a ***beam shielding*** tube.
- User-defined gas parameters and beam shielding materials.
- User-selected ***electric and magnetic fields*** (constant components).
- Event generators including binary ***reaction kinematics*** (CINE by W. Mittig, KINE by M.S. Golovkov).
- Different options for ***data storage*** (histograms, full track,...).
- ***Ancillary detectors*** (silicon and scintillator detectors) included in the simulation.

ActarSim: digitization

The digitization (macro) perform the following tasks:

- calculates the pad geometry; user should introduce basic parameters,
- user should set values for the drift parameters,
- reads the strides event by event,
- calculates the projection into the pad plan, taking into account the drift parameters,
- calculates the induction in each pad of the pad plane,
- stores the results in a collection of signals.





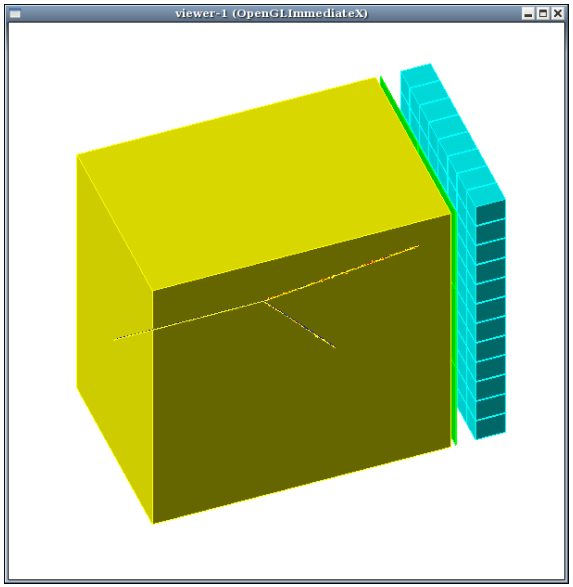
ActarSim: digitization scenarios

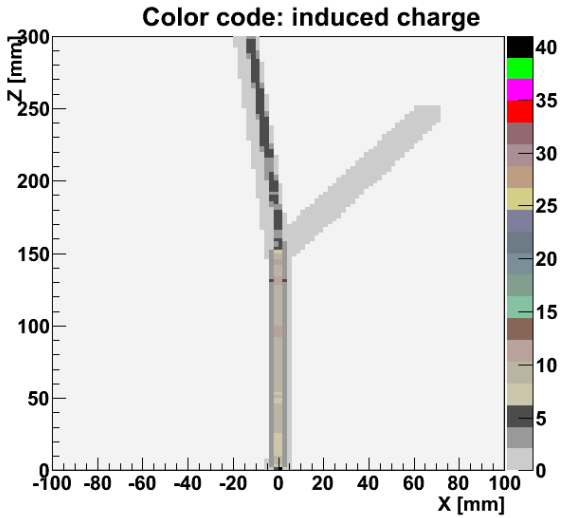
Present digitization scenarios, selectable in the digitization macros:

- MAYA-like: box detector, drift toward a planar pad-plane parallel to beam line;
- TACTIC-like: cylinder detector, drift toward a cylindrical pad-plane concentrical to beam;
- TPC chamber like: drift toward a pad-plane normal to beam line (endcap).

ActarSim: digitization visualization

- MAYA-like geometry
- gas/pressure: isobutane/150 mbar
- square pads (2 mm)
- reaction: ^{11}Li(p,t)^{9}Li at 3A MeV
- wire induction mode [1,2]





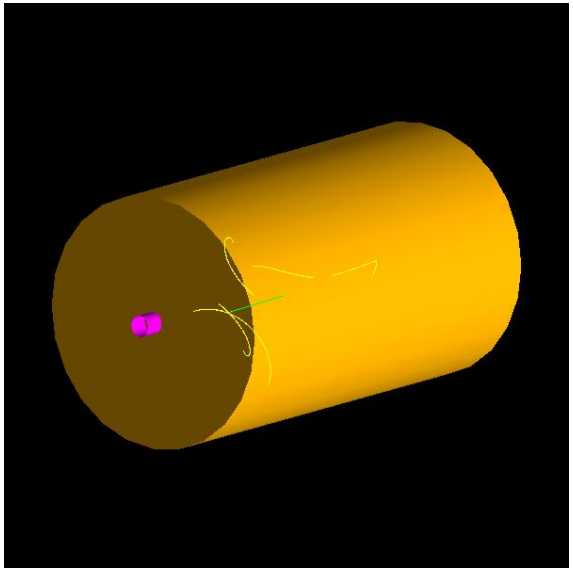
[1] E. Mathieson and J.S. Gordon, Nucl. Instru. Meth. 227 (1984) 277.

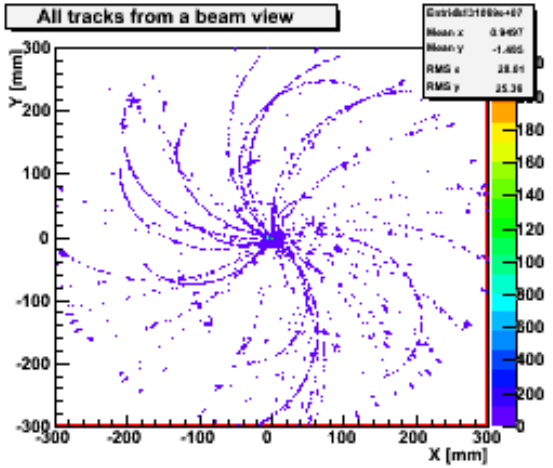
[2] E. Mathieson, Nucl. Instru. Meth. A270 (1988) 602.

ActarSim: digitization visualization

- Cylindrical geometry
- gas/pressure: deuterium/300 mbar
- Magnetic field: 1 T
- reaction: ^{78}Ni(d,p)^{79}Ni at 10A MeV

(cf. E. Benjamim)





ActarSim: development

G4-1.0: Event generators section

G4-1.1: **Trivial generator.** Default generator creating a single particle.
status: Exist with most of the required functionality.

G4-1.2: **CINE/KINE interface.** Interface to the program CINE and KINE
status: Exist.

G4-1.3: **Reaction vertex position and energy.** Determine the position and energy of the reaction vertex.
status: Exist part of the functionality

G4-1.4: **More complex beam description.** noise, contamination, ... (low priority?).
status: Not implemented.

G4-1.5: **Cross sections.** Some code already exists (Beatriz Fernandez).
status: Partially implemented. Unchecked.

ActarSim: development

G4-2.0: Data level

G4-2.1: **Reaction data levels.** (ActarSimData) Contains reaction information, one object to be stored per event.
status: Exist.

G4-2.2: **Track level.** (ActarSimTrack) Optional level with full G4-step information. Requires huge space.
status: Exist. Optimization needed.

G4-2.3: **Simplified track level.** (ActarSimSimpleTrack) Stride (sets of steps) information. The optimization would improve the space efficiency and avoids redundance.
status: Exist. Optimization needed.

G4-3.0: Physics lists, interactions

G4-3.1: **Geant4 actualization.** Use the latest Geant4 version, check new libraries dependencies.
status: To be done.

G4-3.2: **Test low energy energy loss libraries.** Validate the results.
status: Part of the tests done, results not conclusive.

ActarSim: development

G4-4.0: Detector construction:

G4-4.1: **Improve detector description.** Improve on the frames, support elements, ancillary detectors,...
status: Functional version exists, improvements required.

G4-4.2: **Materials description.** Pressure cannot be introduced as external parameters. Create lists.
status: Done, except new materials and gases.

G4-2.3: **Beam shielding.** Realistic implementation not ready.
status: Raw implementation.

G4-5.0: Technical issues:

G4-5.1: **Simplification of Analysis clases.** Removal of duplicate classes in ROOT/G4.
status: To be done.

G4-5.2: **Documentation.** Improvement and uniformization (README, HOWTO, ...).
status: Partially done.

G4-5.3: **(Standard) output information.** Standarize the output messages and use the verbose levels.
status: Partially done.

G4-5.4: **Comments in the code.**.
status: Partially done.

ActarSim: development

D-1.0: Geometry

D-1.1: **Pads geometry.** New geometries should be studied. Study how to implement them.
status: Not done

D-2.0: Drift and diffusion coefficients:

D-2.1: **Drift parameters compilation.** From available literature.
status: Partially done.

D-2.2: **Drift and diffusion model.** Study the possible drift models beyond the simple scheme in use now.
status: Not done.

D-2.3: **Effects on the diffusion of magnetic field.** Lorentz angle, complex trajectories could be discussed.
status: Not done.

D-2.4: **Timing after drift.** Diffusion and threshold properties on the electronics determine timing.
status: Not done.

ActarSim: development

D-3.0: Pad induction

D-3.1: **Study pad induction models.** Different pad induction models are available (wire, GEM, and Micromegas). Study differences and models for the pad induction.
status: partially done.

D-3.2: **Optimization of the induction.** Present model is simple but not optimized (time consuming).
status: Simple model working.

D-4.0: Technical issues:

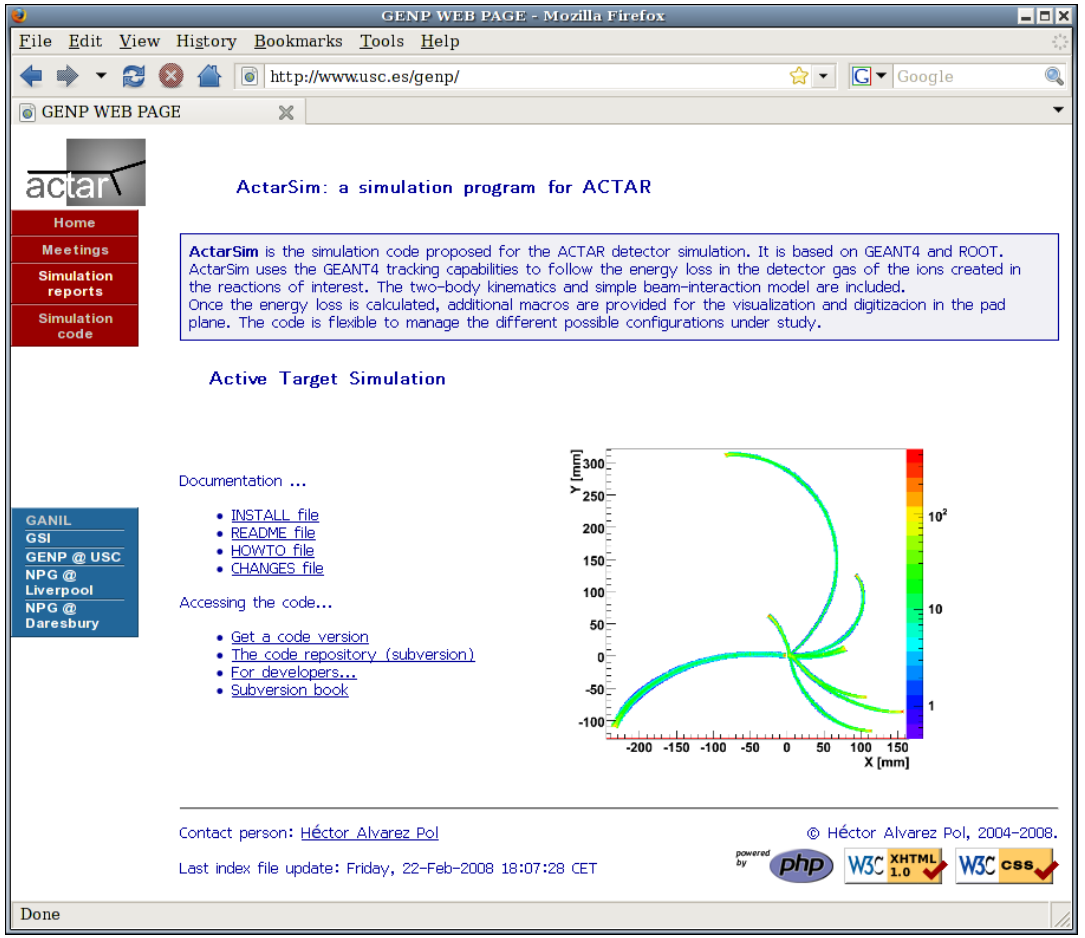
D-4.1: **Compile the code.** The existing code is interpreted (macro) by the ROOT interpreter. A code compilation would improve greatly the velocity.
status: Done.

D-4.2: **Digitization quality histograms.** Histograms about digitization processes and performance.
status: Partially done.

ActarSim: accessibility

http://www.usc.es/genp/

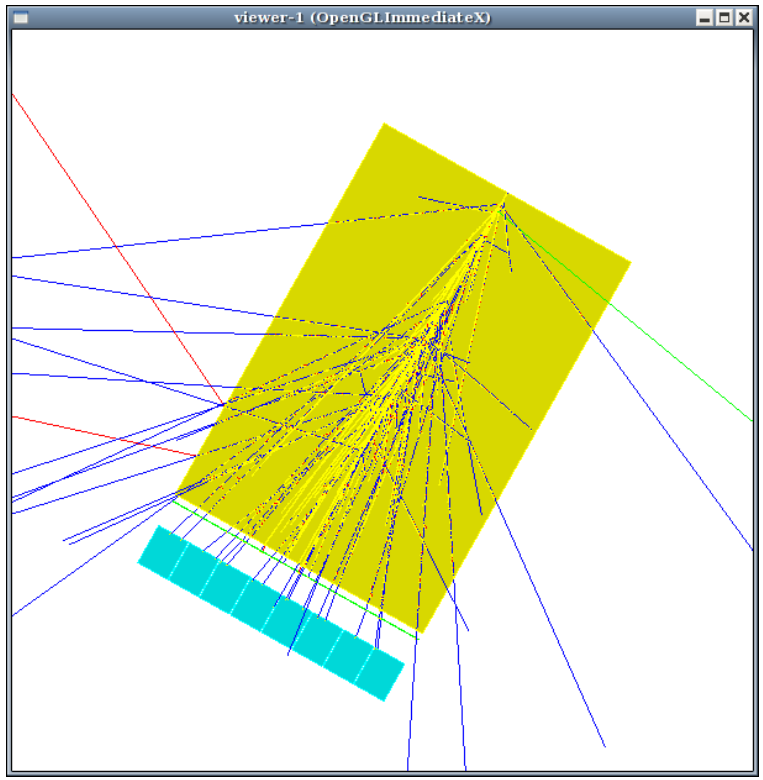
- code repository
- documentation (README, INSTALL, HOWTO, CHANGES)
- presentations of meetings
- simulation reports



A sample run of the simulation code

A top view of the reaction in the chamber.

- reaction: ^{11}Li(p,t)^{9}Li at 3A MeV
- chamber: $200 \times 300 \times 300$ mm^3
- gas: isobutane
- pressure: 300 mbar
- Silicon detector: 300 μm, 100×100 mm^2
- CsI detectors: 25×25 mm^2, 30 mm thick



Particle identification

Particle identifications: (i) $\Delta E - E$, (ii) $E_{gas} - R$

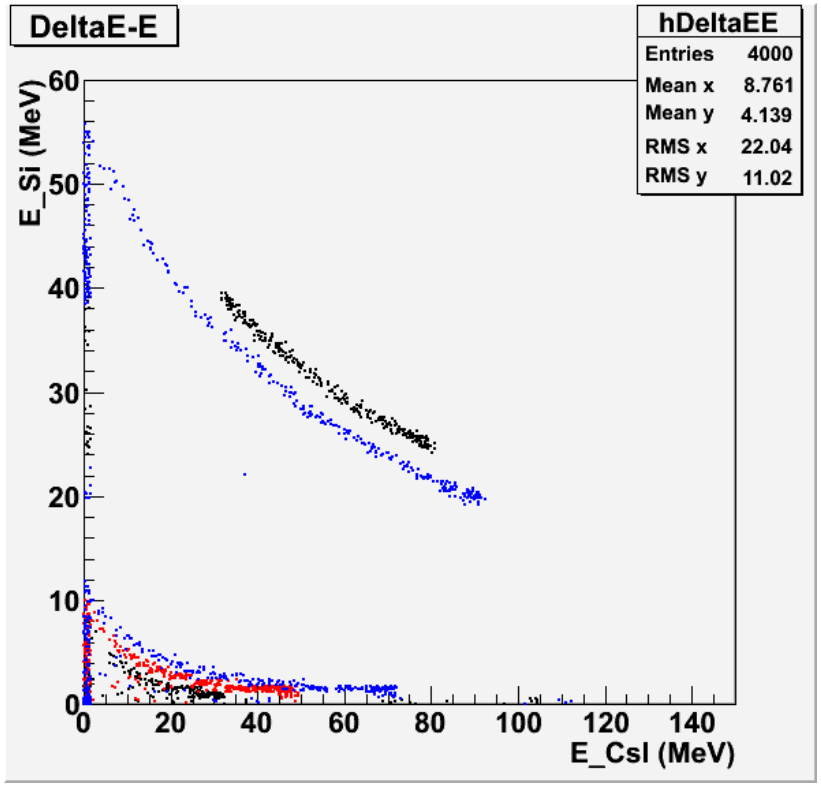
reactions:

- ^{11}Li(p,p)^{11}Li
- ^{11}Li(p,d)^{10}Li
- ^{11}Li(p,t)^{9}Li

Incident Energy: 110 MeV

Silicon: 300 μm

Csi: 30 mm thick



Particle identification

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Particle/Energy: ^{11}Li/33 MeV

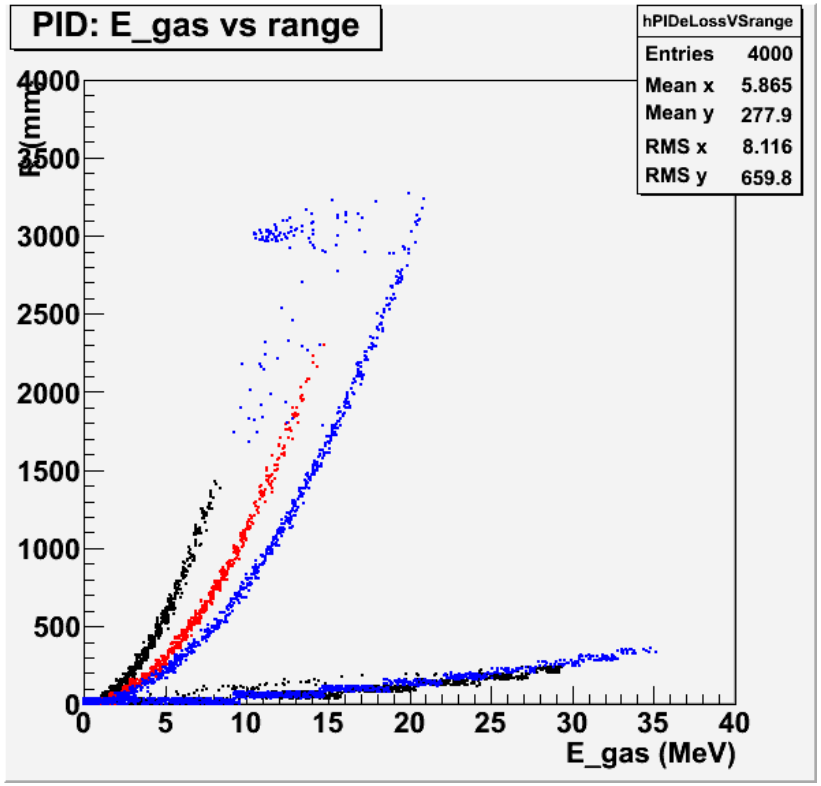
Gas/Pressure: Isobutane/300 mbar

reactions:

- ^{11}Li(p,p)^{11}Li
- ^{11}Li(p,d)^{10}Li
- ^{11}Li(p,t)^{9}Li

Particles stop inside the gas.

- $R = \sum_i r_i$
- $E_{gas} = \sum_i \Delta E_i$



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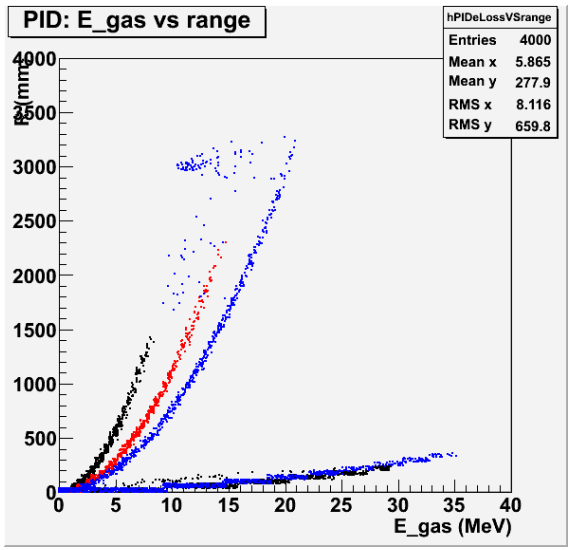
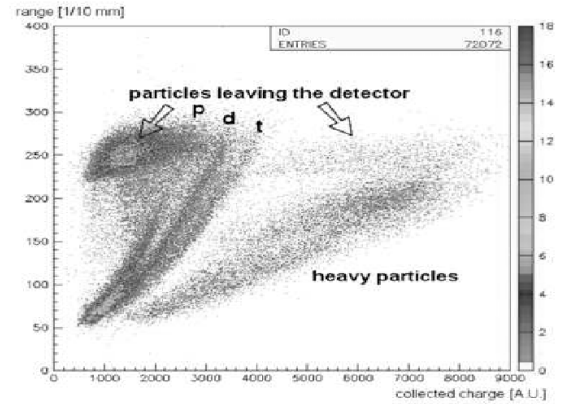




Number of charged pads

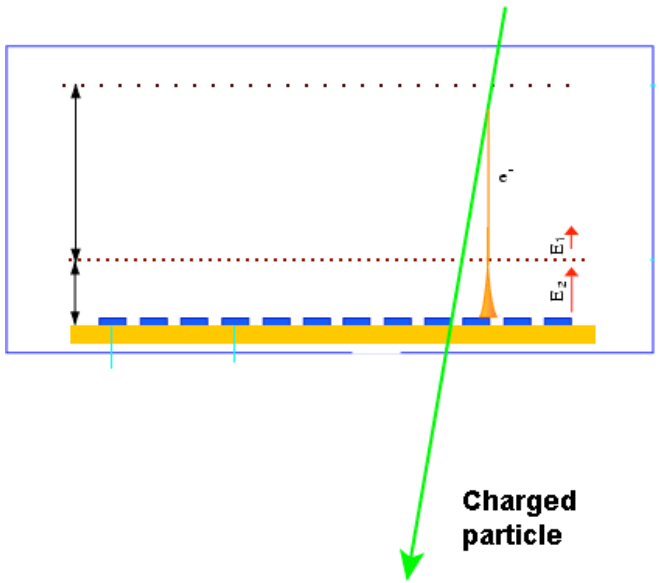
particle/energy: ^{26}Ne/110 MeV

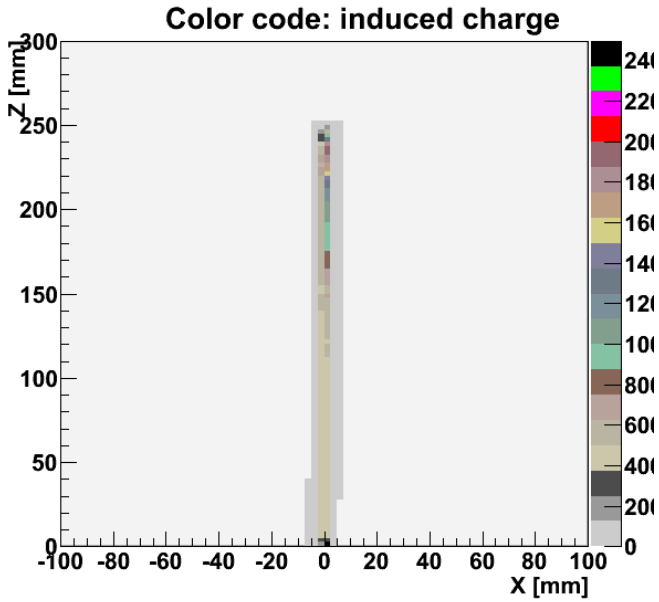
gas/pressure: isobutane/150 mbar

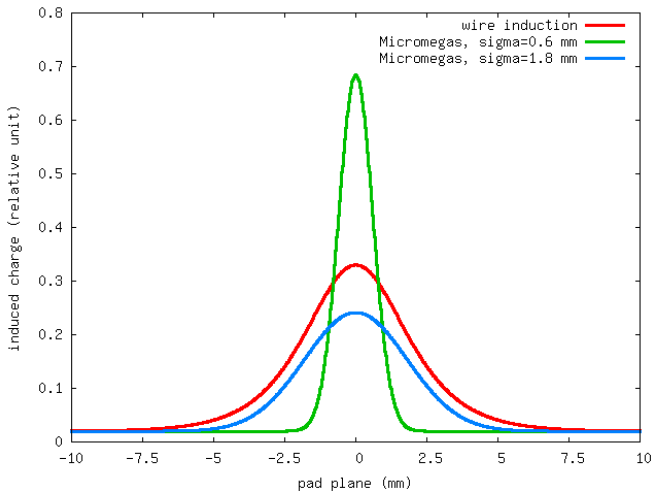
pad size: 2.5 mm

chamber: $200 \times 300 \times 300$ mm^3

charge induction mode: Micromegas







Electron drift velocity and diffusion coefficients

Diffusion: Gaussian distribution [3]:

$$\sigma_x = \sqrt{\frac{2Dx}{W}},$$

W: drift velocity (in mm/s)
D: diffusion coefficient (in mm^2/s)

****

For $E = V/d = 8000(\mathrm{V})/300(\mathrm{mm})$
and $P = 150$ mbar:

$W = 3.89 \times 10^{-2}$ mm/ns
$D = 4.58 \times 10^{-5}$ mm^2/ns
$\sigma_x = 0.6$ mm

[3]: Anna Peisert and Fabio Sauli, Drift and Diffusion of electrons in gases: a compilation, CERN 84-08, 1984

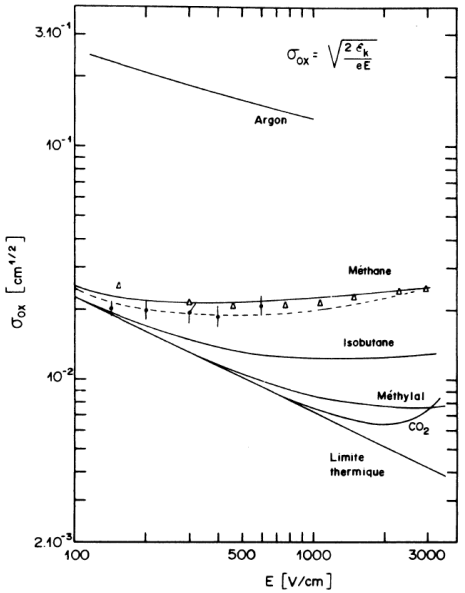


Fig. 31 Schultz (1976)

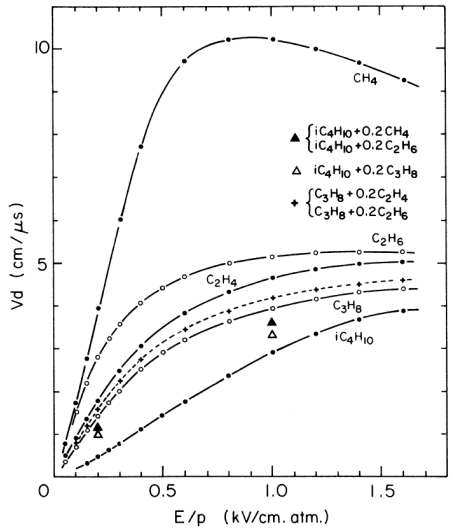


Fig. 185 Lehraus et al. (1982)

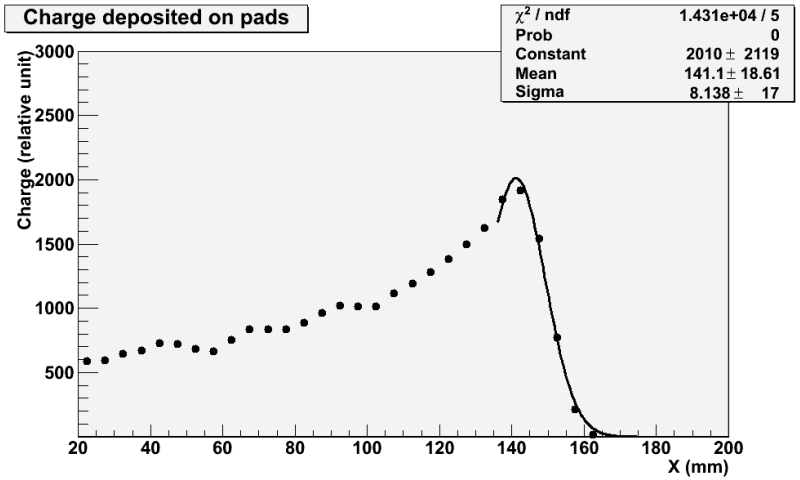
Position resolution with wire induction

particle: ^{9}Li

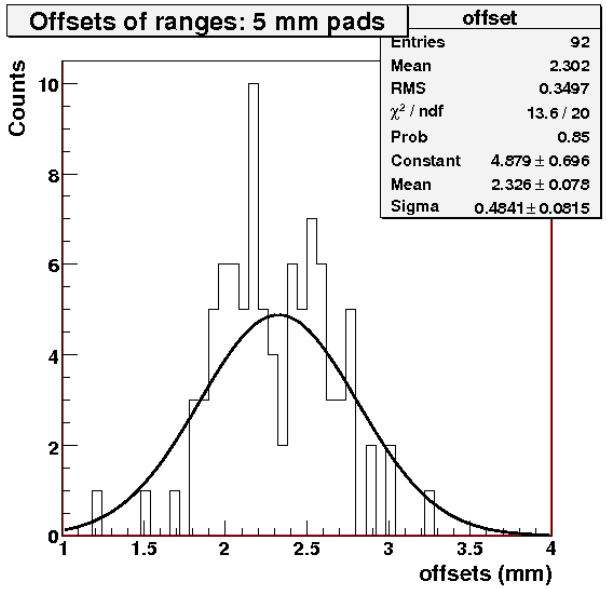
gas/pressure: isobutane/150 mbar

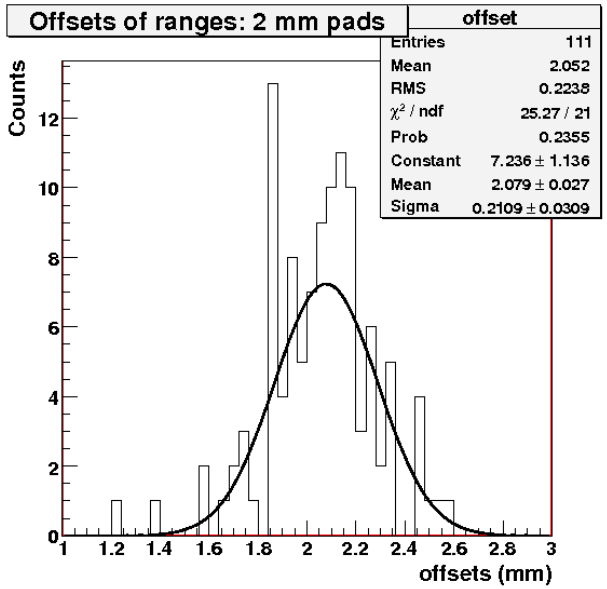
range of ^{9}Li: 120-170 mm

offset: $R_{Geant4} - R_{fit}$



position resolution: $\sim \frac{1}{10}$ pad size





Conclusions

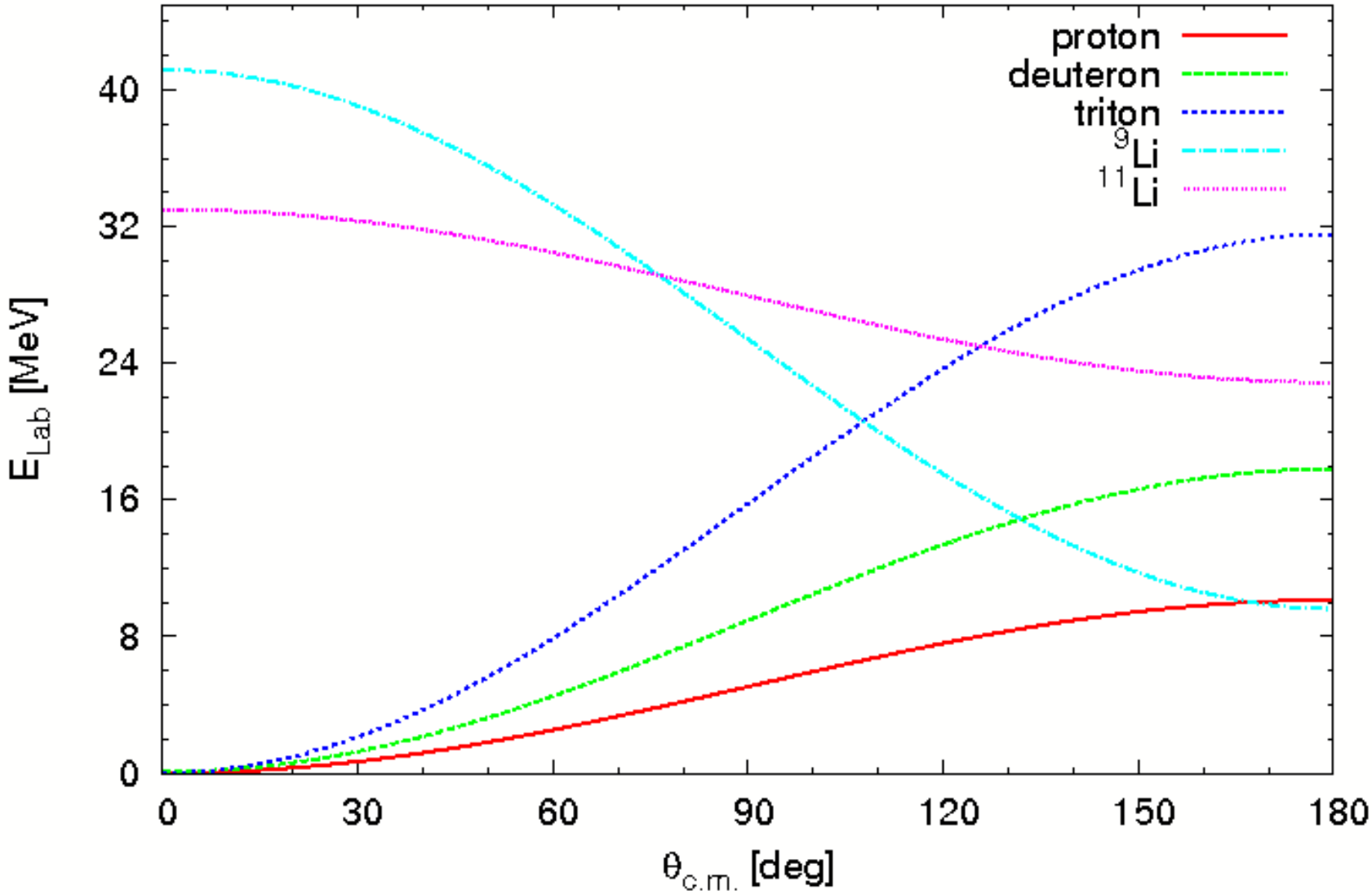
- The work performed during the last years successfully leads to ActarSim
- ActarSim is useful for the setup design and evaluation of the Active Target Detector

What is missing?

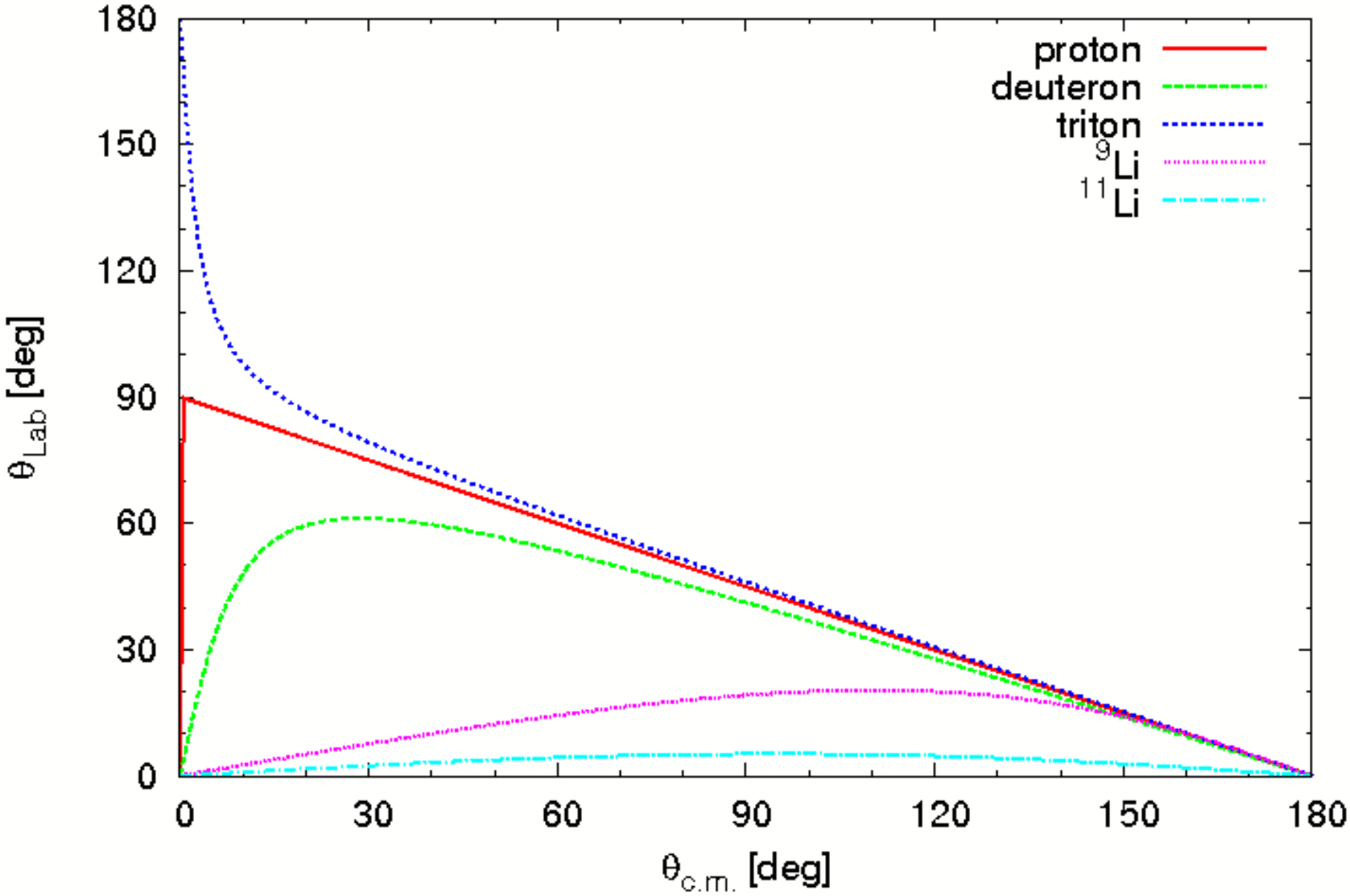
- Apply the analysis algorithms used for experimental data to check the efficiency and resolution (energy, Q-value, position, ...) for various situations. (cf. Thomas' talk)
- Inputs from detector designers (electronics, mechanics).

Thank you for your attention!

Reaction kinematics: $\theta_{c.m.}$-E_{lab}



Reaction kinematics: $\theta_{c.m.}$-θ_{lab}



Reaction kinematics: θ_{lab}-E_{lab}