ACTive TARget Simulations: ACTARSim

Héctor Alvarez Pol

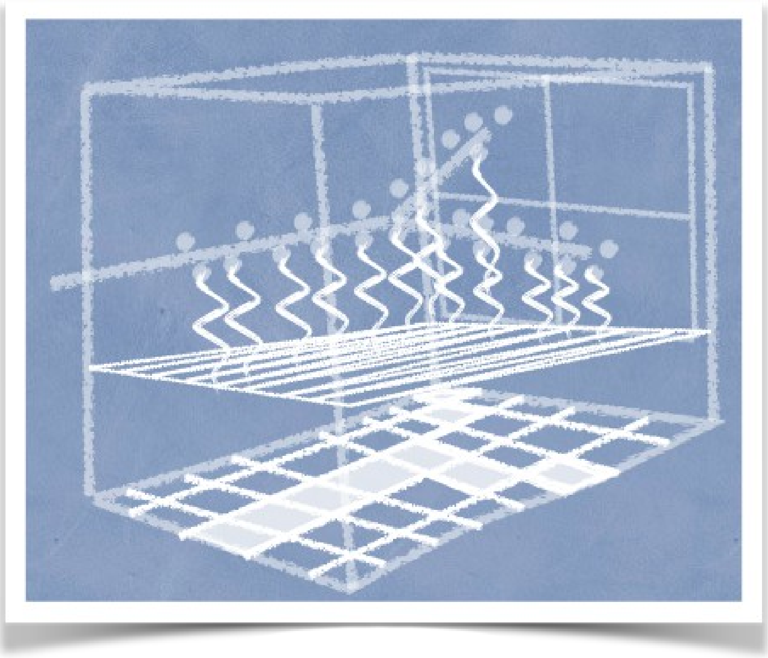
GENP, Univ. de Santiago de Compostela
IGFAE, Santiago de Compostela

Instrumentation Days on Gaseous Detectors
LPC Caen, 5th October 2017

Summary and acknowledgements

ACTive TARget Simulations:
ACTARSim

- Active Targets: *a detector overview from a point of view of a simulation code*.
- Demands for simulation: why this is a difficult case.
- The ACTARSim code.
- Some results with ACTARSim.
- Ongoing work and perspectives.

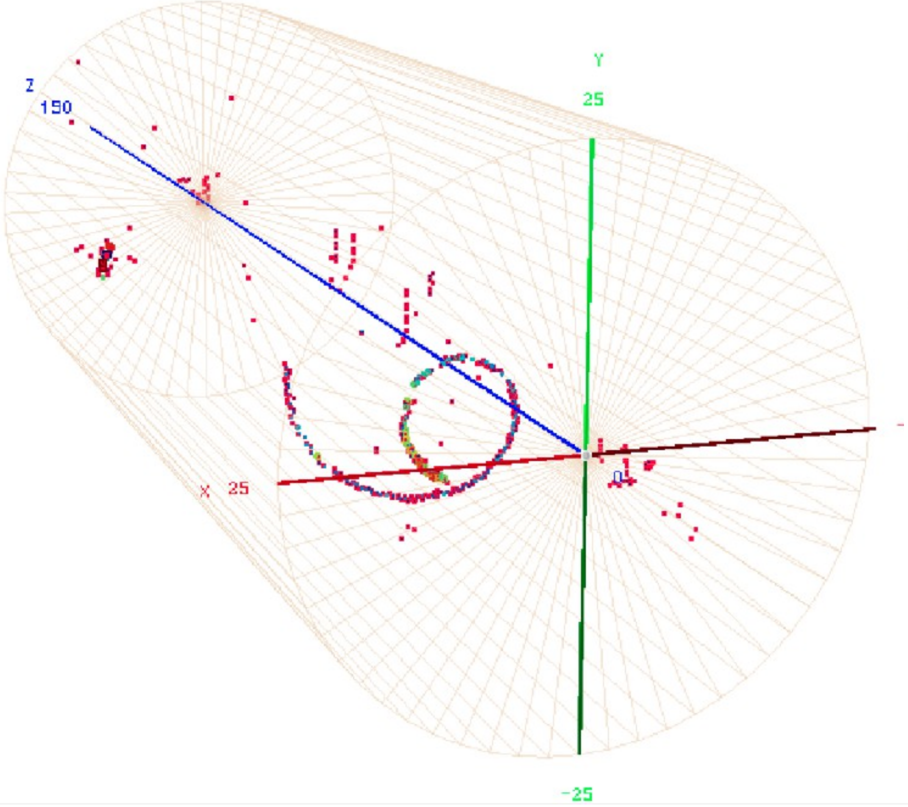


This project has received funding from the **European Union's Horizon 2020** research and innovation programme under grant agreement No 654002 and **Xunta de Galicia "Proxectos Plan Galego IDT"**, project 2013-PG015: "Física de núcleos exóticos con Detectores Activos".

Active Target concept for exotic nuclei

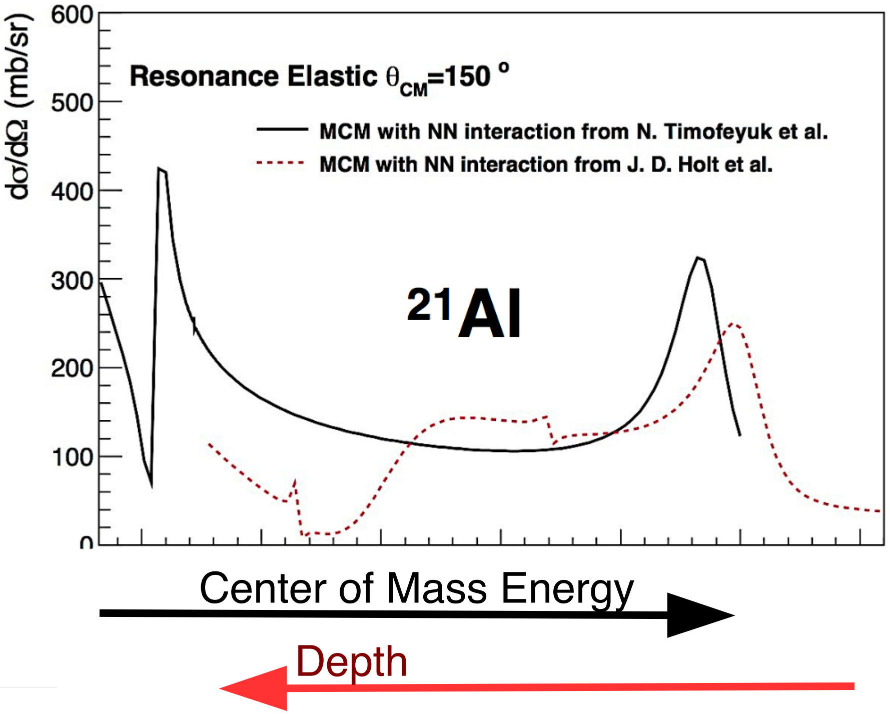
In short: the detection gas is the target itself.

- High geometric efficiency. High detection efficiency.
- High thickness, allows to scan in energy. High luminosity (x100 or even more).



Y. Ayyad et al., J. of Physics CS 876 (2017) 012003

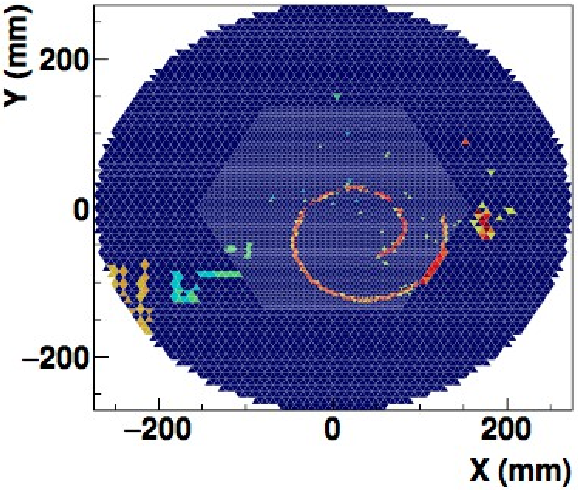
B. Fernández et al. Proposal for HIE-ISOLDE - ^{20}Mg(p,[^{21}Al],p)

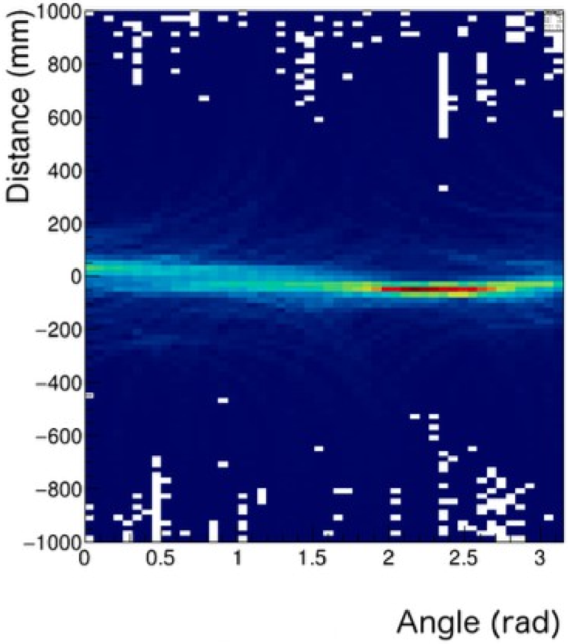


Active Target concept for exotic nuclei

In short: the detection gas is the target itself.

- High geometric efficiency. High detection efficiency.
- High thickness. High luminosity.
- Control on the reaction energy. Very low threshold.
- Full 3D tracking of participant particles.
- In many cases, close to zero background. Ideal for low statistics reactions and short-lived species.

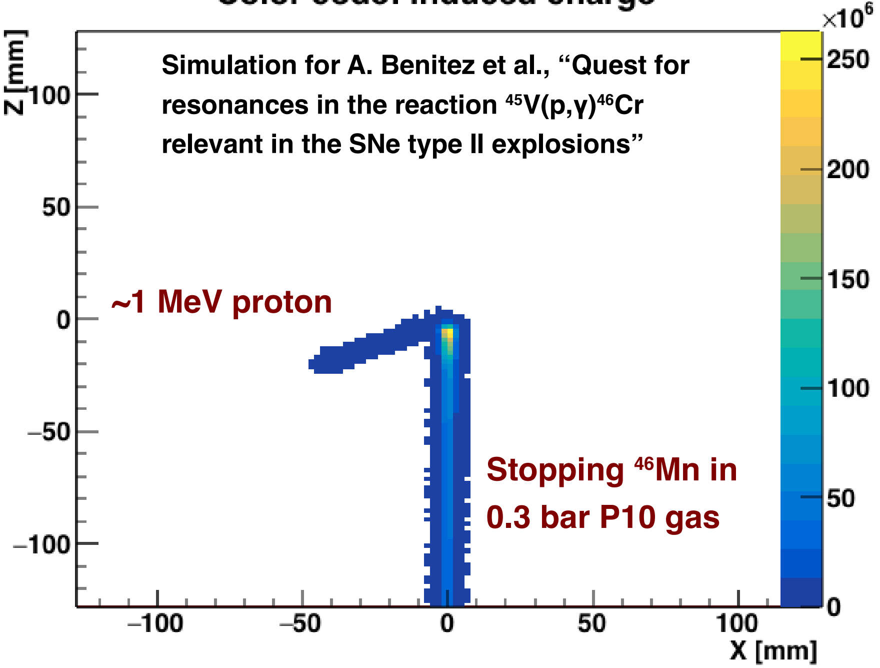




Y. Ayyad et al. J. of Physics CS 876 (2017) 012003

Active Target concept for exotic nuclei

Color code: induced charge

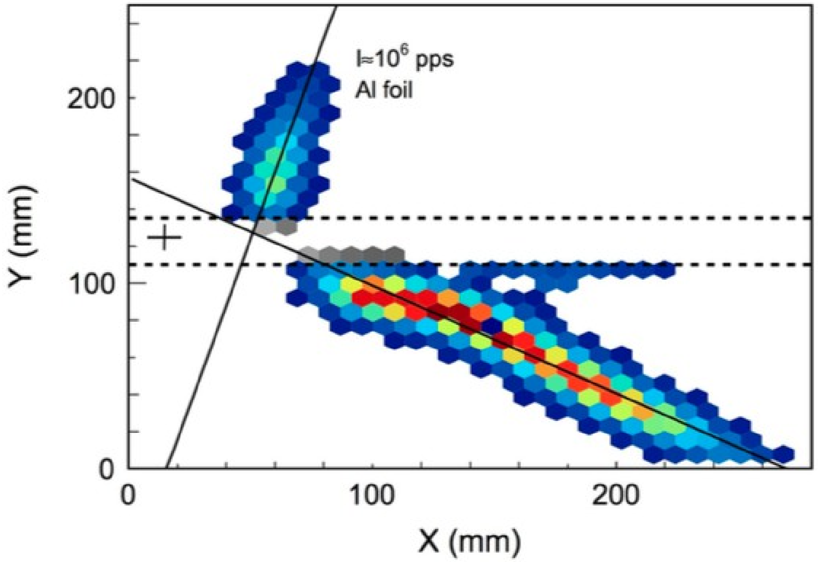


Simulation for A. Benitez et al., "Quest for resonances in the reaction $^{45}V(p,\gamma)^{46}Cr$ relevant in the SNe type II explosions"

~1 MeV proton

Stopping ^{46}Mn in 0.3 bar P10 gas

C. Rodríguez et al., NIM 768, 179 (2014)

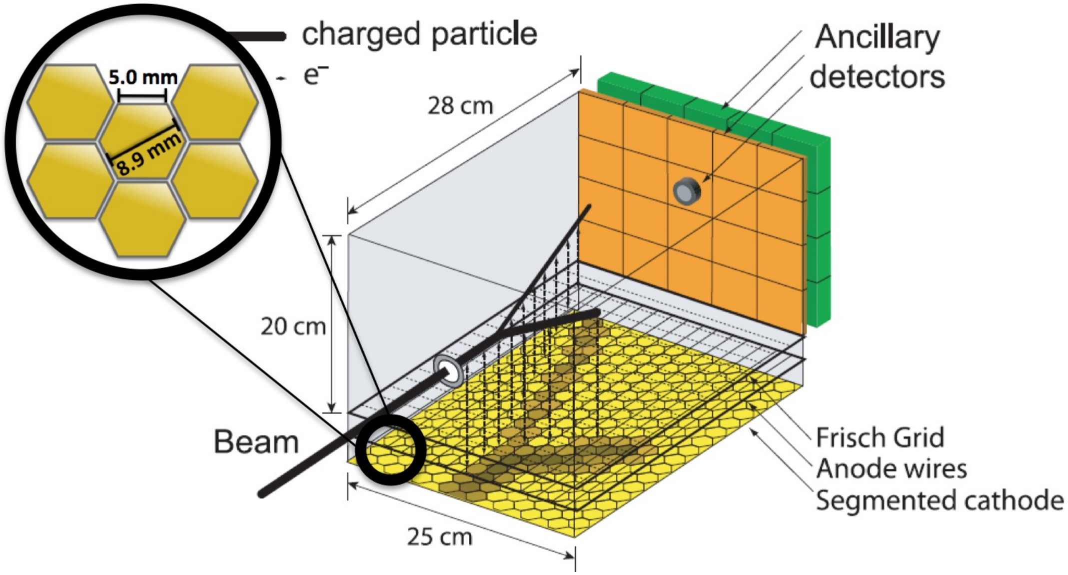


But many complications:

- Gas detector control, gain stability, large dynamic range required, ...
- Many channels for high resolution, complex electronics, ...
- Difficult reconstruction.

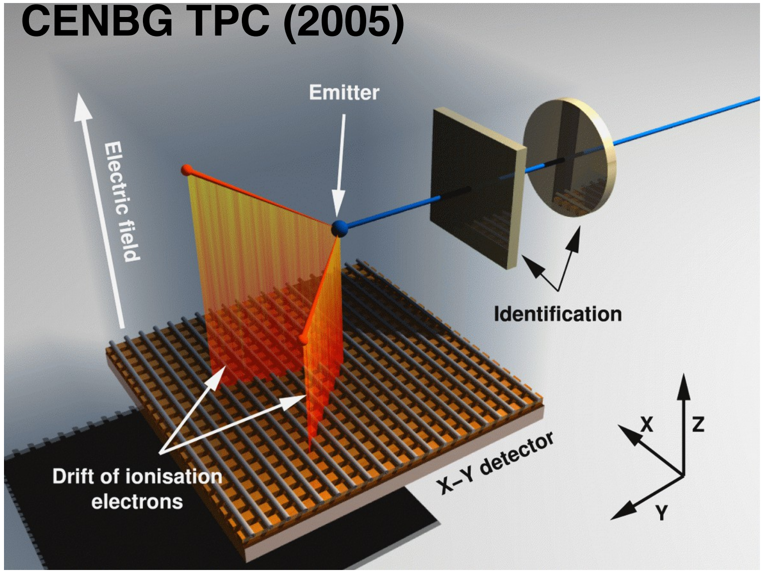
Active Target concept: detectors

MAYA (GANIL 2003)



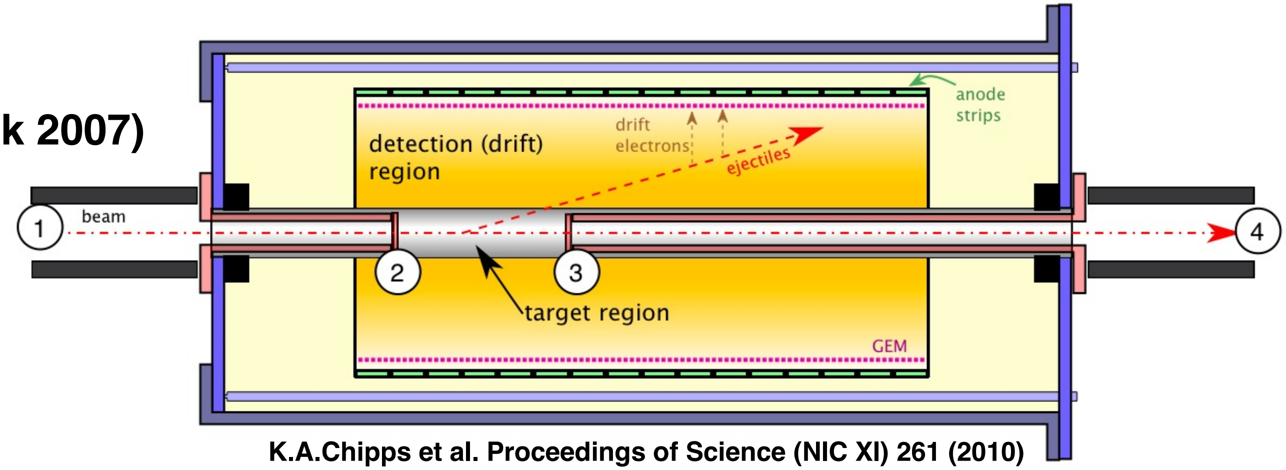
C.E.Demonchy et al. Nucl. Instrum. Meth. Phys. Res. A 583, 341 (2007)

CENBG TPC (2005)



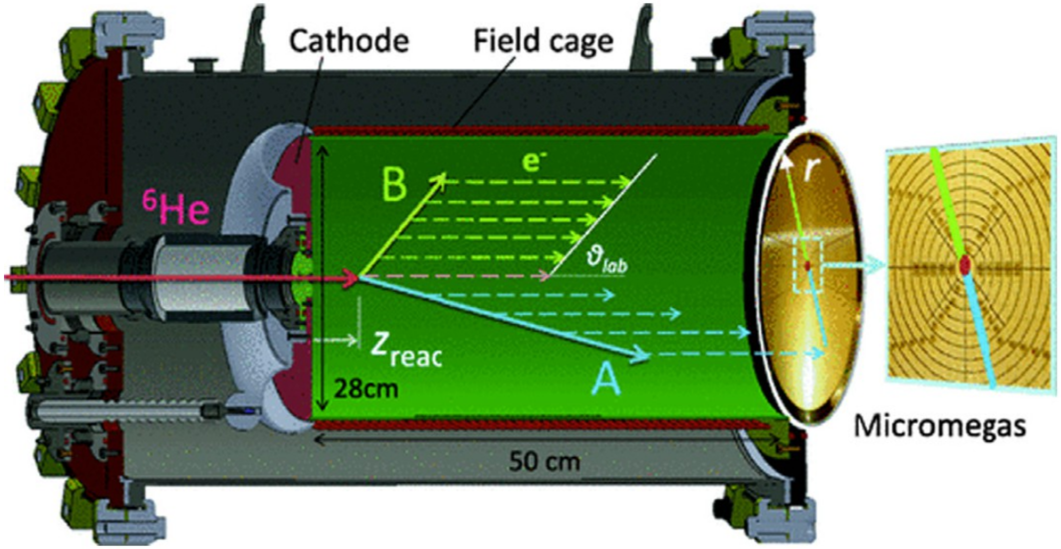
B.Blank et al. Nucl. Instrum. Meth. Phys. Res. A 613, 65 (2010)

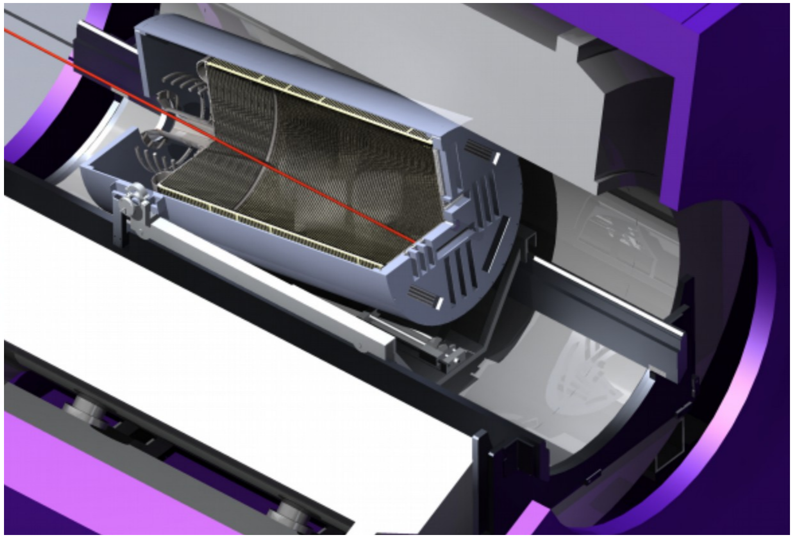
TACTIC (TRIUMF, U. York 2007)



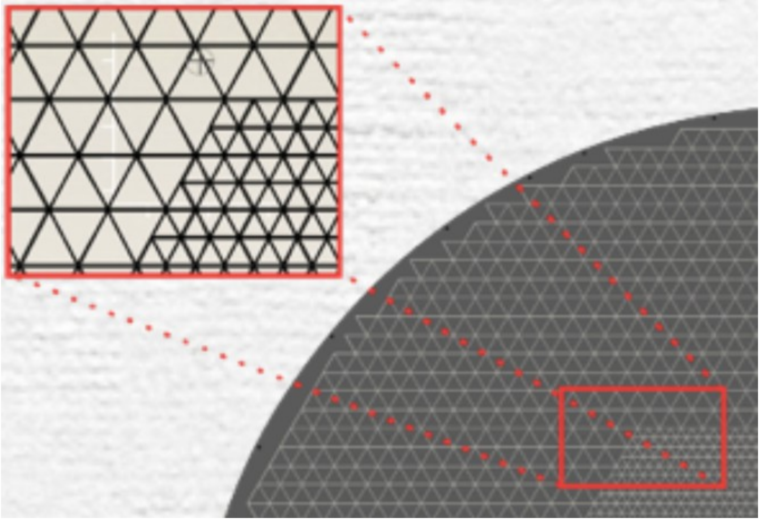
K.A.Chipps et al. Proceedings of Science (NIC XI) 261 (2010)

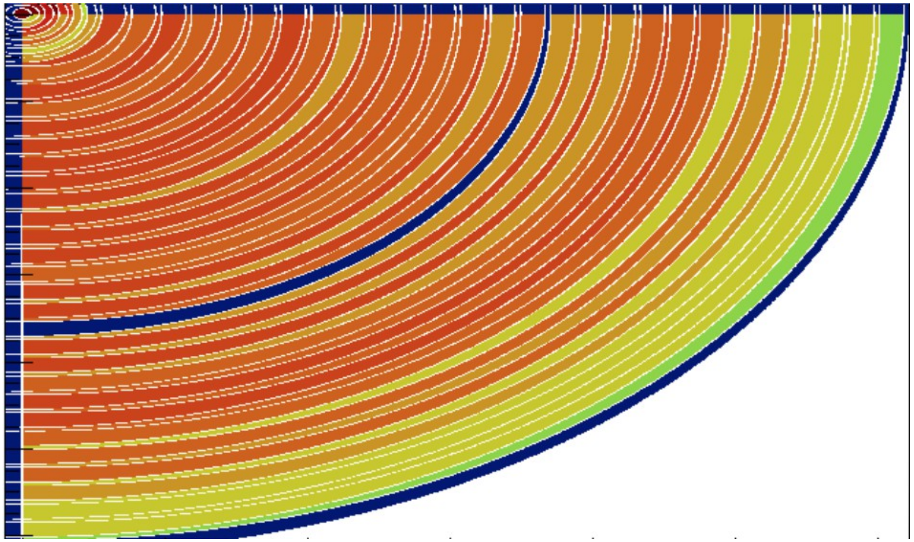
Active Target concept: detectors





ATTPC (MSU, 2015)





W. Mittig et al. NIM A 784 (2015) 494–498

The ACTAR TPC project

The ACTAR TPC detector

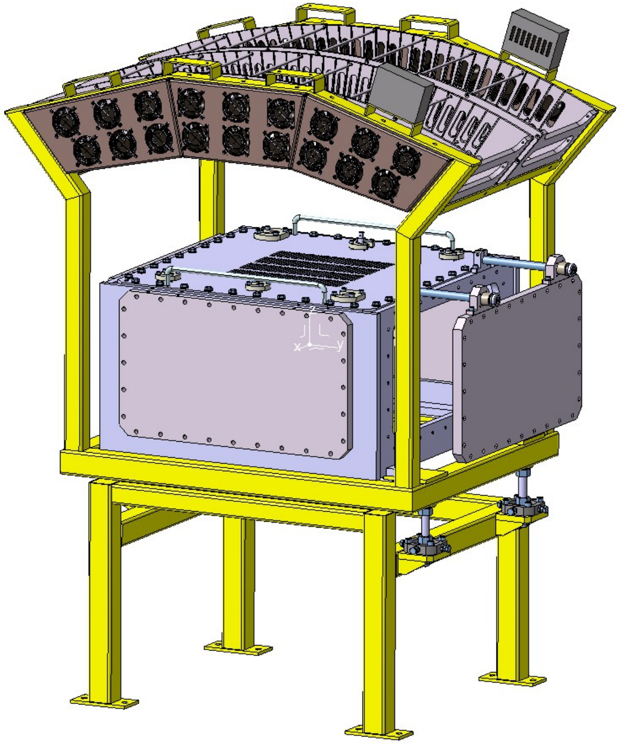
Leading a new generation of Active target devices, it overcomes many of the limitations with present devices, funded via an ERC Starting grant (2014-2019).

Physics cases:

- One and two nucleon transfer reactions.
- Rare and exotic nuclear decay (2p, β-2p, …).
- Transfer-induced fission.
- Inelastic scattering and giant resonances.
- Resonant scattering of astrophysics interest.

Detector Design:

- Amplification = MICROMEGAS
- Pad sizes of 2x2 mm^2: 16384 channels.
- ANR General Electronics for TPC’s (GET).
- Improved data throughput + internal trigger.



http://pro.ganil-spiral2.eu/laboratory/detectors/actartpc

ACTARSim: a simulation code for ACTAR TPC

ACTARSim (since 2005)

ACTARSim is a **Geant4 + ROOT** code for the ACtive TARgets simulation.

- Developed for the ACTAR TPC design and MAYA analysis.
- Initial development at USC, maintained and extended in GANIL since 2008.
- New developments ongoing during ACTAR-TPC construction period, responsabilities back to USC (2013).
- We acknowledge recent contributions from: T. Marchi (Leuven), P. Cabanelas (USC), Y. Ayyad (MSU). Analysis results performed by P. Konczykowski will be included here.

GEANT4 is used for the production and tracking of primaries and secondaries above E_{cut} = 1 keV. ROOT is used for the calculation of the drift and diffusion of the electronic clouds, the induction in the pad plane, data persistence, ...

What is doing the simulation?

Evaluation of the energy and time resolution, detection efficiency, reconstruction algorithm evaluation, trigger pattern efficiency, …, requiring:

GEANT4

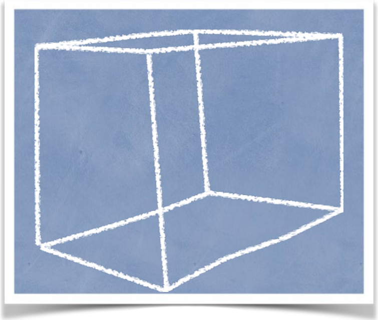
- Complete **geometrical description** of the setup including ancillary detectors.
- Accurate **energy loss** in the gas, windows, and additional media.
- Beam propagation and **reaction model**: 2-body and manybody kinematics, decay...

ROOT

- **Electron transport model** and parameters adjusted to the gas pressure and fields.
- **Amplification model**, including time formation of the signal at the pad plane.
- (3D)**Reconstruction of the signal** from the pad plane information.
- **Track model fit**: energy loss, range, transformations to parameter space, …
- Reconstruction for possible reactions covering/shadowing the search, background...

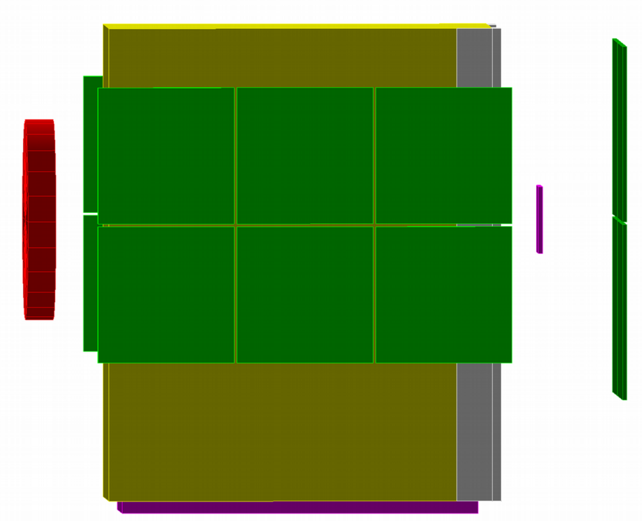
ACTARSim overview: the detectors in Geant4

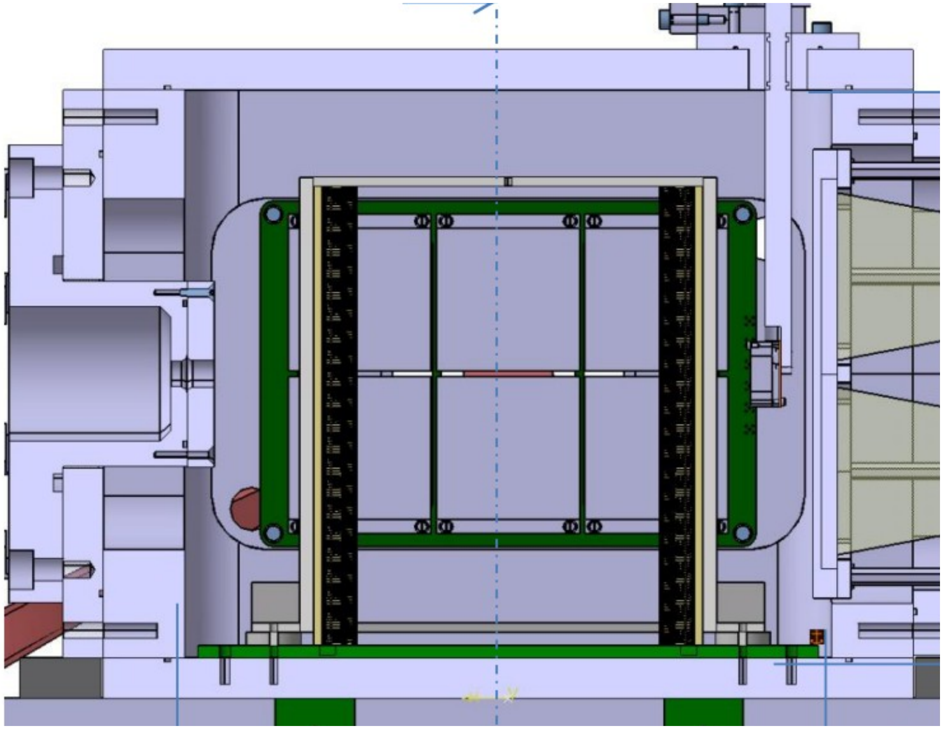
1. Detectors (gas box) geometry:



- General cube (MAYA or ACTAR-TPC).
- General cylinder (drift on endcaps or sides).
- Easy size modification for design.
- Predefined detectors with fixed configurations:

ACTAR TPC Demonstrator:





ACTARSim overview: the detectors in Geant4

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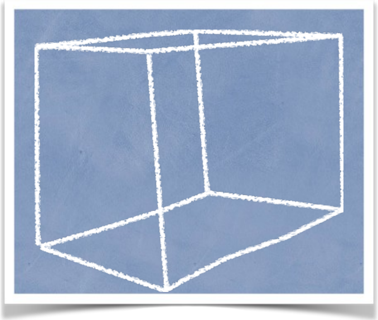

- General cube (MAYA or ACTAR-TPC).
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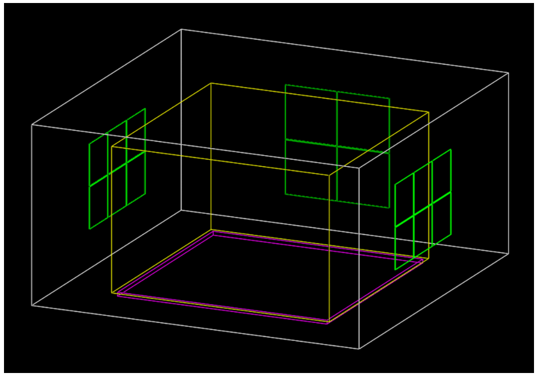
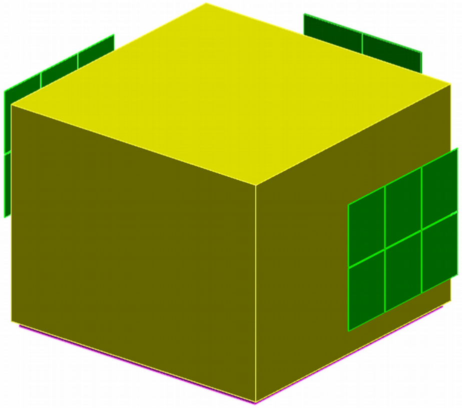
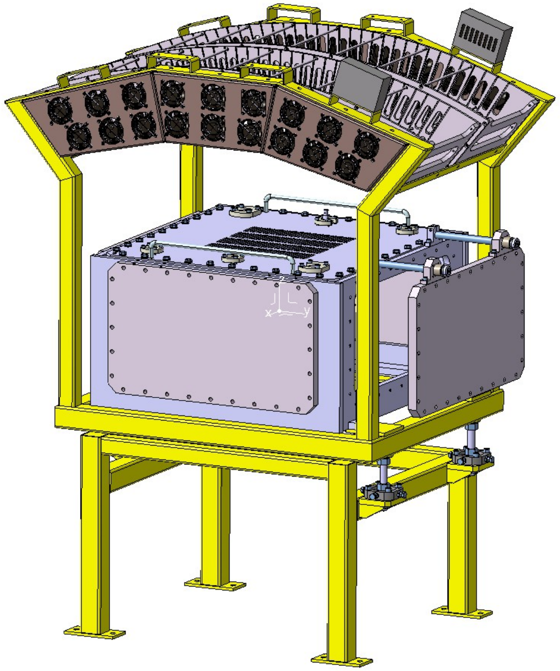
ACTAR TPC (full detector, preliminary version).







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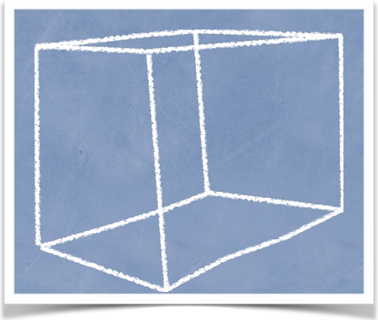
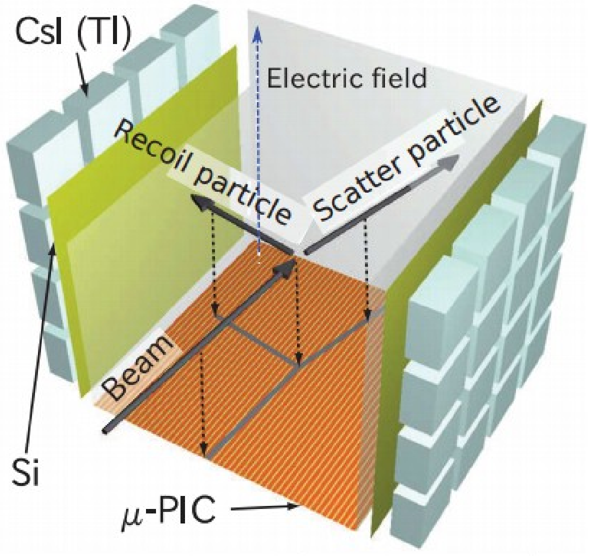
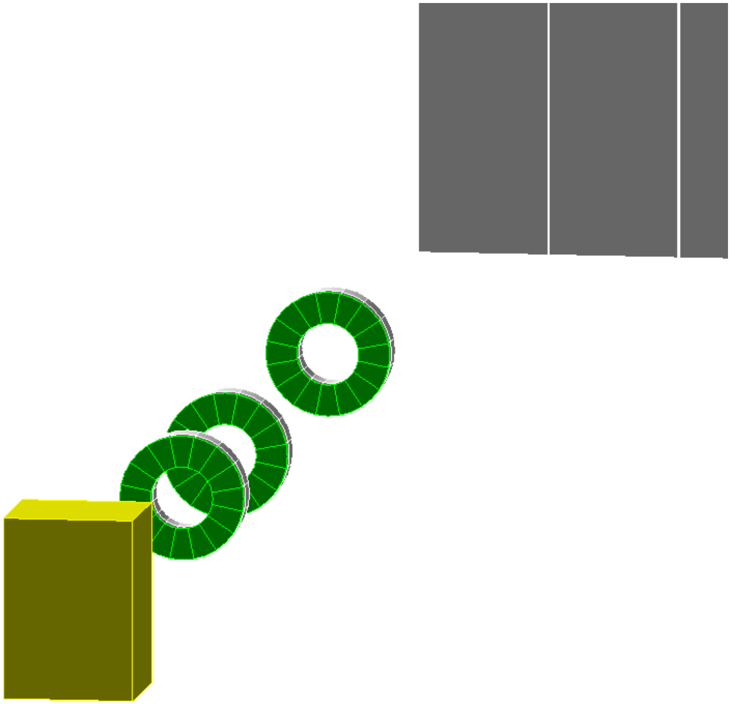


- General cube (MAYA or ACTAR-TPC).
- General cylinder (drift on endcaps or sides).
- Easy size modification for design.
- Predefined detectors with fixed configurations:

MAIKO (by Y. Ayyad, Osaka/MSU).



T Furuno et al 2014 J. Phys.: Conf. Ser. 569 012042



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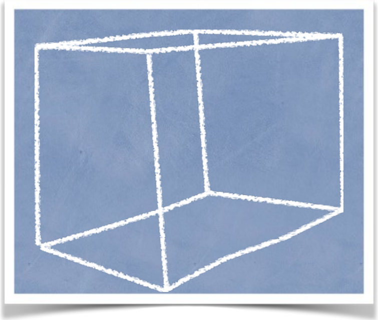
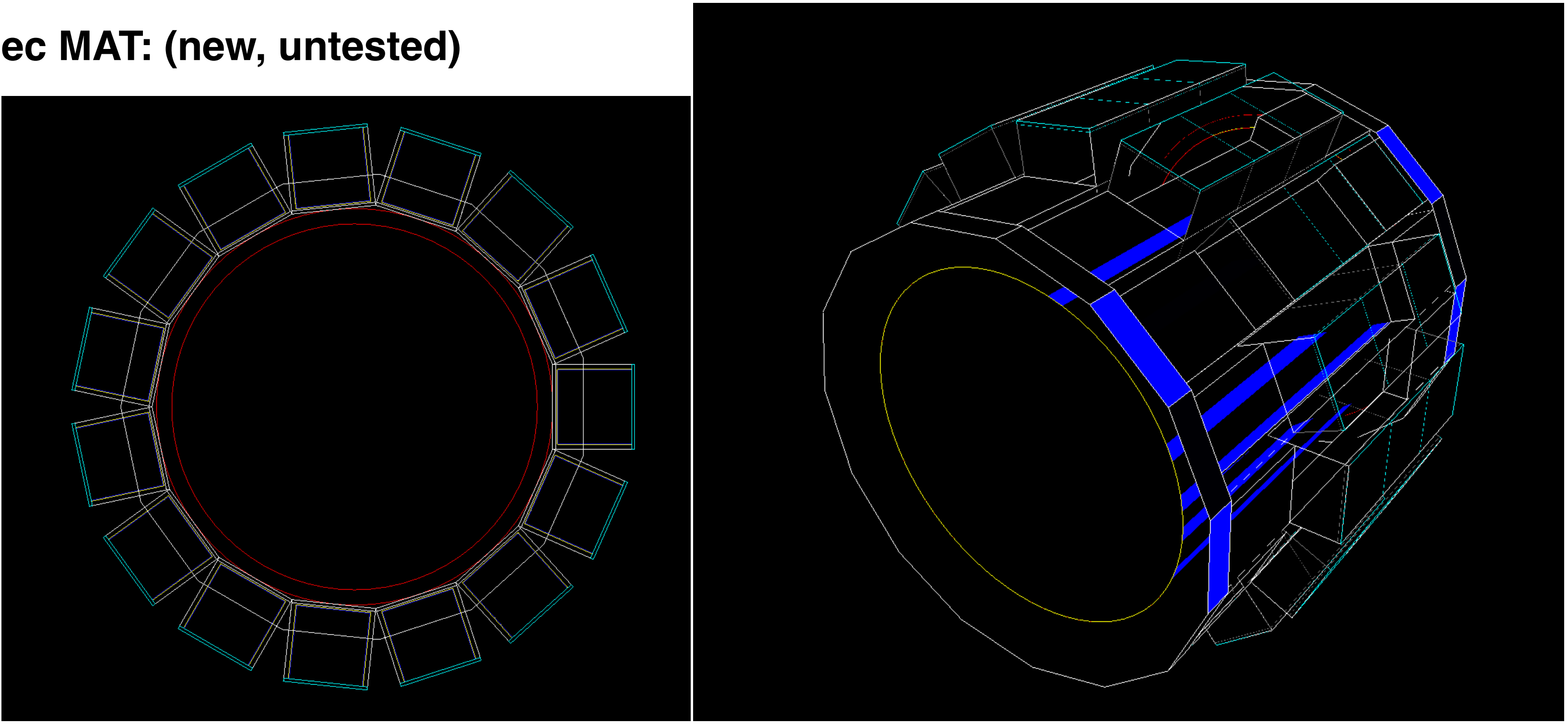


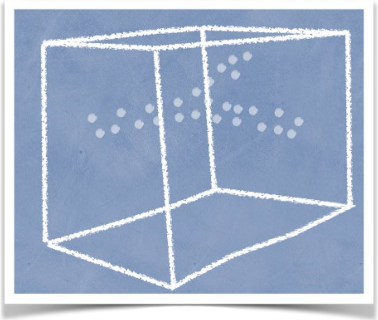
- General cube (MAYA or ACTAR-TPC).
- General cylinder (drift on endcaps or sides).
- Easy size modification for design.
- Predefined detectors with fixed configurations:

http://fys.kuleuven.be/iks/ns/research/specmat

Spec MAT: (new, untested)



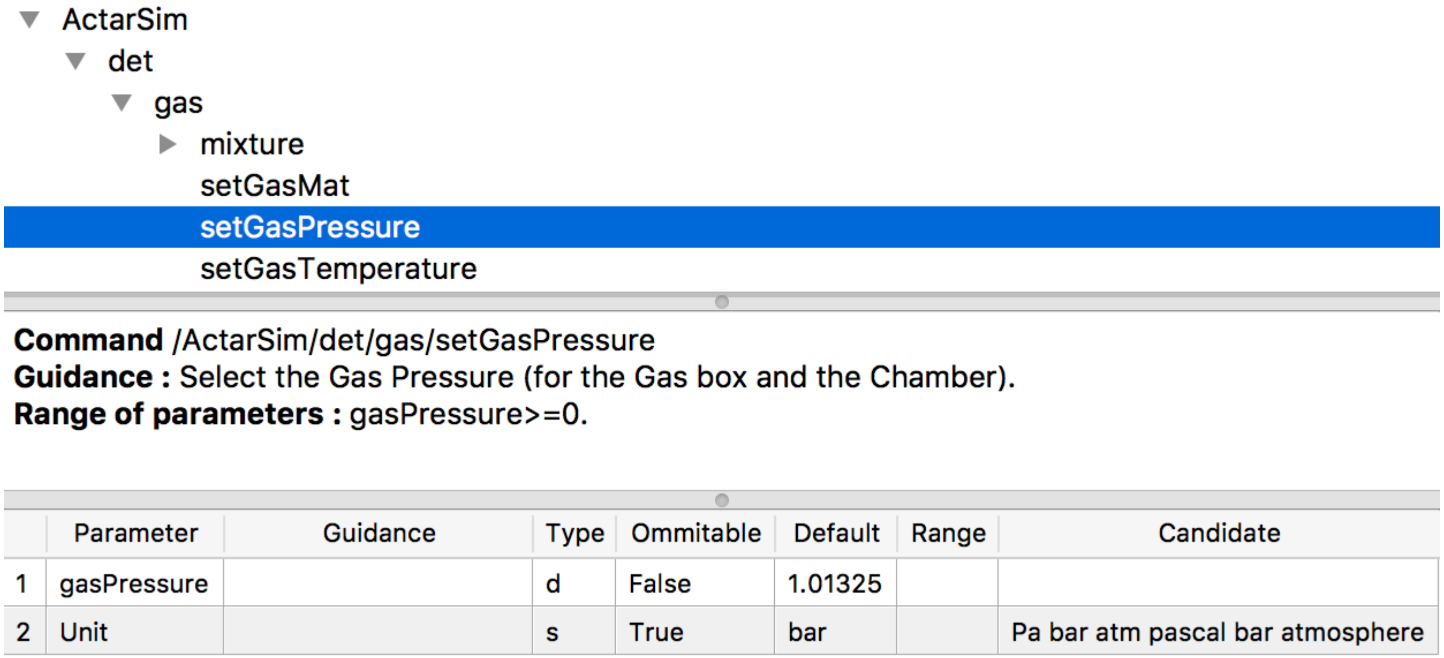
ACTARSim overview: the detectors in Geant4



1. Detectors geometry: predefined or configurable.

2. Gas and pressure:

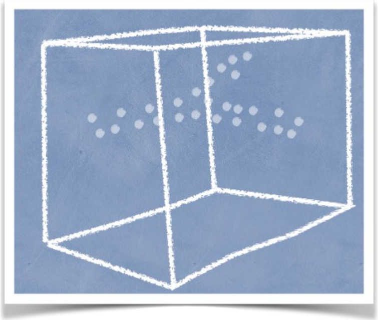
- Most gases of interest for AT predefined.
- Presure and temperature can be defined by the user:



Command /ActarSim/det/gas/setGasPressure
Guidance : Select the Gas Pressure (for the Gas box and the Chamber).
Range of parameters : gasPressure>=0.

	Parameter	Guidance	Type	Ommitable	Default	Range	Candidate
1	gasPressure		d	False	1.01325		
2	Unit		s	True	bar		Pa bar atm pascal bar atmosphere

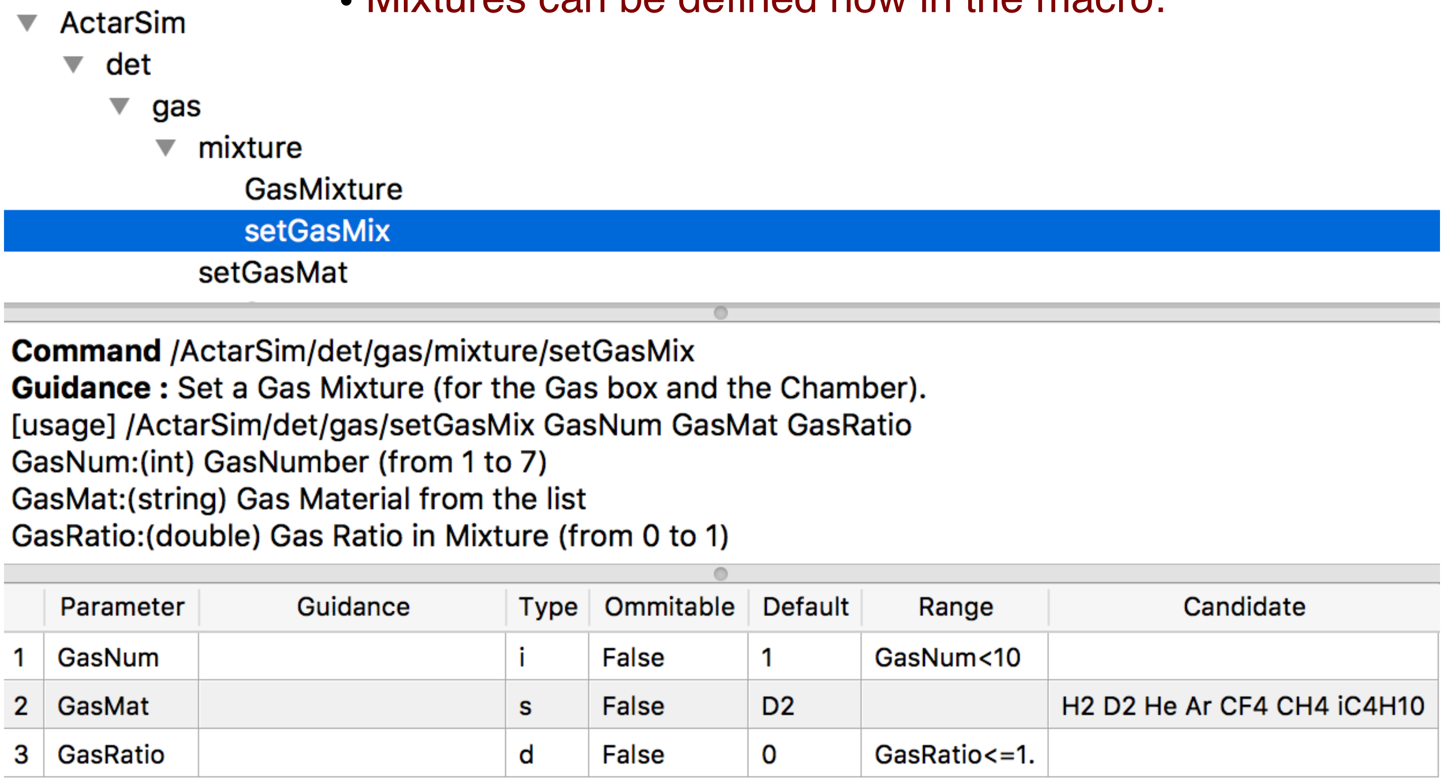
ACTARSim overview: the detectors in Geant4



1. Detectors geometry: predefined or configurable.

2. Gas and pressure:

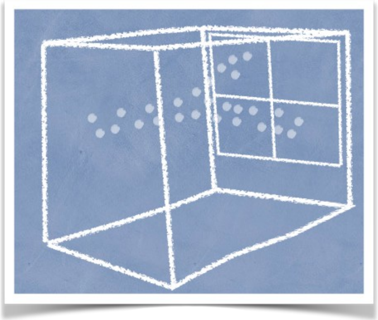
- Most gases of interest for AT predefined.
- Presure and temperature can be defined by the user.
- Mixtures can be defined now in the macro:



Command /ActarSim/det/gas/mixture/setGasMix
Guidance : Set a Gas Mixture (for the Gas box and the Chamber).
[usage] /ActarSim/det/gas/setGasMix GasNum GasMat GasRatio
GasNum:(int) GasNumber (from 1 to 7)
GasMat:(string) Gas Material from the list
GasRatio:(double) Gas Ratio in Mixture (from 0 to 1)

	Parameter	Guidance	Type	Ommitable	Default	Range	Candidate
1	GasNum		i	False	1	GasNum<10	
2	GasMat		s	False	D2		H2 D2 He Ar CF4 CH4 iC4H10
3	GasRatio		d	False	0	GasRatio<=1.	

ACTARSim overview: the detectors in Geant4



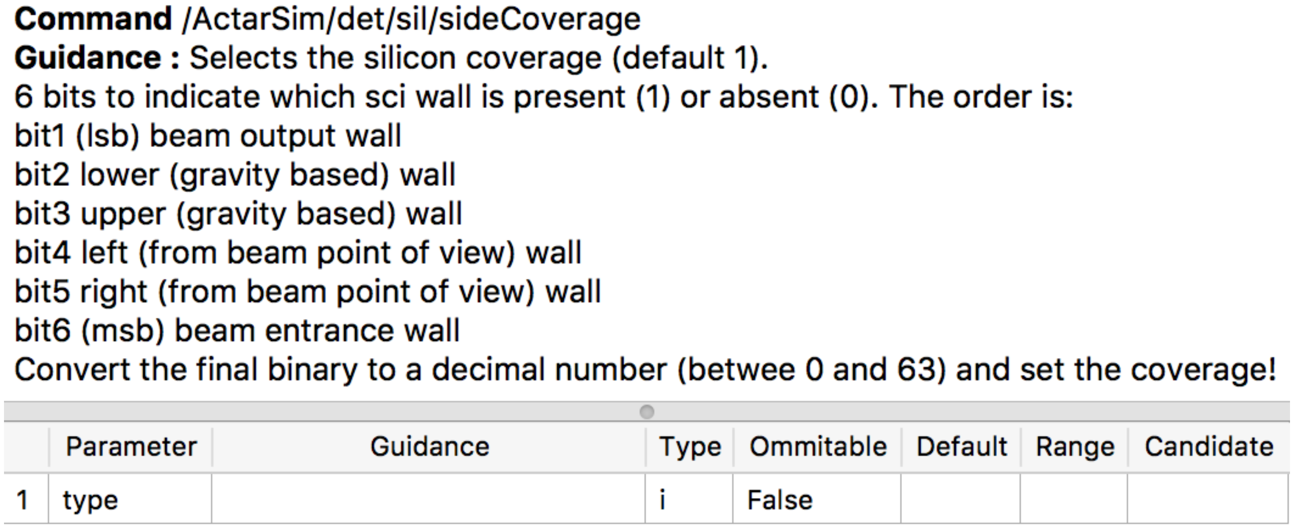
1. Detectors geometry: predefined or configurable.

2. Gas and pressure: pure or mixtures, selectable pressure.

3. Ancillary detectors:

- Configurable (standard MAYA) silicon DSSD layers.
- Configurable (standard MAYA) CsI[Tl] detectors.
- New ancillary should be included as soon as fixed or for specific setups.

It should not be too complex to mix with other Geant4 simulated setups.

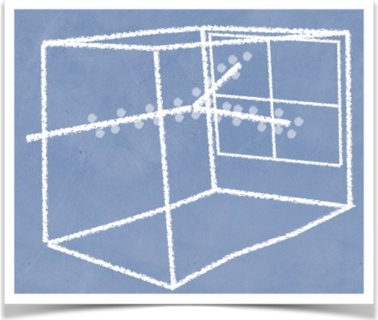


Command /ActarSim/det/sil/sideCoverage
Guidance : Selects the silicon coverage (default 1).
6 bits to indicate which sci wall is present (1) or absent (0). The order is:
bit1 (lsb) beam output wall
bit2 lower (gravity based) wall
bit3 upper (gravity based) wall
bit4 left (from beam point of view) wall
bit5 right (from beam point of view) wall
bit6 (msb) beam entrance wall
Convert the final binary to a decimal number (betwee 0 and 63) and set the coverage!

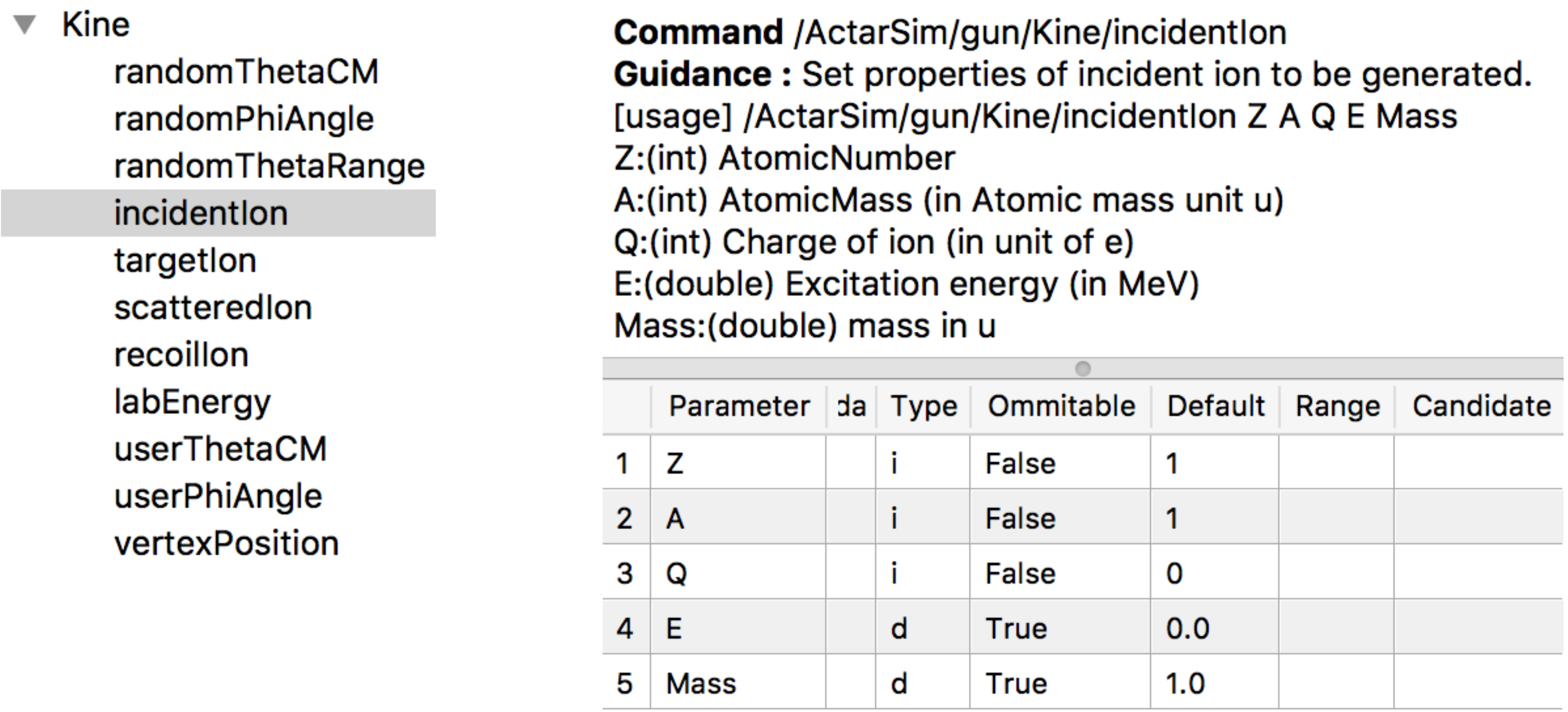
	Parameter	Guidance	Type	Ommitable	Default	Range	Candidate
1	type		i	False			

ACTARSim overview: the Geant4 transport

1. Kinematics calculator and particle gun:



- Event generator (2-body relativistic kinematics) with realistic vertex (position and energy after beam interaction in gas).
- … Or complete control over the particle triggered by the gun.



▼ Kine
- randomThetaCM
- randomPhiAngle
- randomThetaRange
- incidentIon
- targetIon
- scatteredIon
- recoilIon
- labEnergy
- userThetaCM
- userPhiAngle
- vertexPosition

Command /ActarSim/gun/Kine/incidentIon
Guidance : Set properties of incident ion to be generated.
[usage] /ActarSim/gun/Kine/incidentIon Z A Q E Mass
Z:(int) AtomicNumber
A:(int) AtomicMass (in Atomic mass unit u)
Q:(int) Charge of ion (in unit of e)
E:(double) Excitation energy (in MeV)
Mass:(double) mass in u

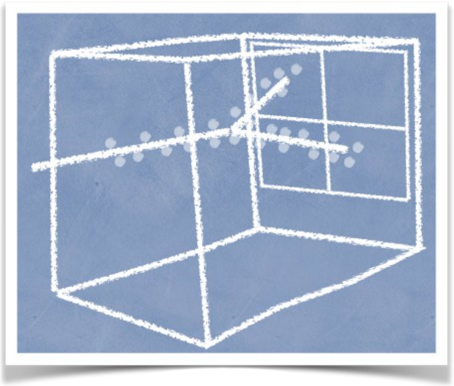
	Parameter	da	Type	Ommitable	Default	Range	Candidate
1	Z		i	False	1		
2	A		i	False	1		
3	Q		i	False	0		
4	E		d	True	0.0		
5	Mass		d	True	1.0		

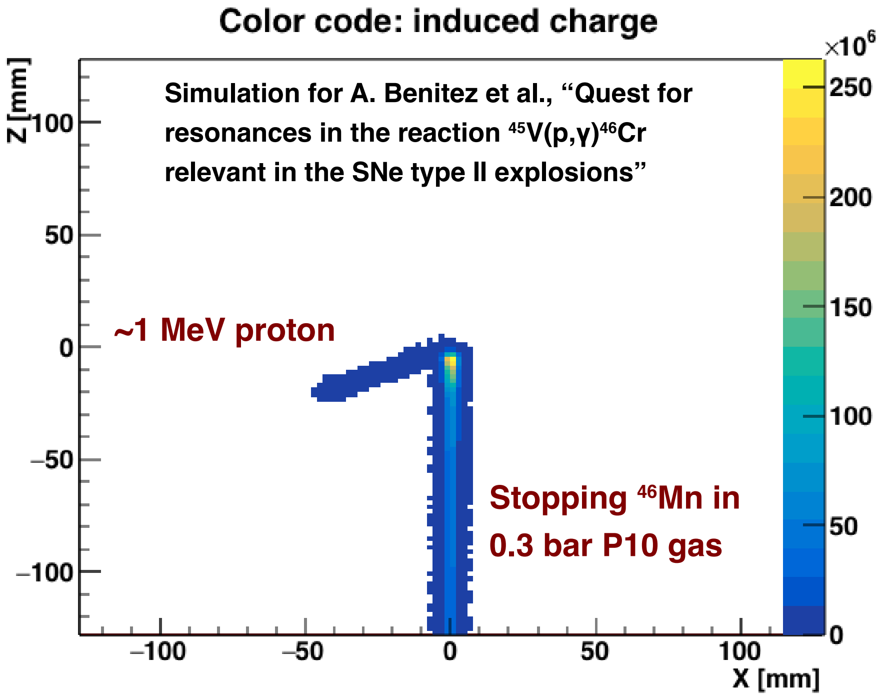
ACTARSim overview: the Geant4 transport

1. Kinematics calculator integrated and particles gun.

2. Physics interaction in Geant4:

- Realistic description of discrete and continuum processes.
- User selectable physics packages (in .mac configuration).
- Realistic beam-gas interaction with gaussian beam profile.



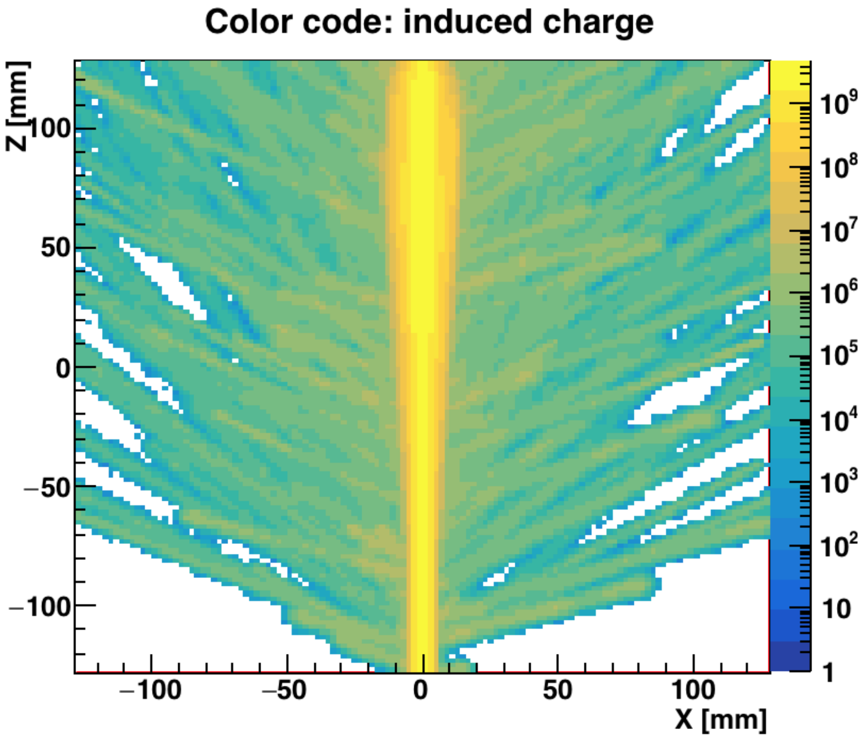


Color code: induced charge

Simulation for A. Benitez et al., “Quest for resonances in the reaction $^{45}\mathrm{V}(p,\gamma)^{46}\mathrm{Cr}$ relevant in the SNe type II explosions”

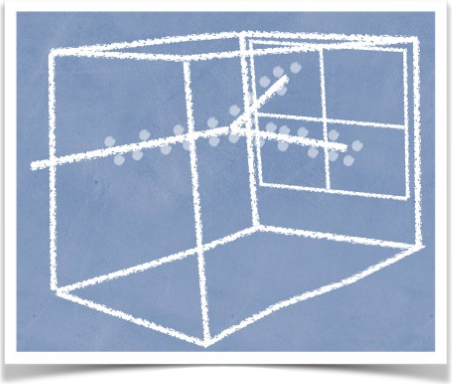
~1 MeV proton

Stopping ^{46}Mn in 0.3 bar P10 gas



Color code: induced charge

ACTARSim overview: the Geant4 transport



1. Kinematics calculator integrated and particles gun.

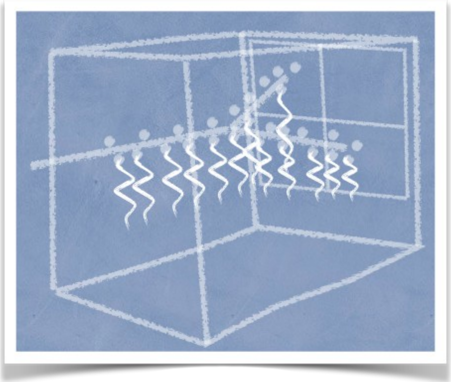
2. Physics interaction in Geant4.

3. Data output (standard ROOT TFile from Geant4):

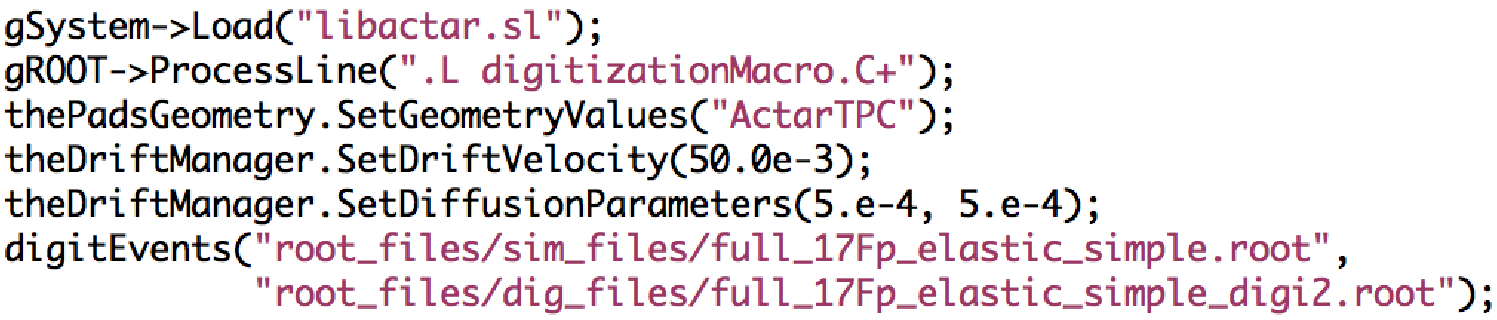
- Efficient TClonesArray in TTrees stored in ROOT TFiles.
- Storing **strides** (groups of steps) decreasing output size.
- Only the energy loss of beam and reaction primaries used for the calculation of the ionization in the gas.
- The TTree also contains the Hits in the ancillary detectors and additional information (beamInfo, primaryInfo, ...).

ACTARSim overview: ROOT digitization

1. Drift and diffusion in the electric field:



- Drift by constant electric field included. Modular to introduce other drift models for different magnetic and electric drifts.
- Drift (velocity, diffusion) parameters required as user input.



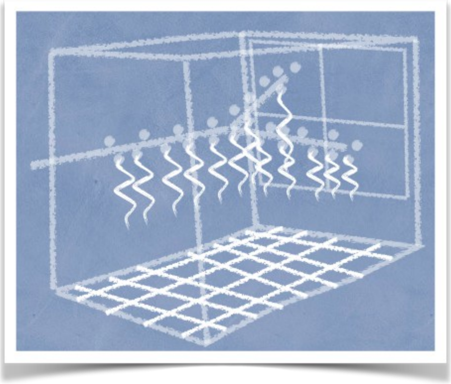
```
gSystem->Load("libactar.sl");
gROOT->ProcessLine(".L digitizationMacro.C+");
thePadsGeometry.SetGeometryValues("ActarTPC");
theDriftManager.SetDriftVelocity(50.0e-3);
theDriftManager.SetDiffusionParameters(5.e-4, 5.e-4);
digitEvents("root_files/sim_files/full_17Fp_elastic_simple.root",
            "root_files/dig_files/full_17Fp_elastic_simple_digi2.root");
```

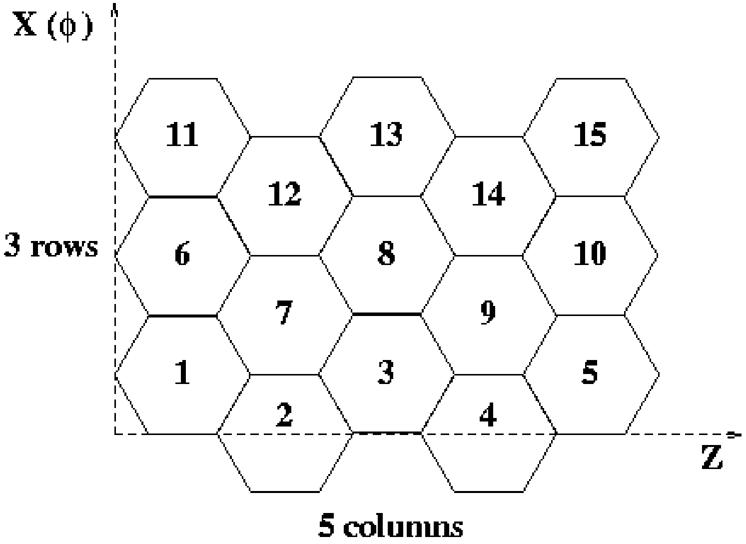
ACTARSim overview: ROOT digitization

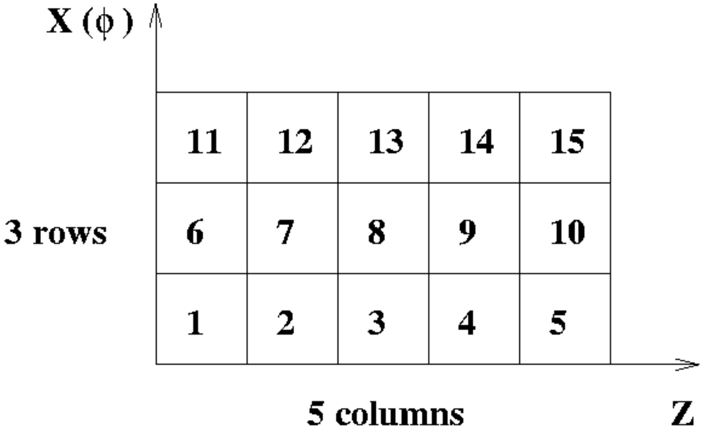
1. Drift and diffusion in the electric field:

2. Amplification and pad induction:

- GEM, micromegas and wires amplification schemes included, as well as the induction in the pad plane.
- Variable size, hexagonal- or square-shaped pad planes.
- Predefined pad plane geometry for ACTAR TPC and MAYA.







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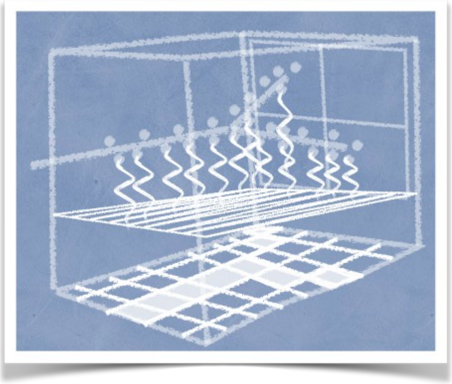
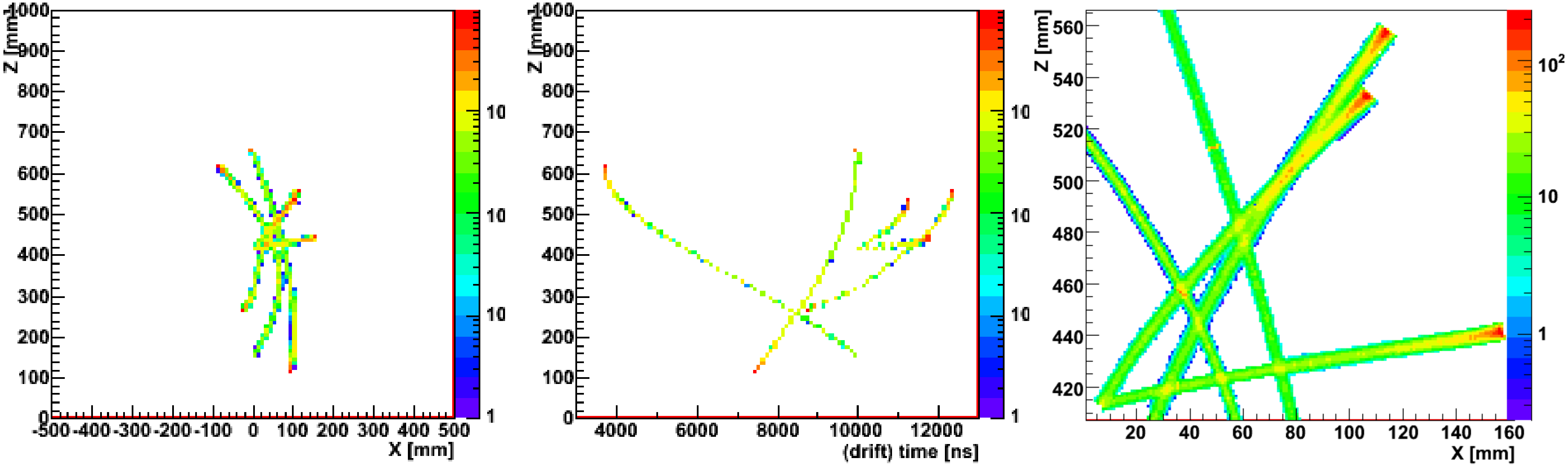


1. Drift and diffusion in the electric field.

2. Amplification and pad induction.

3. Induction calculation and pad signal output:

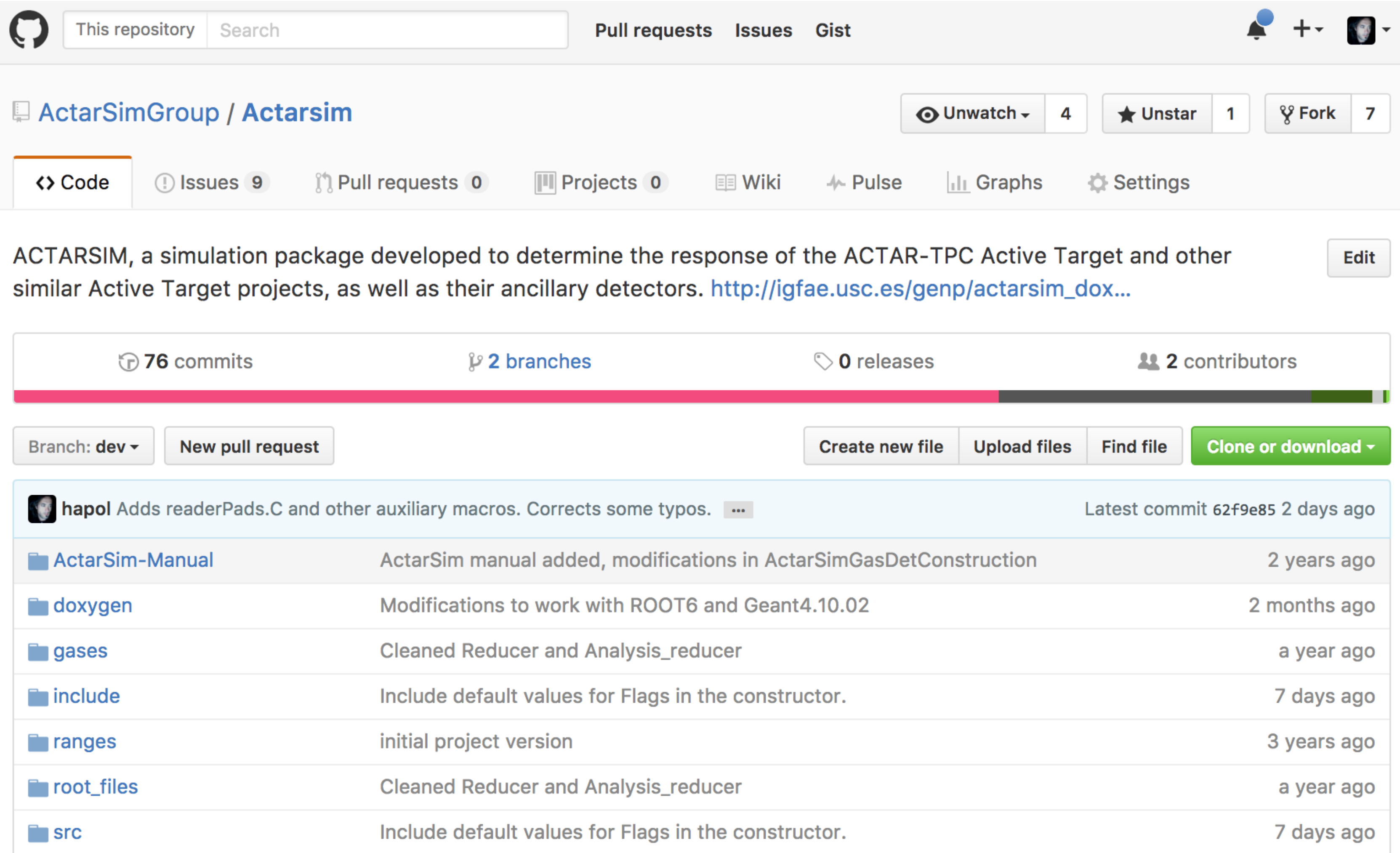
- The induced charge in each pad is calculated including timing.
- Results are stored in a TTree (TClonesArray) of pads with signal, ready for further analysis.



Examples with different pad plane resolution.

ACTARSim: a simulation code for ACTAR TPC

https://github.com/ActarSimGroup/Actarsim



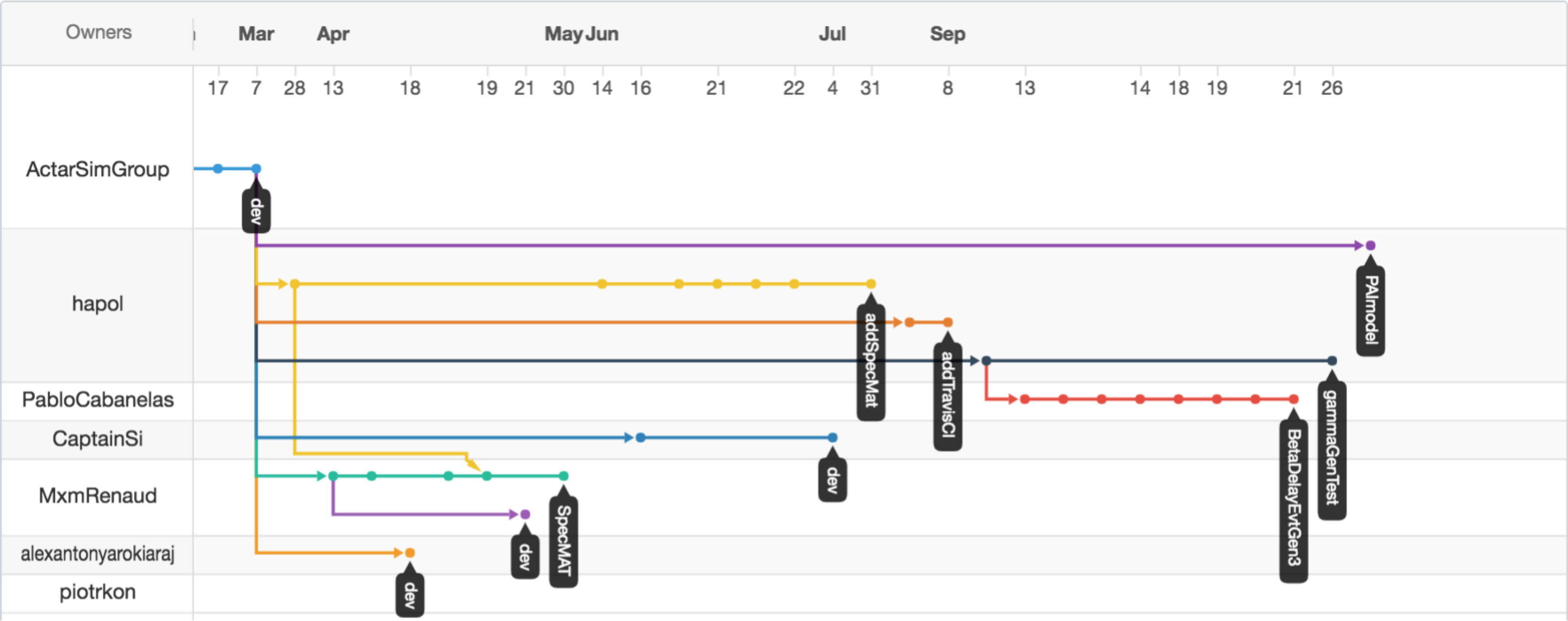
ACTARSIM, a simulation package developed to determine the response of the ACTAR-TPC Active Target and other similar Active Target projects, as well as their ancillary detectors. http://igfae.usc.es/genp/actarsim_dox...

hapol Adds readerPads.C and other auxiliary macros. Corrects some typos. ... Latest commit `62f9e85` 2 days ago

ActarSim-Manual	ActarSim manual added, modifications in ActarSimGasDetConstruction	2 years ago
doxygen	Modifications to work with ROOT6 and Geant4.10.02	2 months ago
gases	Cleaned Reducer and Analysis_reducer	a year ago
include	Include default values for Flags in the constructor.	7 days ago
ranges	initial project version	3 years ago
root_files	Cleaned Reducer and Analysis_reducer	a year ago
src	Include default values for Flags in the constructor.	7 days ago

ACTARSim overview: recent work

- Recently upgrade to ROOT6 and Geant4.10.2 (or Geant4.10.3 from Dec 2016).
- Complete doxygen documentation (developers): **http://igfae.usc.es/genp/actarsim_doxygen/**
- Active development, 4 main contributors, several development branches.
- Ongoing program of **evaluation of energy loss in gas** compared with other simulations and experiment data.



ACTARSim: evaluation of energy loss in gas

Evaluation of the energy loss properties of the physics libraries in Geant4:

- **Energy loss** obtained from the step energy loss sum in 300 mm.
- **Energy straggling** as RMS of the energy loss distribution.
- **Angular straggling** given by the step angle at the end of the absorber.
- **Lateral spread** given by the sigma of the position distribution (x-position in the XZ plane) at the end of the absorber.
- D_2, H_2, iC_4H_{10} as target gases, 1 atm. Range larger than the gas volume.
- p, ^{4}He, ^{12}C, ^{24}Mg, ^{56}Fe as projectiles.
- Geant4 libraries: emstandard_opt3 and ionGasModels.

Analysis by Piotr Konczykowski (USC), 2016.

ACTARSim: evaluation of energy loss in gas

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More details in https://agenda.infn.it/getFile.py/access?contribId=14&sessionId=11&resId=0&materialId=slides&confId=12079
and https://github.com/ActarSimGroup/Actarsim/issues/11

get gases, 1 atm. Range larger than the gas volume.

He, ^{12}C, ^{24}Mg, ^{56}Fe as projectiles.

- Geant4 libraries: emstandard_opt3 and ionGasModels.

Notable differences among Geant4 em libraries

For protons, Geant4 and SRIM agrees within 5% in energy loss and energy straggling, but angular straggling and lateral spread could disagree up to 30%.

For heavy ions, notable differences between Geant4 and SRIM could be found in all the gases, with “erratic” values. Not coincident with data, when available.

Analysis by Piotr Konczykowski (USC), 2016.

ACTARSim: evaluation of energy loss in gas

Does Geant4 describe the energy losses of slow heavy ions in gases?

- Notable differences between results using em physics lists which are valide for the given energy range.
- New models in Geant4 (ionGasModel, PAI, PAIPhot, …) requires detailed testing.
- Heavy ions energy loss at very low energy is not properly covered.

Lack of proper evaluation of the charge state close to the stopping point.

So, let’s test the energy loss in detail, starting with alphas

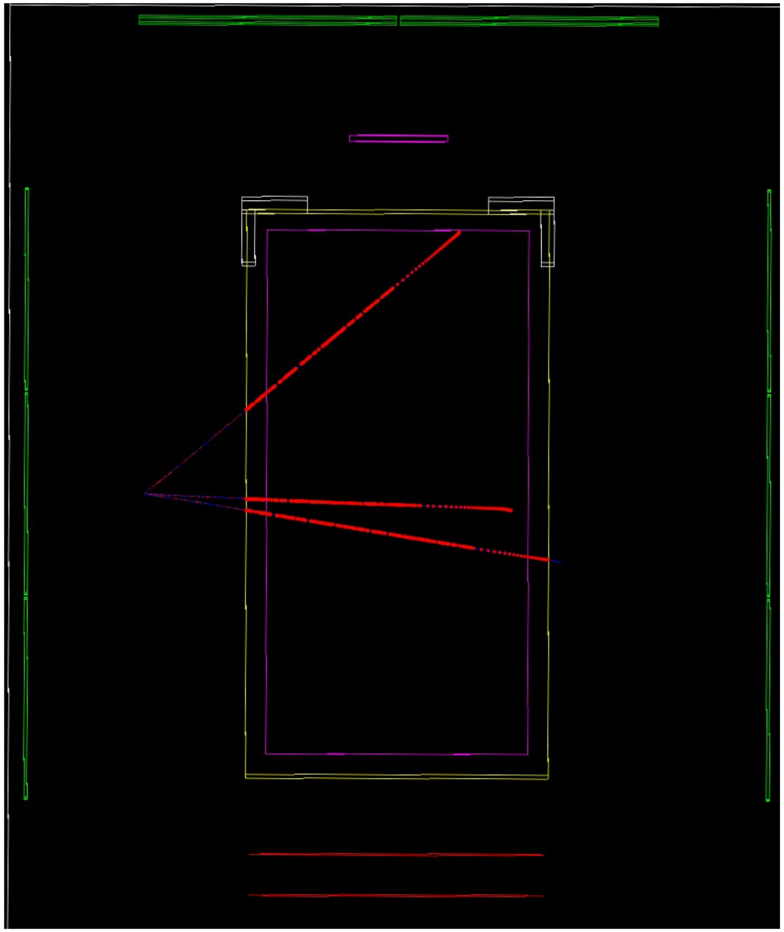
ACTARSim: triple α analysis

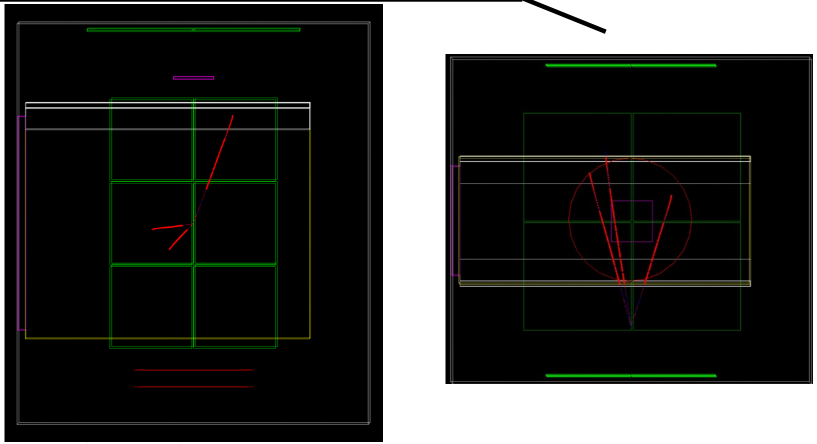
Real data + simulation test of range and energy loss reconstruction:

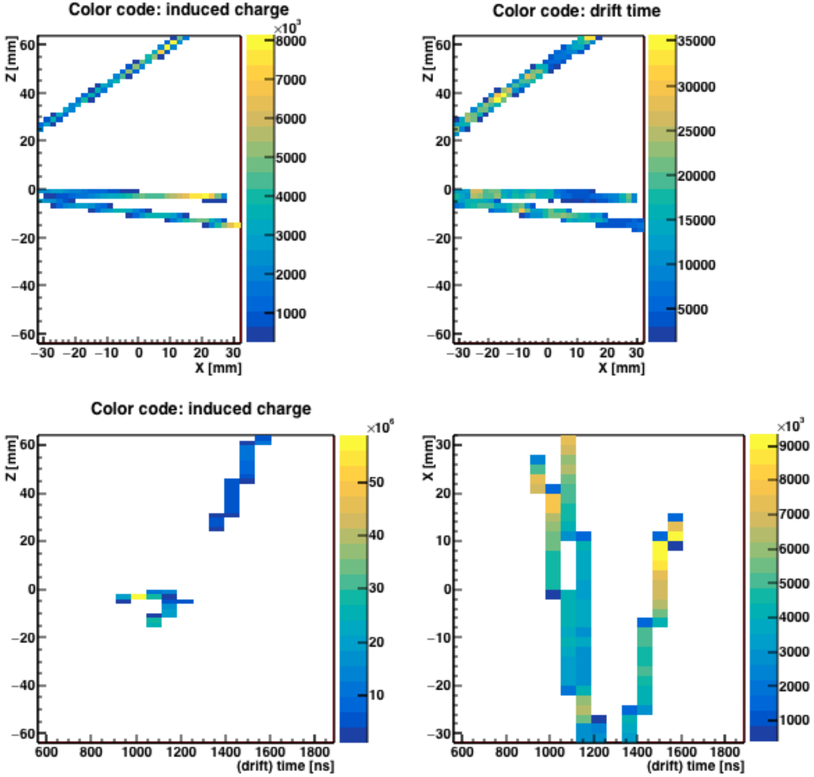
- **ACTAR TPC Demonstrator** with a **3-alpha source** (^{239}Pu, ^{241}Am and ^{244}Cm with energies of 5.15, 5.48 and 5.8 MeV respectively) located outside the field cage.
- Trigger on central pads (**reduced angular acceptance** to $\theta<4^{\circ}$ and $\Phi<15^{\circ}$).
- The gas used for the experiment was iC_4H_{10} at 105.6 mbar (W=23eV in sim).
- Usual cathode voltages of -2500 V and thin wires at -350 V (to guide the field lines homogeneously to the Micromegas mesh). GET Frontend electronics.
- Signal threshold of 10 times above the noise level (~2000 electrons???).
- Sampled at a frequency of 25 MHz and recorded in a 12-bit ADC.
- **Regarding simulation**: ACTARSim reproduction of the Demonstrator setup with a 3-alpha source generator. **Geant4 with emstandard opt3** physics list.
- Electron drift parameters according to the reduced electric field from MAGBOLZ.
- Trajectories obtained by a 3-Dimensional **linear least squares fit**.

Analysis Piotr Konczykowski (USC), data from G. Grinyer, J. Pancin, T. Roger (GANIL)

ACTARSim: triple α analysis



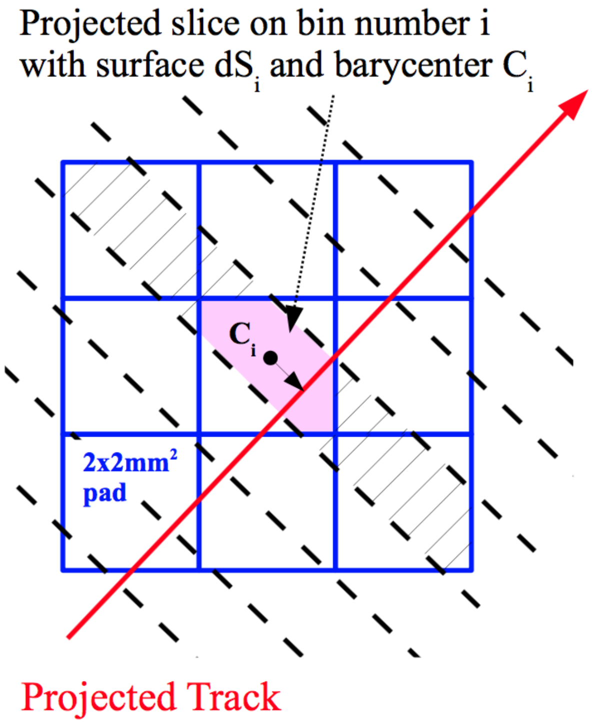




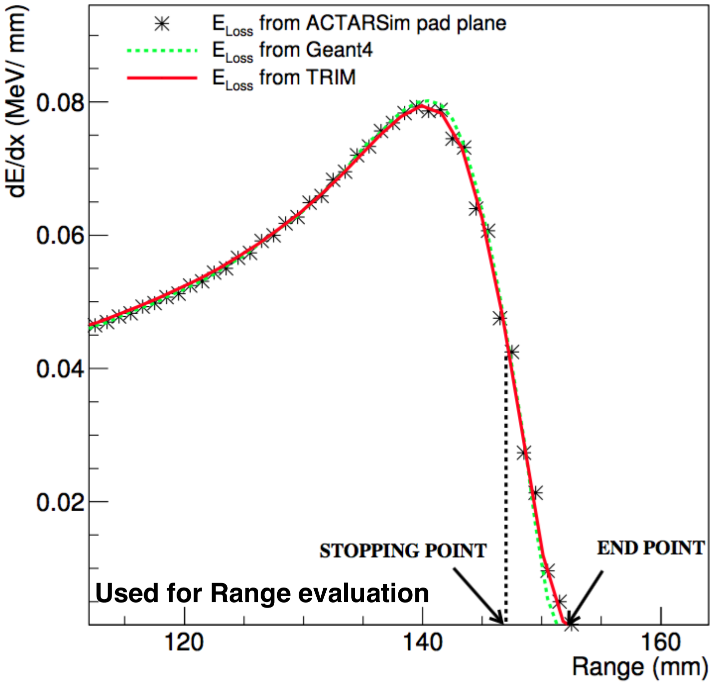
ACTARSim: energy loss in triple α analysis

Energy loss profile: is constructed on each bin of the 3D-track projection by adding the slices carrying a portion of the charge Q_{pad} proportional to their surface dS_i (pink).

- The total charge in each bin is the sum over slices. A 2mm binning was used here with good results.
- “Average” profile fixing the end point (avoid straggling).



$$Q_{bin} = \sum_{i=1}^{N} \frac{dS_i}{S_{pad}} Q_{pad_i}$$



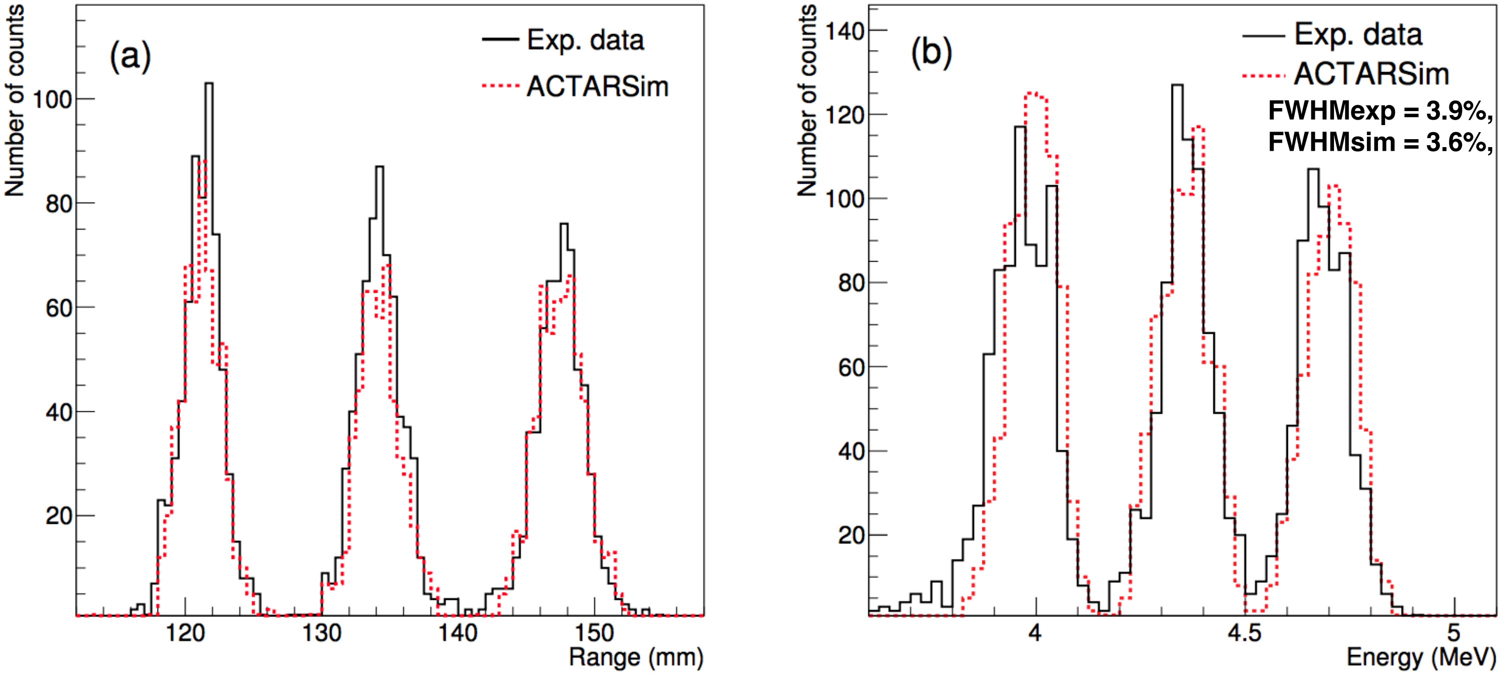
To study the electron transverse diffusion, we plotted the standard deviation of the barycenters of each slice:

$$\sigma_T = \sqrt{\frac{1}{Q_{bin}} \sum_{i=1}^{N} Q_{pad_i} (C_i - \mu)^2}$$

ACTARSim: range and energy in triple α analysis

- **Exp. vs sim. results**: a very good agreement in range and reconstructed energy.
- Sim. range includes a 1mm global offset (possibly an error in source positioning).

Isotopes	Eα (MeV)	R^{exp} (mm)	σ_R^{exp} (mm)	R^{sim} (mm)	σ_R^{sim}	R^{TRIM} (mm)	σ_R^{TRIM} (mm)
^{239}Pu	5.15	121.2(6)	1.41(5)	122.5(7)	1.45(7)	121	1.34
^{241}Am	5.48	134.1(7)	1.61(6)	135.3(8)	1.64(8)	134	1.48
^{244}Cm	5.80	147.5(7)	1.65(7)	148.4(8)	1.69(8)	147	1.69

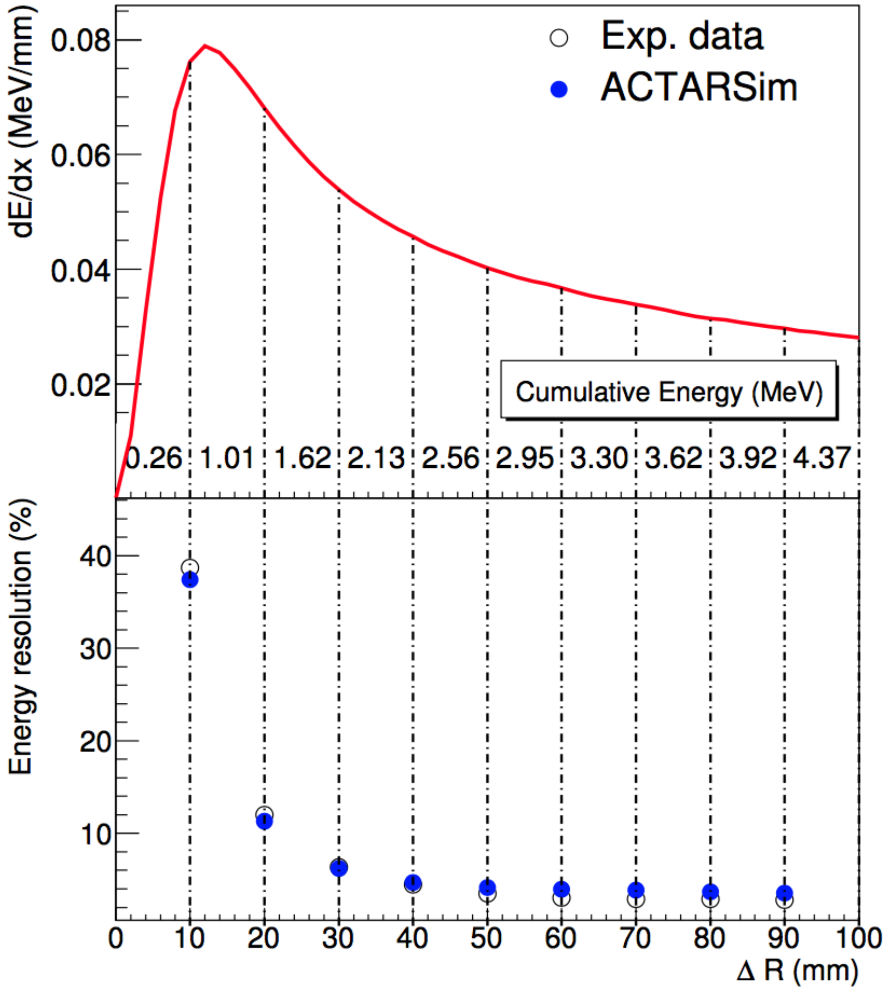


FWHMexp = 3.9%, 3.4%, 3.2%
FWHMsim = 3.6%, 3.7%, 3.2%

ACTARSim: energy resolution in triple α analysis

Energy resolution (lower plot) as a function of the distance (ΔR) from the end of the Brag peak (upper plot). This is equivalent to study the **energy resolution as a function of the alpha's energy**.

- For ΔR =10 mm the resolution is high due to the important straggling effect.
- For ΔR > 40 mm, after the Bragg maximum, energy resolution stabilizes around 4% (FWHM).

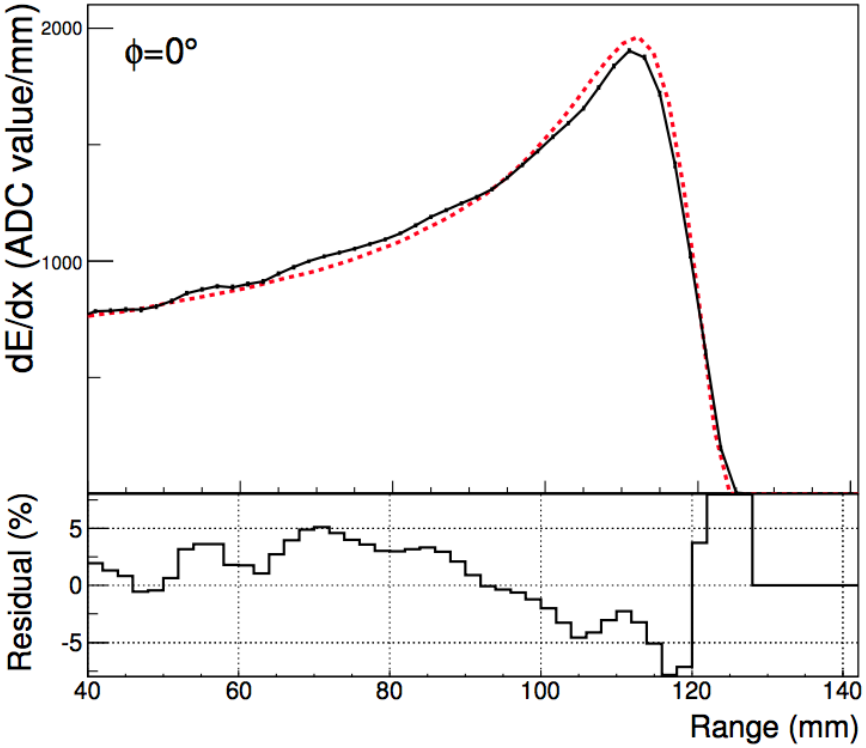


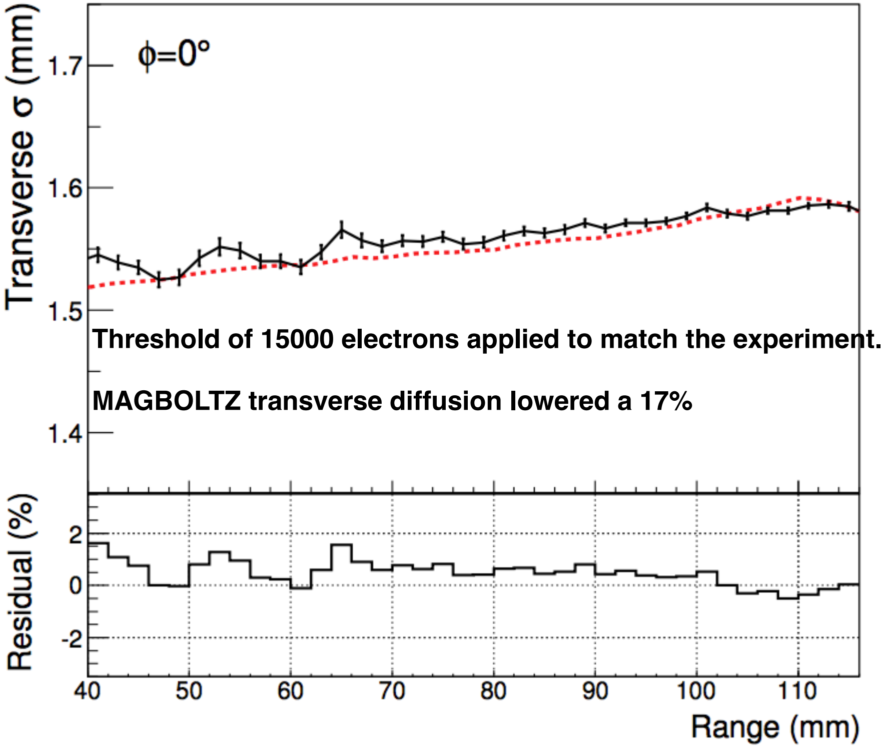
ACTARSim: energy loss profile in triple α analysis

- Exp. profile fit: cumulated exp. profiles using a **χ^2 minimization with 2 parameters** (height and longitudinal shift).

The fitted simulation profiles are slightly more peaked which makes the end point shorter than in the data. Fit is robust for different vertical angle(Φ).

- Transversal fit depends on the vertical angle (Φ), exp. pad threshold and D_T.





Threshold of 15000 electrons applied to match the experiment.

MAGBOLTZ transverse diffusion lowered a 17%

ACTARSim: conclusions and perspectives

- **ACTARSim**: a detailed implementation of ACTAR TPC (and SpecMAT, ...) and a set of ancillary detectors. Easy to configure for different setups and reactions.
- ActarSim ready for testing and, actually in use in several laboratories, still lacking user documentation, … but please, contact us for support.
- Successful description of the stopping observables of alphas in isoC_4H_{10}.
- Ongoing program for the test of Geant4 physics libraries for the ions and energy ranges of interest in our nuclear physics experiments.
- There is no general analysis framework associated with ACTARSim.
- Future: Evolution to a framework? Other frameworks in the market? FAIRRoot-based frameworks, use of GARFIELD on Geant4, …

Code available (Git Workflow) in: **https://github.com/ActarSimGroup/Actarsim**

Class and file documentation: **http://igfae.usc.es/genp/actarsim_doxygen**

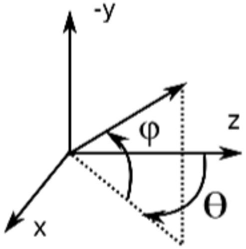
Thank you very much for your attention!

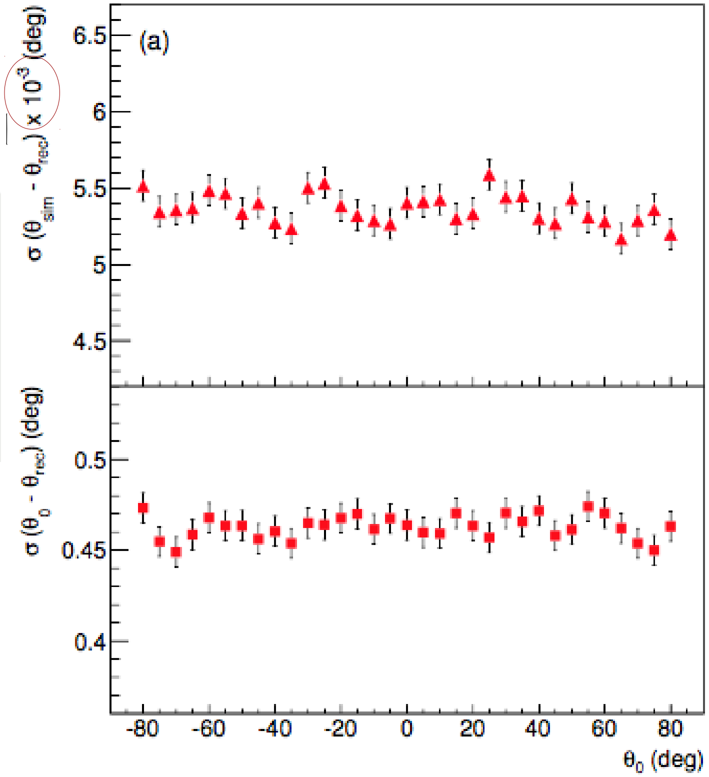
Additional slides

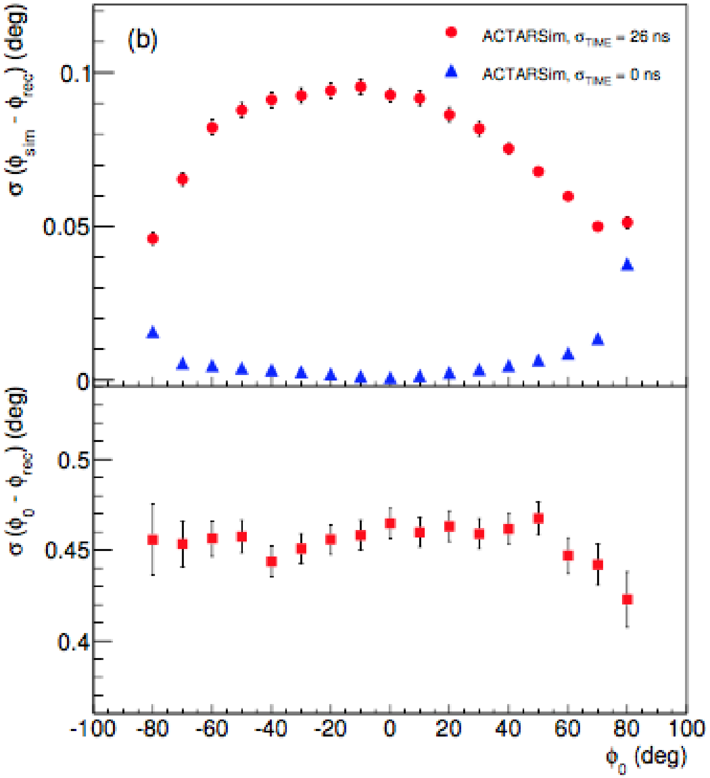
ACTARSim: angles in triple α analysis

Reconstruction using a 3D linear least squares fit: evaluated in simulation comparing the initial (θ_0, Φ_0) and simulation (θ_{sim}, Φ_{sim}) with fit angles (θ_{rec}, Φ_{rec}).

- The reconstructed **horizontal angle (θ) resolution** is in the order of 5×10^{-3} deg.
- The **vertical angular (Φ) resolution depends on the initial angle** (as the number of active pads change). For σ_{TIME}=26ns (pulser), reaches 0.1 deg.







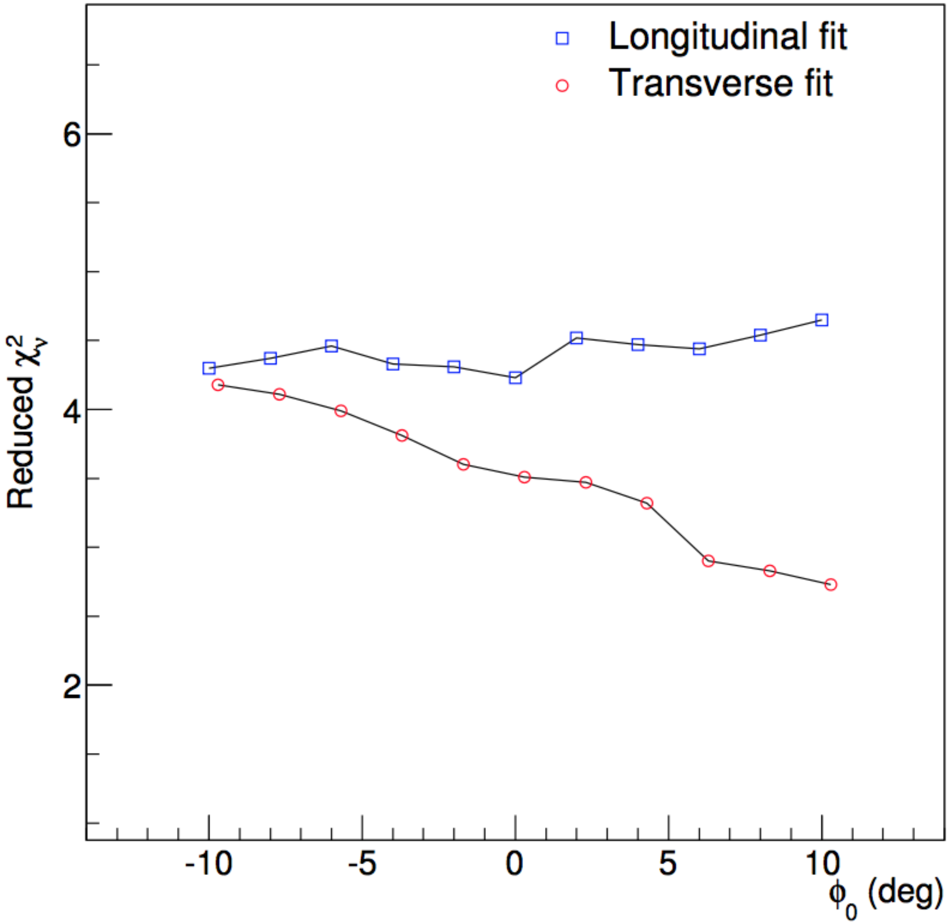
ACTARSim: triple α analysis

Reduced χ² defined respectively as:

$$\chi^2_{red} = \frac{1}{N-2}\sum\frac{(\frac{dE}{dx}^{exp} - \frac{dE}{dx}^{sim})^2}{N_e} \qquad \chi^2_{red} = \frac{1}{N-2}\sum\frac{(\sigma_T^{exp} - \sigma_T^{sim})^2}{\varepsilon^2_{\sigma_T}}$$

Where N_e, the number of electrons in the pad, is estimated from the experimental signal amplitude.

- The profile binning is proportional to cos Φ for comparing similar slices.
- Some effects not account for in simulation results in a dependence of the transverse fit with angle Φ.



ACTARSim: perspectives

FAIRRoot frameworks:

- ATTPC (Yassid Ayyad, MSU)
- ACTAF in R3BRoot, using GARFIELD within G4 (mail from Oleg Kiselev, GSI):

1) The package R3BRoot + Garfield itself is made running.

2) The first version of the small chamber geometry within R3BRoot + Garfield is made.

3) Some changes made – different gas, correct potentials, etcetera.

4) Different particle guns are tried – simple beam and ASCII file made by the external generator.

5) Influence of the energy threshold for the electron production in gas is observed. High threshold – fast tracking but no e-ion pairs in gas, low threshold – very slow simulations.

6) Signals on the readout pads are observed.

7) Electric field calculations with ANSYS made. Investigation of the field profiles shown some field deformations. The optimization of the potentials on the field-forming circles are needed.

8) Simulations with the ANSYS field maps are coming.

Two real problems are found: very slow (minutes up to hours per event) simulation in case of low-energy electron production in gas; the geometry needs to be made twice – for R3BRoot and Garfield.

What do Active Targets require from simulation?

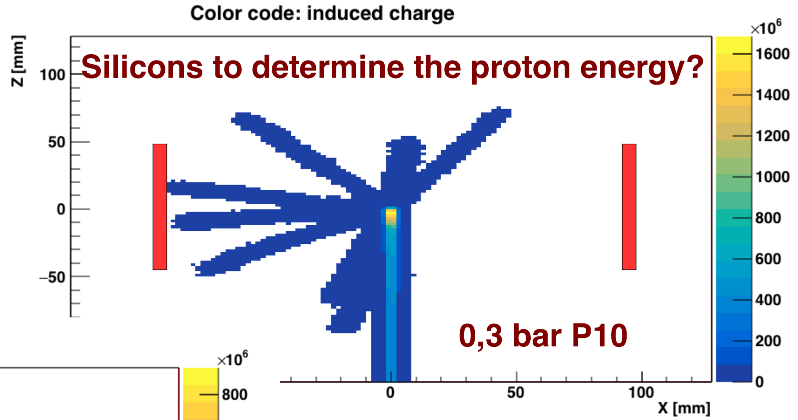
- Evaluation of the setup: gas pressure, position of ancillary detectors.

Example: proton decay of ^{46}Cr after beta decay of ^{46}Mn

A. Benitez et al., Proposal for GANIL (2017)

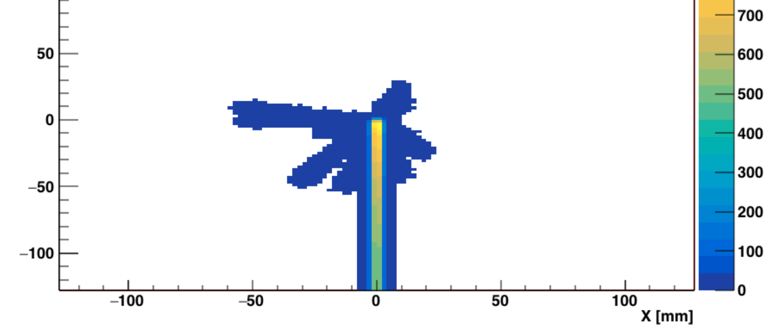
Quest for resonances in the reaction ^{45}V(p,γ)^{46}Cr relevant in the SNe type II explosions

Color code: induced charge



Color code: induced charge

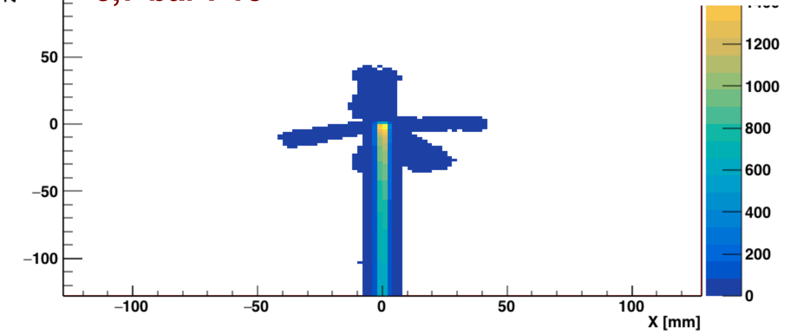
0,5 bar P10



Are proton tracks long enough to be separated from the beam?

Color code: induced charge

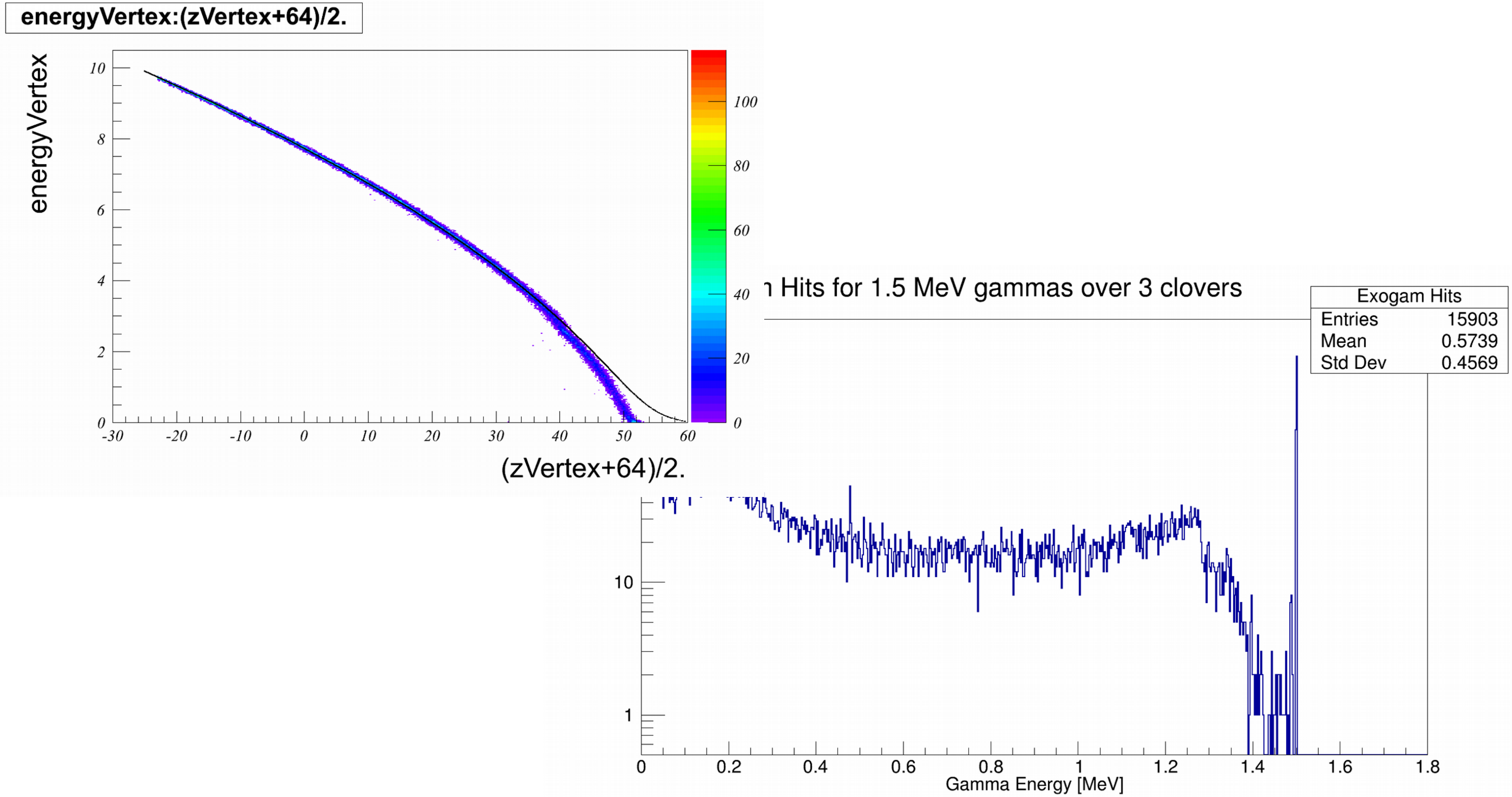
0,7 bar P10



What is the beam energy ^{46}Mn to stop the beam in the center of the gas target for 0.3, 0,5 and 0.7 bar of P10 gas?

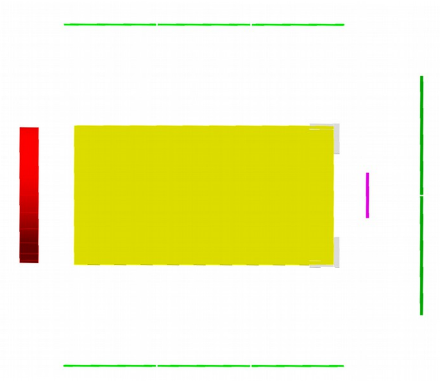
What do Active Targets require from a simulation?

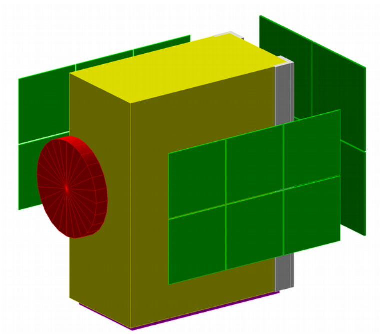
- Evaluation of the setup: gas pressure, position of ancillary detectors.
- Evaluation of the energy and time resolution.

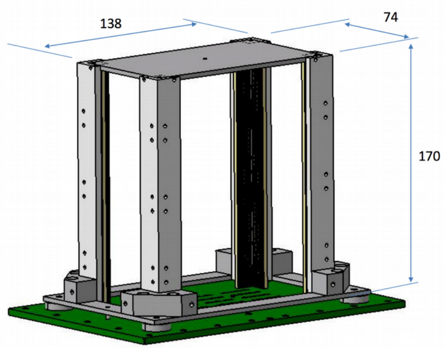


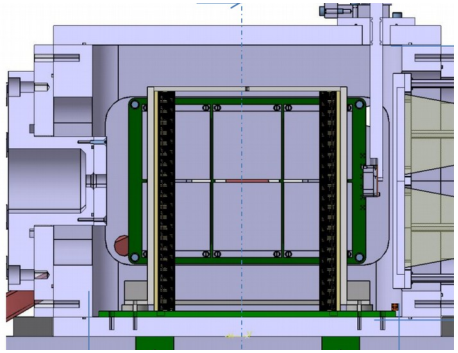
ACTARSim overview: the detectors in Geant4

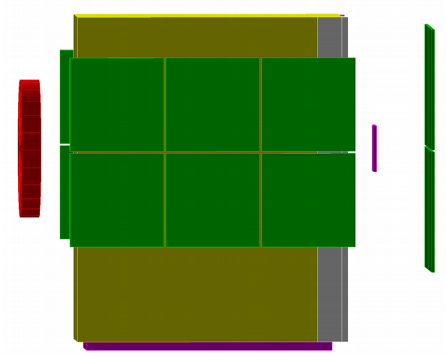
ACTAR TPC Demonstrator:

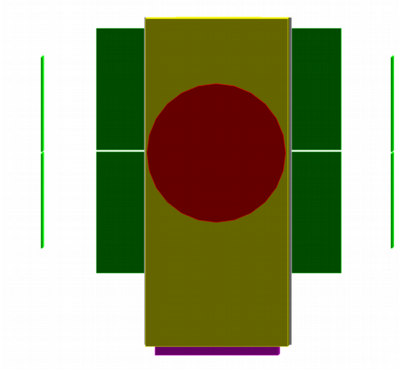


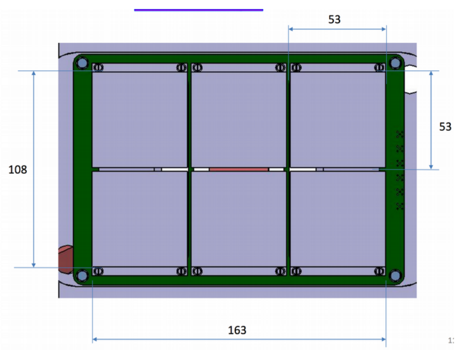


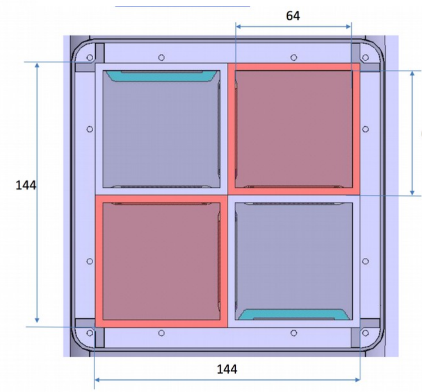




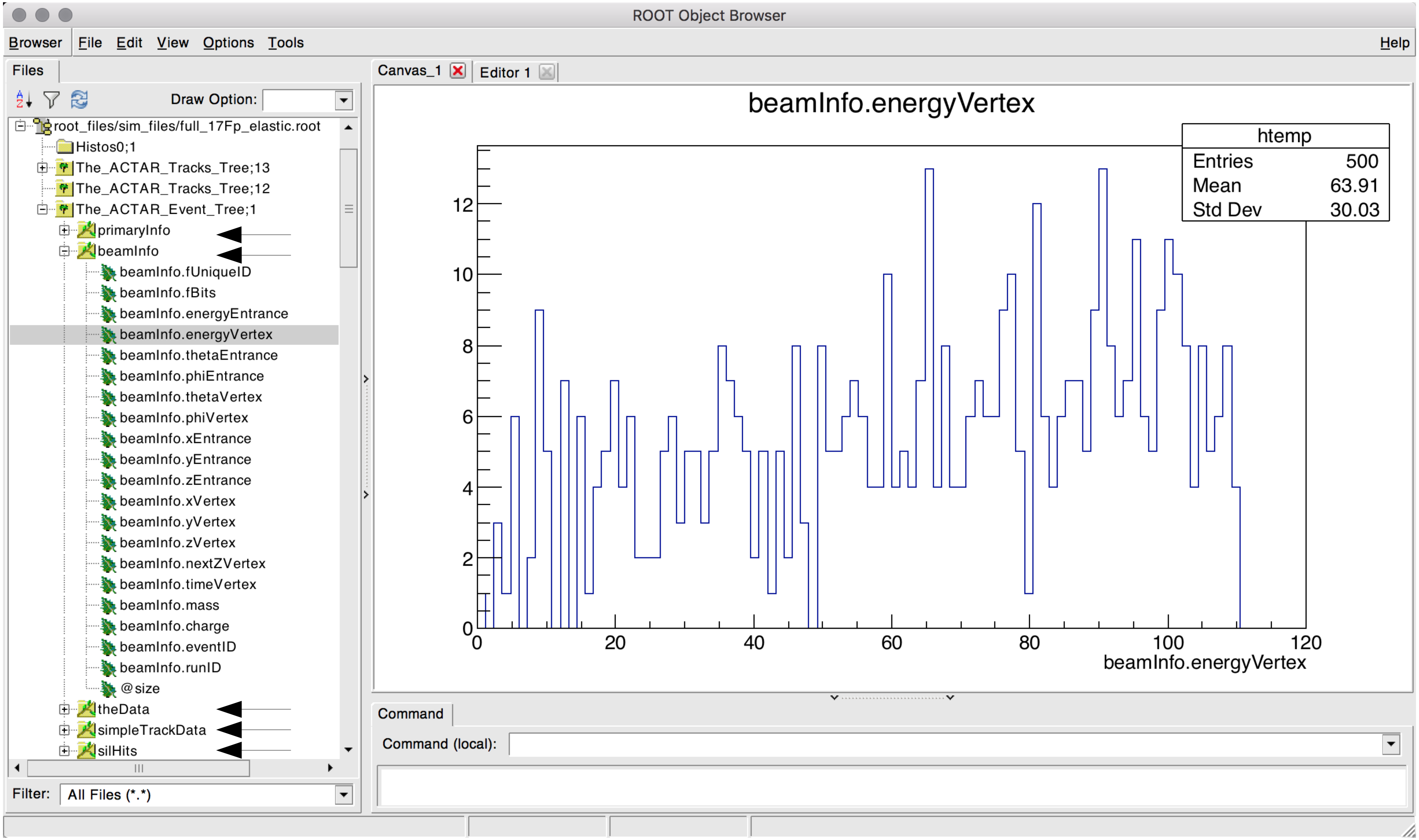








ACTARSim overview: the Geant4 transport



htemp	
Entries	500
Mean	63.91
Std Dev	30.03

What do Active Targets require from a simulation?

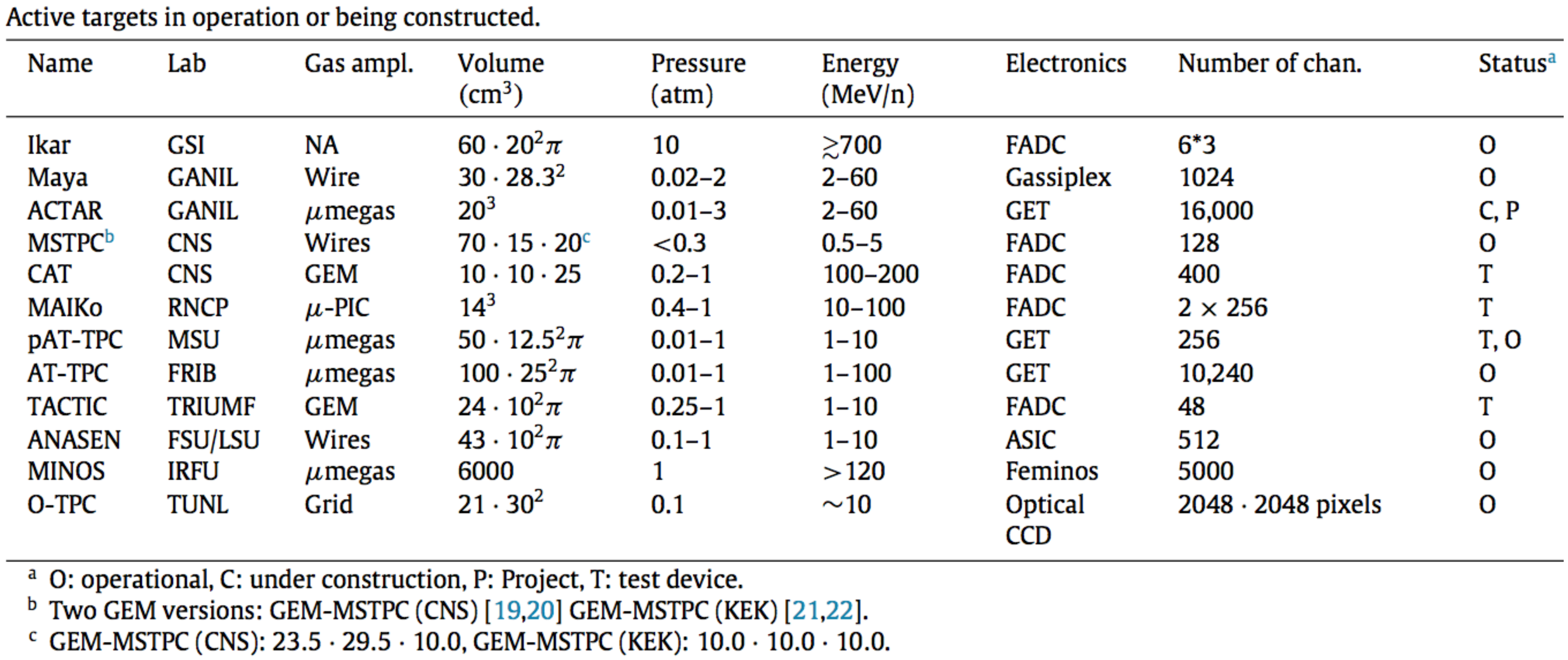
- Evaluation of the setup: gas pressure, position of ancillary detectors.
- Evaluation of the energy and time resolution.
- Evaluation of detection efficiency.

What do Active Targets require from a simulation?

- Evaluation of the setup: gas pressure, position of ancillary detectors.
- Evaluation of the energy and time resolution.
- Evaluation of detection efficiency.
- Evaluation of reconstruction algorithms, trigger pattern efficiency, …

Active Target concept: detectors

A non-comprehensive list of Active Target detectors in operation or being constructed:



Active targets in operation or being constructed.

Name	Lab	Gas ampl.	Volume (cm^3)	Pressure (atm)	Energy (MeV/n)	Electronics	Number of chan.	Status[a]
Ikar	GSI	NA	$60 \cdot 20^2\pi$	10	$\gtrsim$700	FADC	6*3	O
Maya	GANIL	Wire	$30 \cdot 28.3^2$	0.02–2	2–60	Gassiplex	1024	O
ACTAR	GANIL	μmegas	20^3	0.01–3	2–60	GET	16,000	C, P
MSTPC[b]	CNS	Wires	$70 \cdot 15 \cdot 20$[c]	<0.3	0.5–5	FADC	128	O
CAT	CNS	GEM	$10 \cdot 10 \cdot 25$	0.2–1	100–200	FADC	400	T
MAIKo	RNCP	μ-PIC	14^3	0.4–1	10–100	FADC	2 × 256	T
pAT-TPC	MSU	μmegas	$50 \cdot 12.5^2\pi$	0.01–1	1–10	GET	256	T, O
AT-TPC	FRIB	μmegas	$100 \cdot 25^2\pi$	0.01–1	1–100	GET	10,240	O
TACTIC	TRIUMF	GEM	$24 \cdot 10^2\pi$	0.25–1	1–10	FADC	48	T
ANASEN	FSU/LSU	Wires	$43 \cdot 10^2\pi$	0.1–1	1–10	ASIC	512	O
MINOS	IRFU	μmegas	6000	1	>120	Feminos	5000	O
O-TPC	TUNL	Grid	$21 \cdot 30^2$	0.1	~10	Optical CCD	2048 · 2048 pixels	O

[a] O: operational, C: under construction, P: Project, T: test device.

[b] Two GEM versions: GEM-MSTPC (CNS) [19,20] GEM-MSTPC (KEK) [21,22].

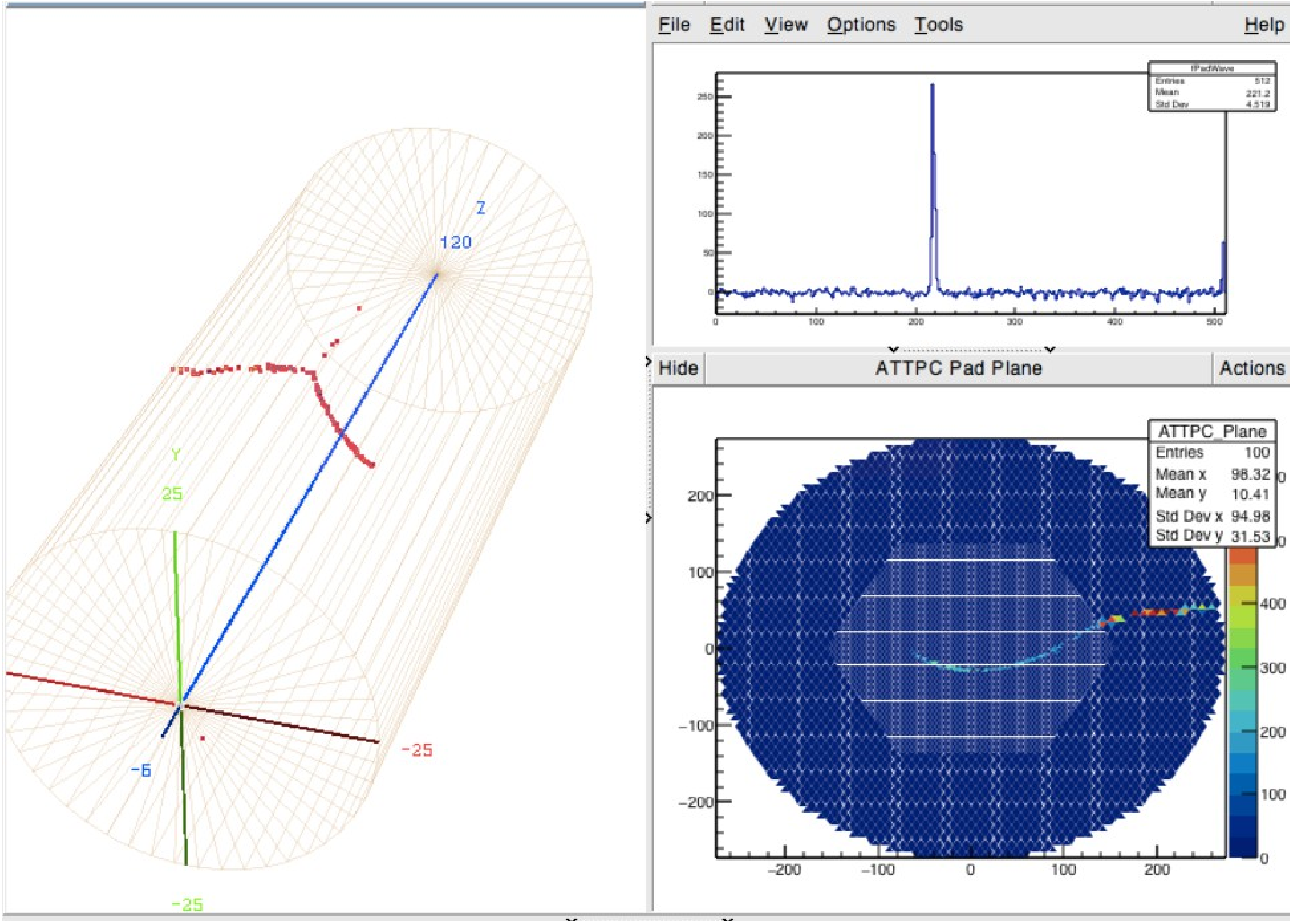
[c] GEM-MSTPC (CNS): 23.5 · 29.5 · 10.0, GEM-MSTPC (KEK): 10.0 · 10.0 · 10.0.

Review: Active targets for the study of nuclei far from stability.

S. Beceiro-Novo, T. Ahn, D. Bazin, W. Mittig, Progress in Particle and Nuclear Physics 84 (2015) 124–165.

What do Active Targets require from a simulation?

Event viewers, event display, graphical interpretation, ...



Courtesy Y. Ayyad (MSU)

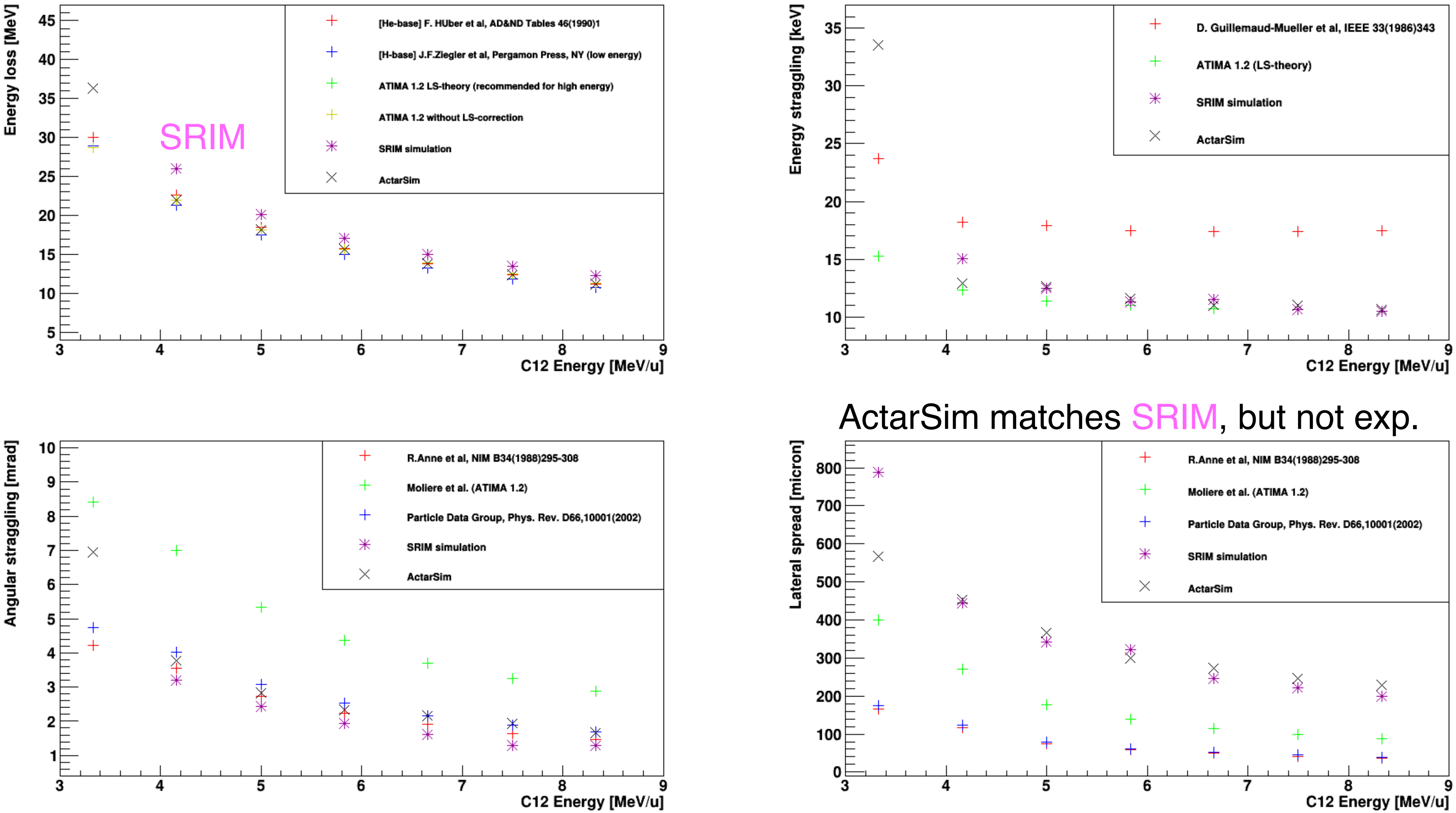
Active Target concept. What for?

Direct and resonant reactions in direct and inverse kinematics, for nuclear structure, astrophysics and applications:

- **Elastic scattering**: matter distributions in stable and exotic nuclei, exploring halo nuclei, ...
- **Inelastic scattering**: probe of the nuclear equation of state, giant n-pole resonances, structure...
- **Transfer**: fine nuclear structure probe, pairing or 3body interactions, ...
- **Fusion** reactions: cross sections, ...
- **Fission** characterization, fission barriers: control of the excitation energy.
- **Resonant scattering**: astrophysical interest reactions, clusters or quasi-molecular structures in light nuclei, ...
- **Implantation and decay**: rare decays (n-particle decay), beta-delayed gamma emission, ...

ACTARSim: evaluation of energy loss in gas

^{12}C on deuterium gas STP:

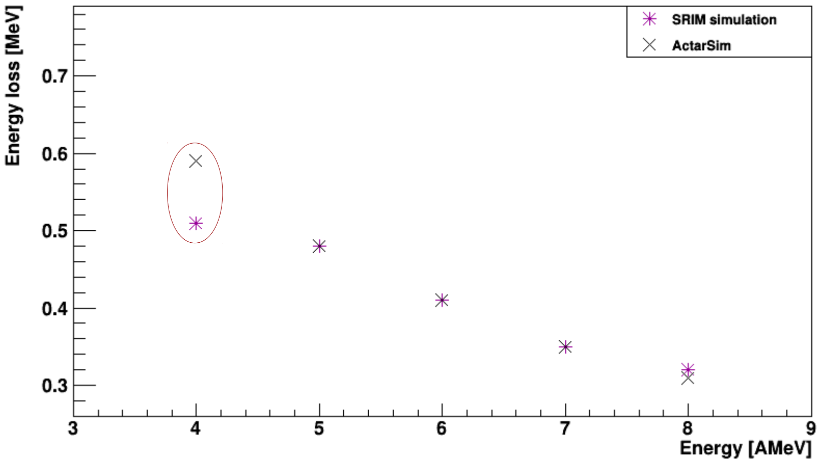


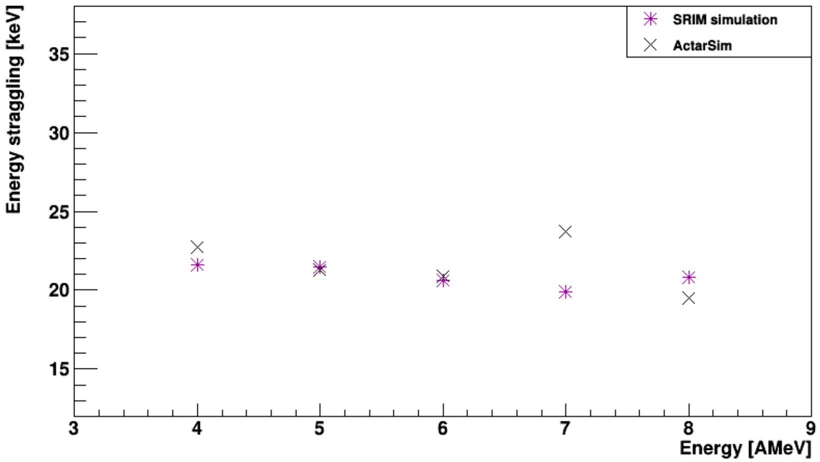
ActarSim matches SRIM, but not exp.

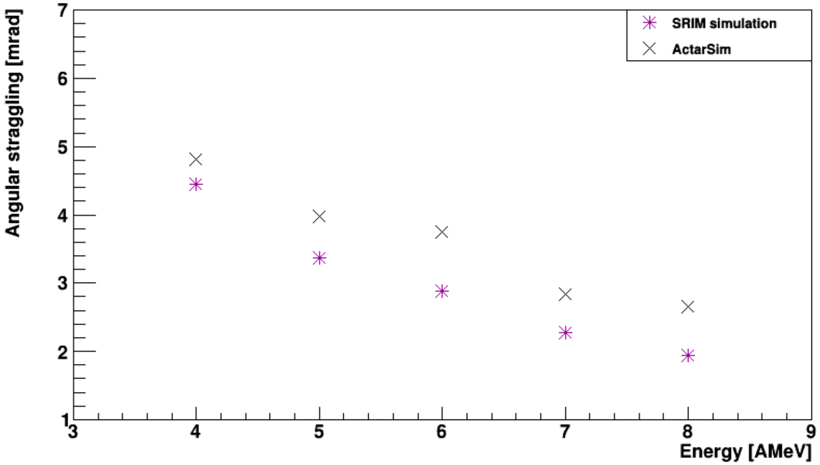
Courtesy Piotr Konczykowski (USC)

ACTARSim: evaluation of energy loss in gas

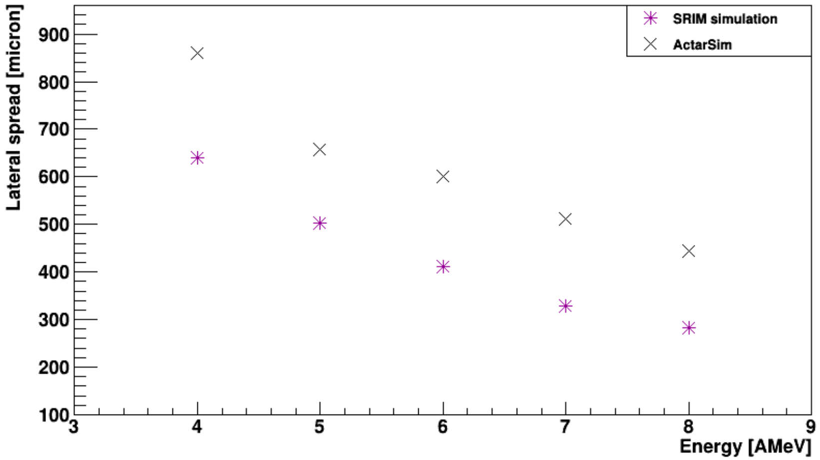
Proton on deuterium gas STP:





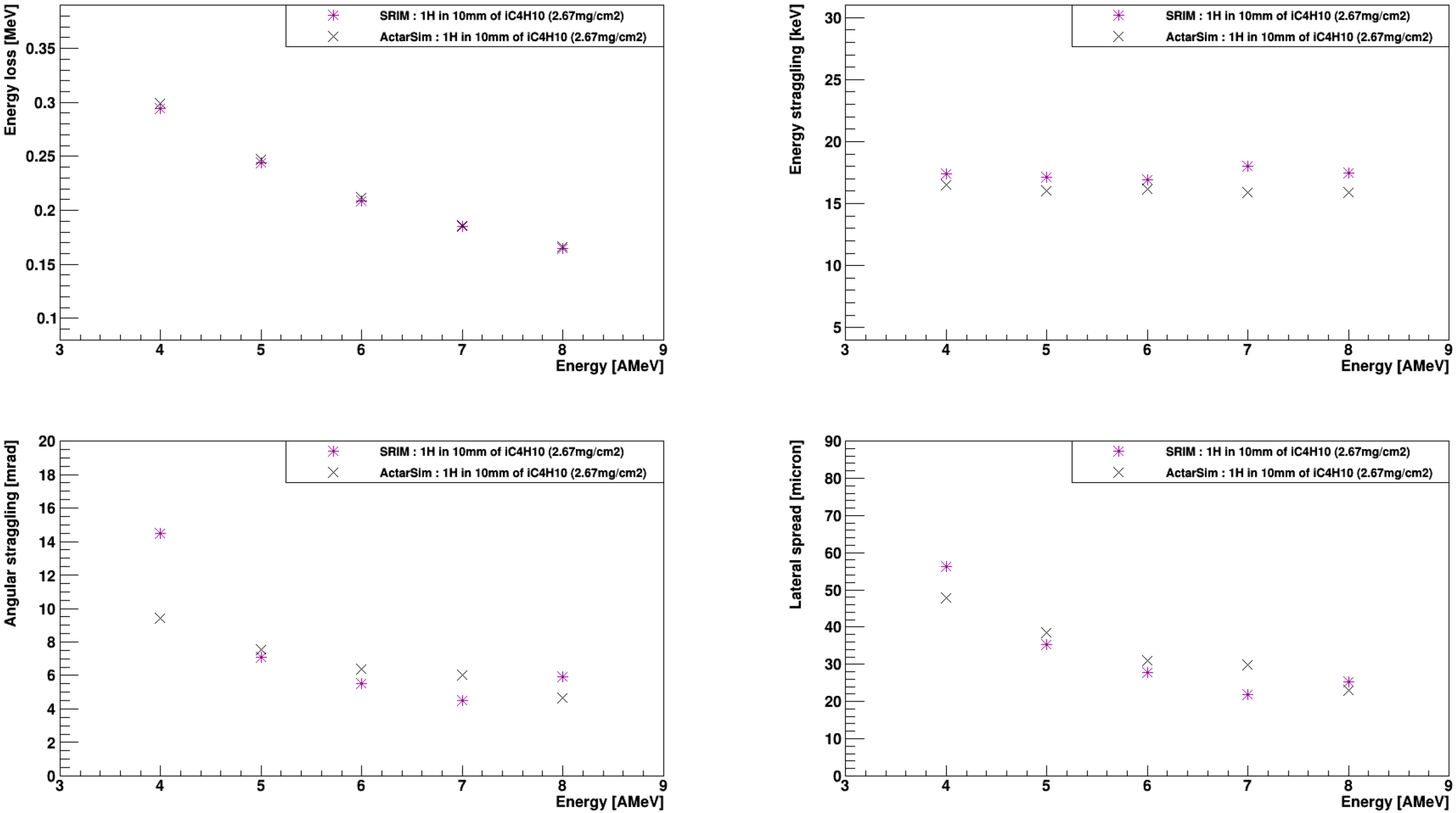


~20-25% difference



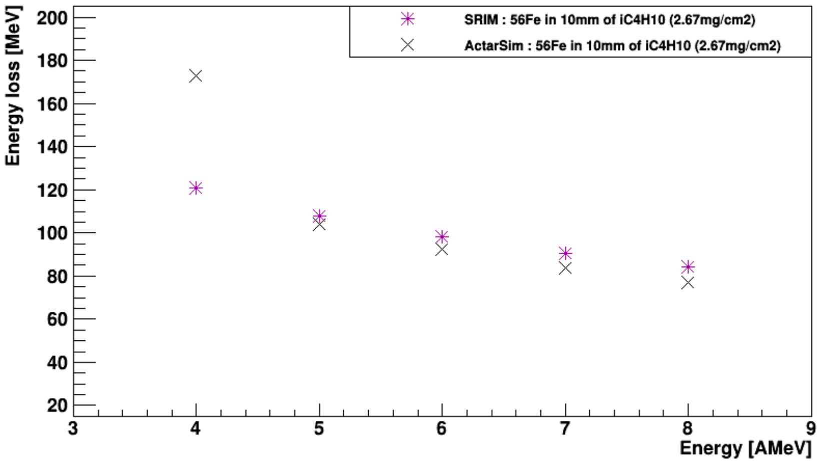
ACTARSim: evaluation of energy loss in gas

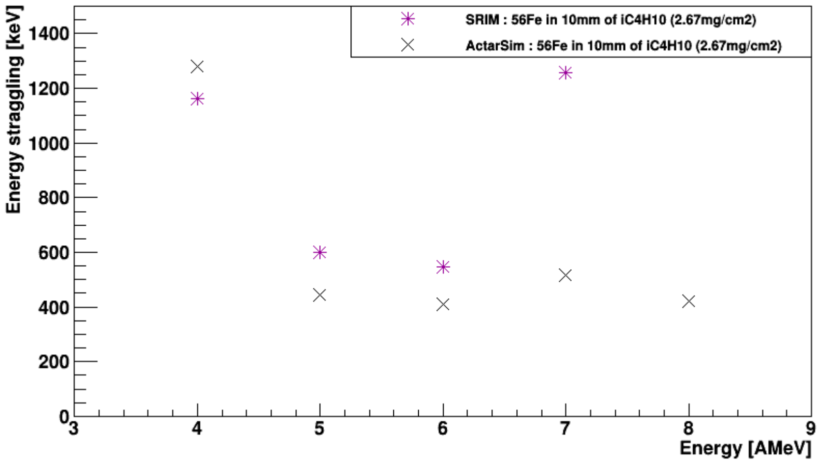
Proton on i-C_4H_{10} gas STP:

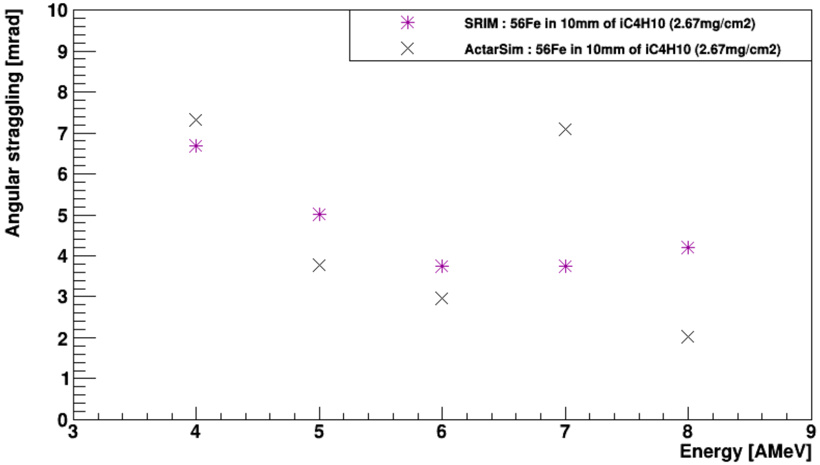


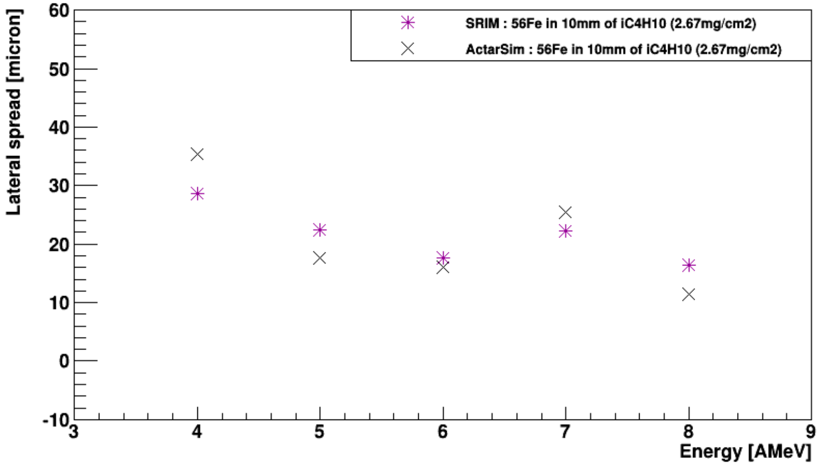
ACTARSim: evaluation of energy loss in gas

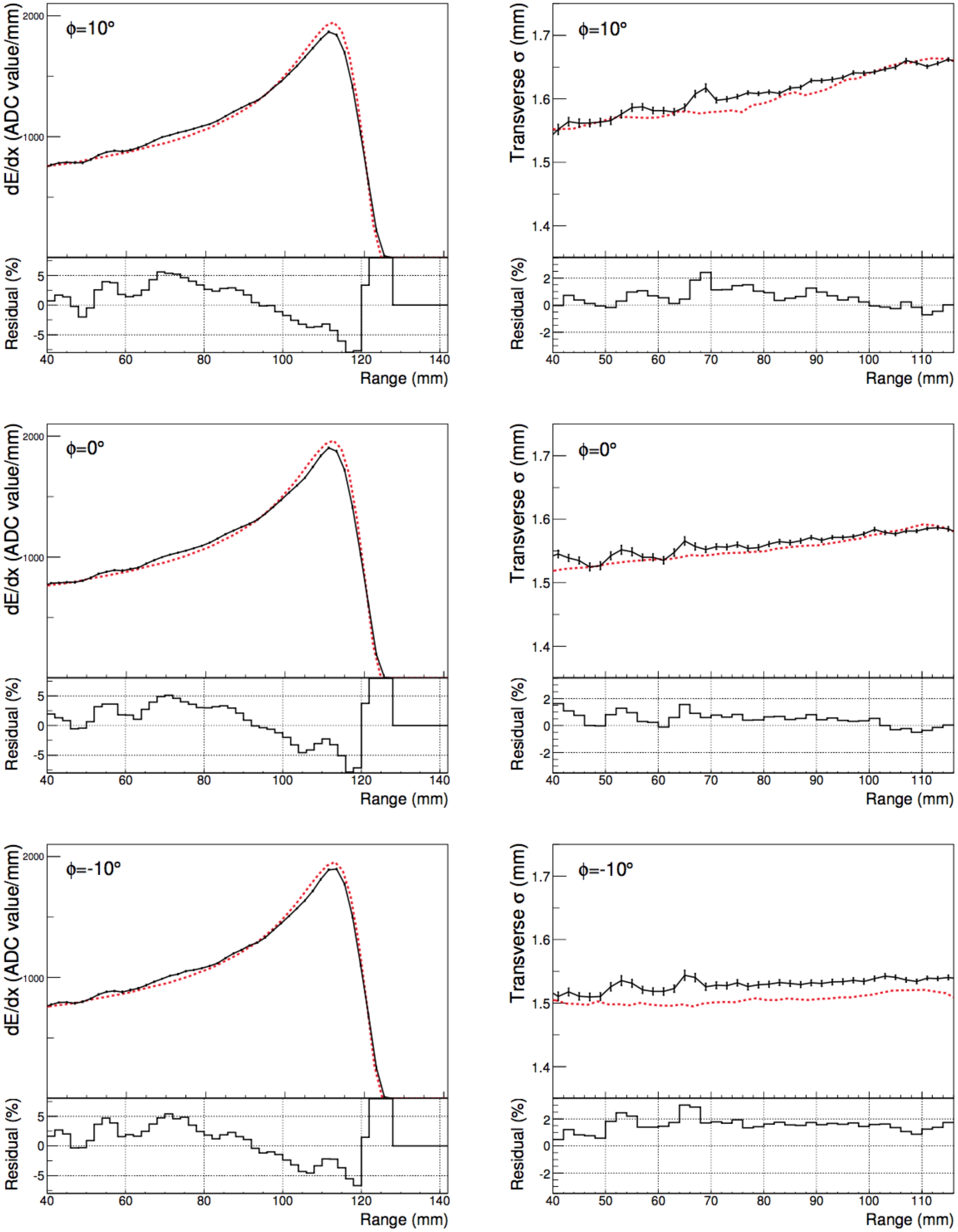
^{56}Fe on i-C_4H_{10} gas STP:





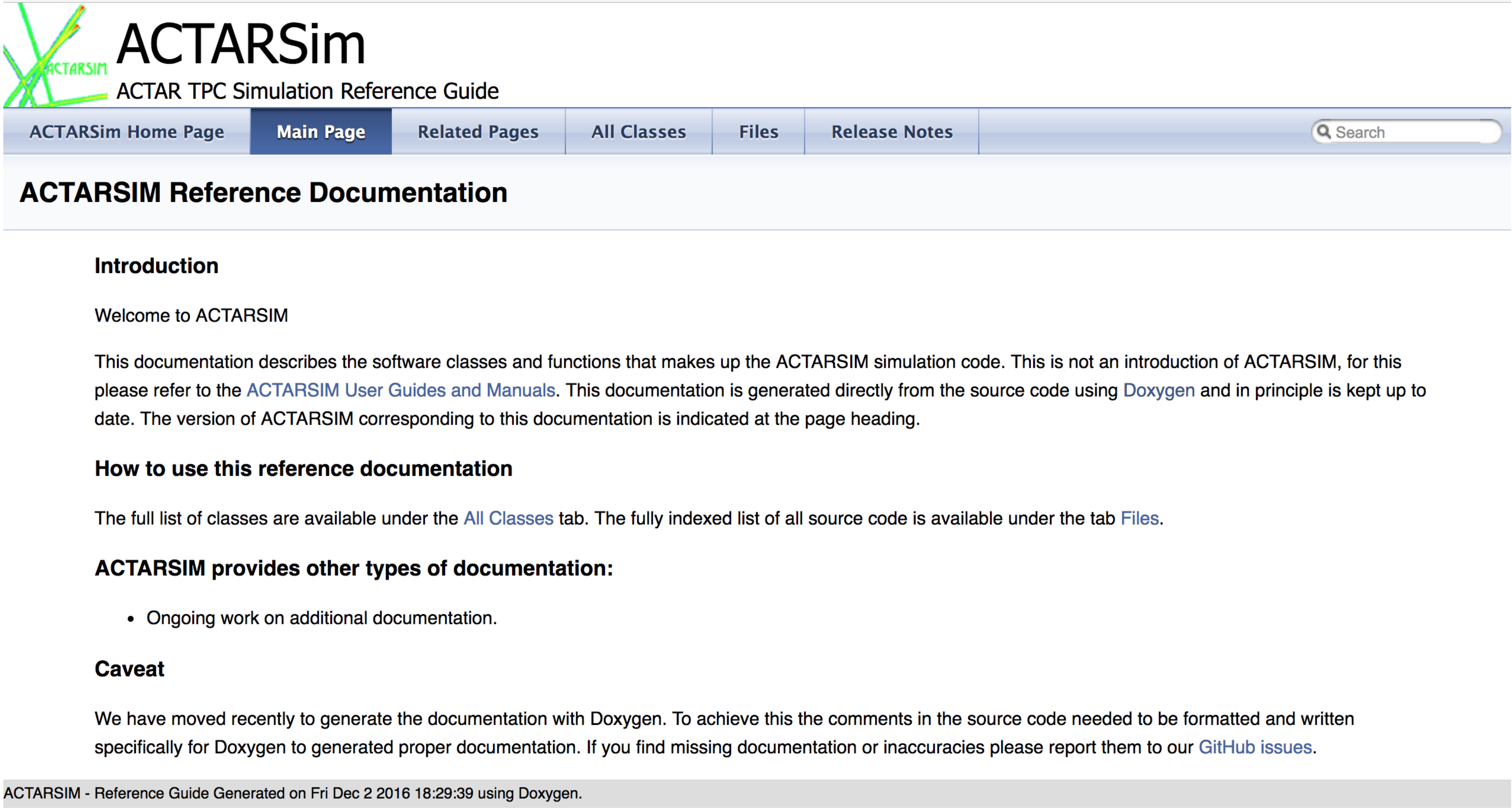





ϕ=10°
ϕ=0°
ϕ=-10°
dE/dx (ADC value/mm)
2000
1000
Residual (%)
5
0
-5
40
60
80
100
120
140
Range (mm)
Transverse σ (mm)
1.7
1.6
1.5
1.4
2
0
-2
40
50
60
70
80
90
100
110
Range (mm)

ACTARSim: a simulation code for ACTAR TPC

http://igfae.usc.es/~genp/actarsim_doxygen/



ACTARSim

ACTAR TPC Simulation Reference Guide

ACTARSIM Reference Documentation

Introduction

Welcome to ACTARSIM

This documentation describes the software classes and functions that makes up the ACTARSIM simulation code. This is not an introduction of ACTARSIM, for this please refer to the ACTARSIM User Guides and Manuals. This documentation is generated directly from the source code using Doxygen and in principle is kept up to date. The version of ACTARSIM corresponding to this documentation is indicated at the page heading.

How to use this reference documentation

The full list of classes are available under the All Classes tab. The fully indexed list of all source code is available under the tab Files.

ACTARSIM provides other types of documentation:

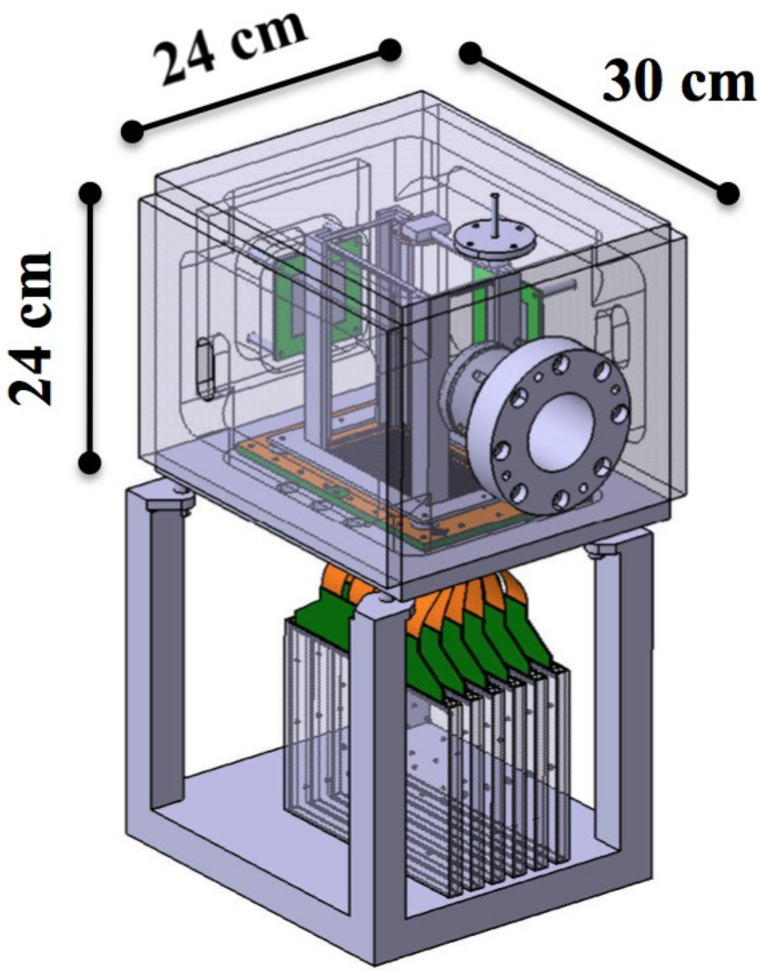
- Ongoing work on additional documentation.

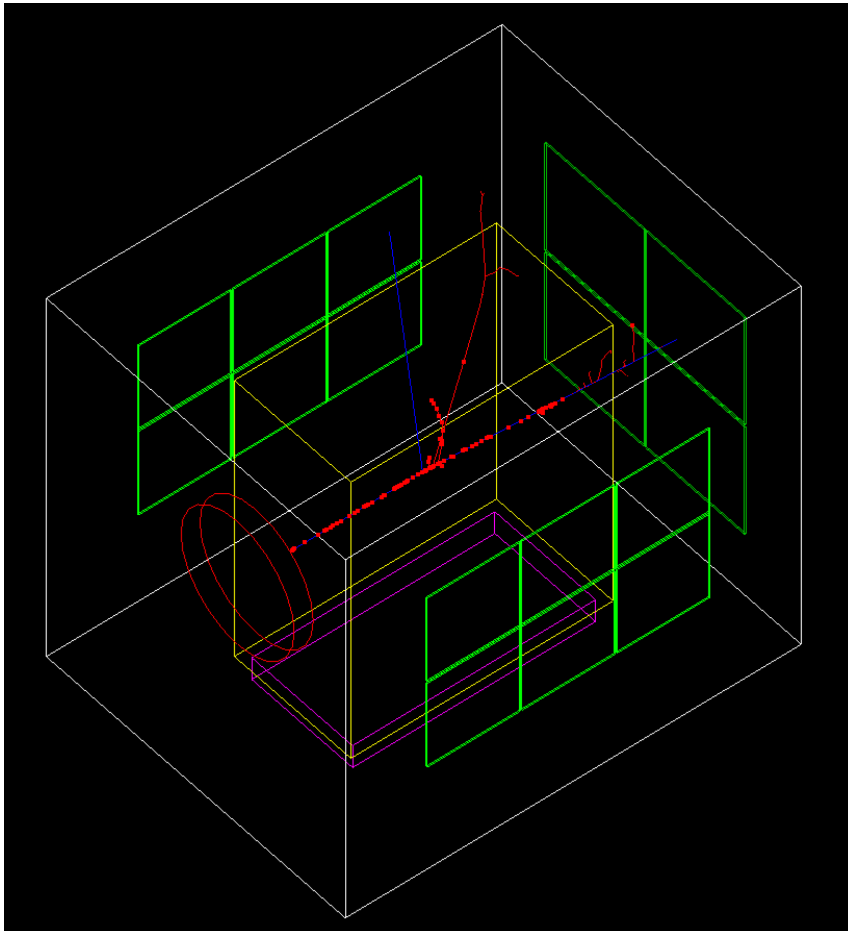
Caveat

We have moved recently to generate the documentation with Doxygen. To achieve this the comments in the source code needed to be formatted and written specifically for Doxygen to generated proper documentation. If you find missing documentation or inaccuracies please report them to our GitHub issues.

ACTARSIM - Reference Guide Generated on Fri Dec 2 2016 18:29:39 using Doxygen.

ACTAR-TPC demonstrator in ACTARSim:





emstandard : the standard electromagnetic library in Geant4

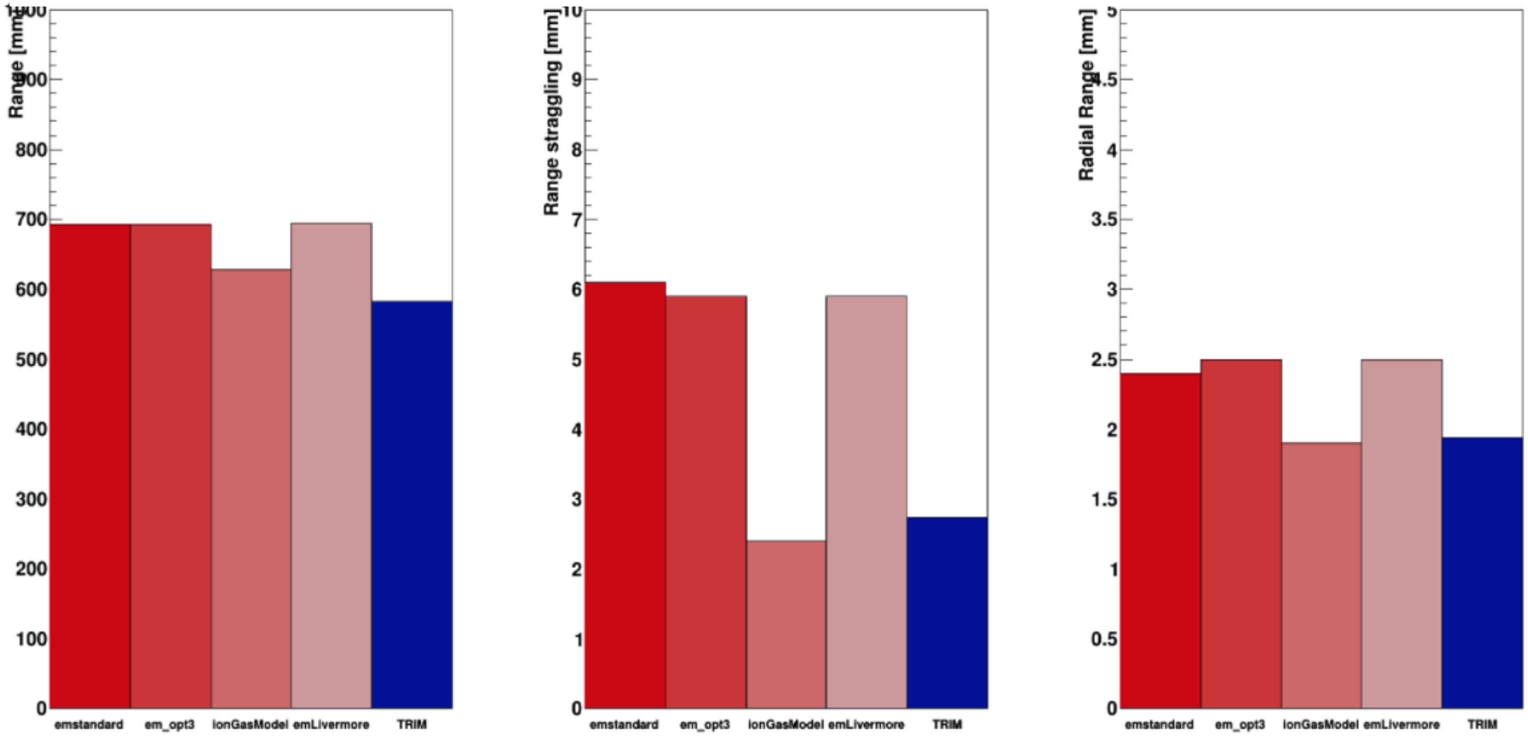
emstandard_opt3 : G4IonParametrisedLossModel used for ion ionisation based on ICRU73 ion stopping data and G4NuclearStopping process added.

emLivermore : based on the Livermore low-energy electromagnetic model.

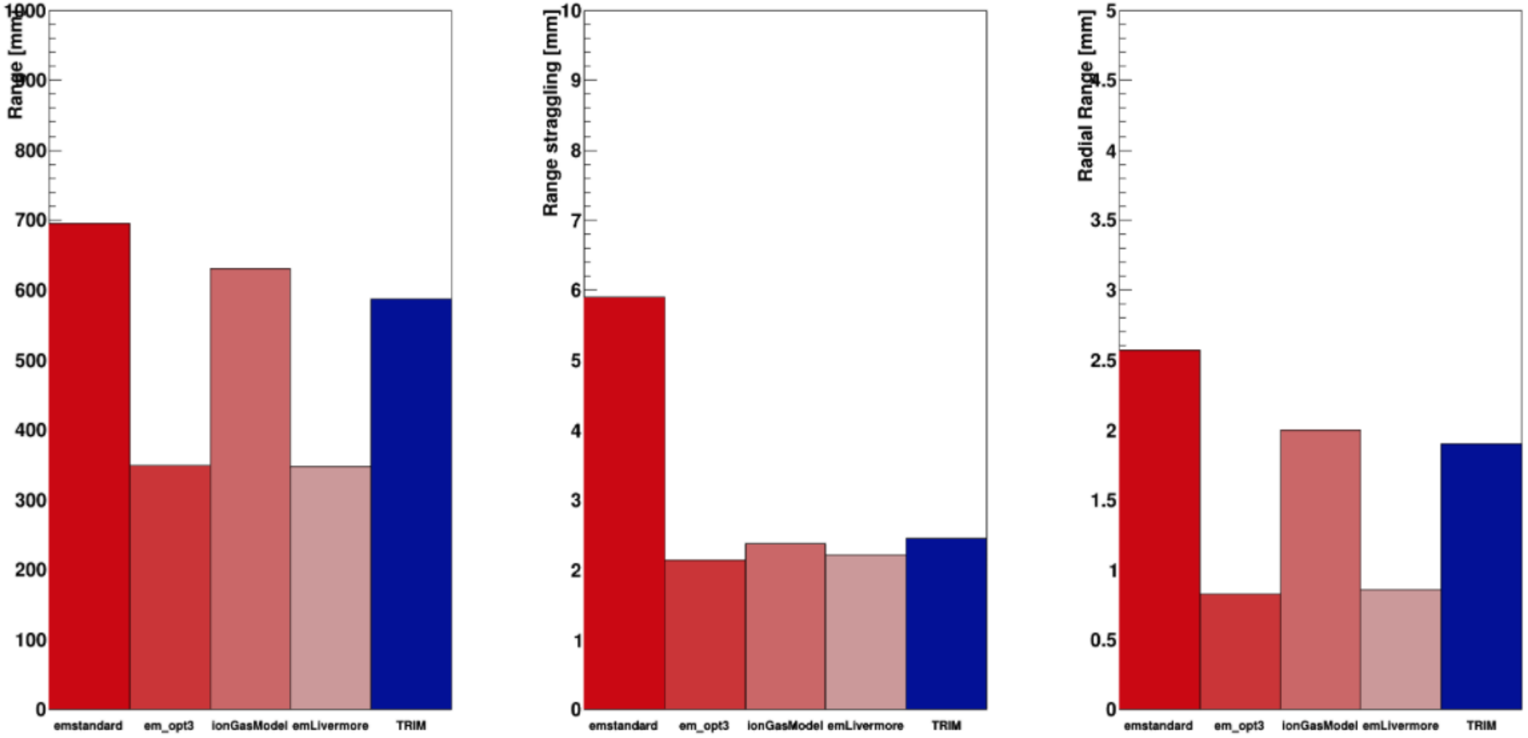
ionGasModel : only used in TestEm7 exemple. It was created specialy for low-density gas volume to disable the effective charge approach of the ion. In the example it used on top of emstandard library.

Here are the range values of a 60MeV 12C beam :

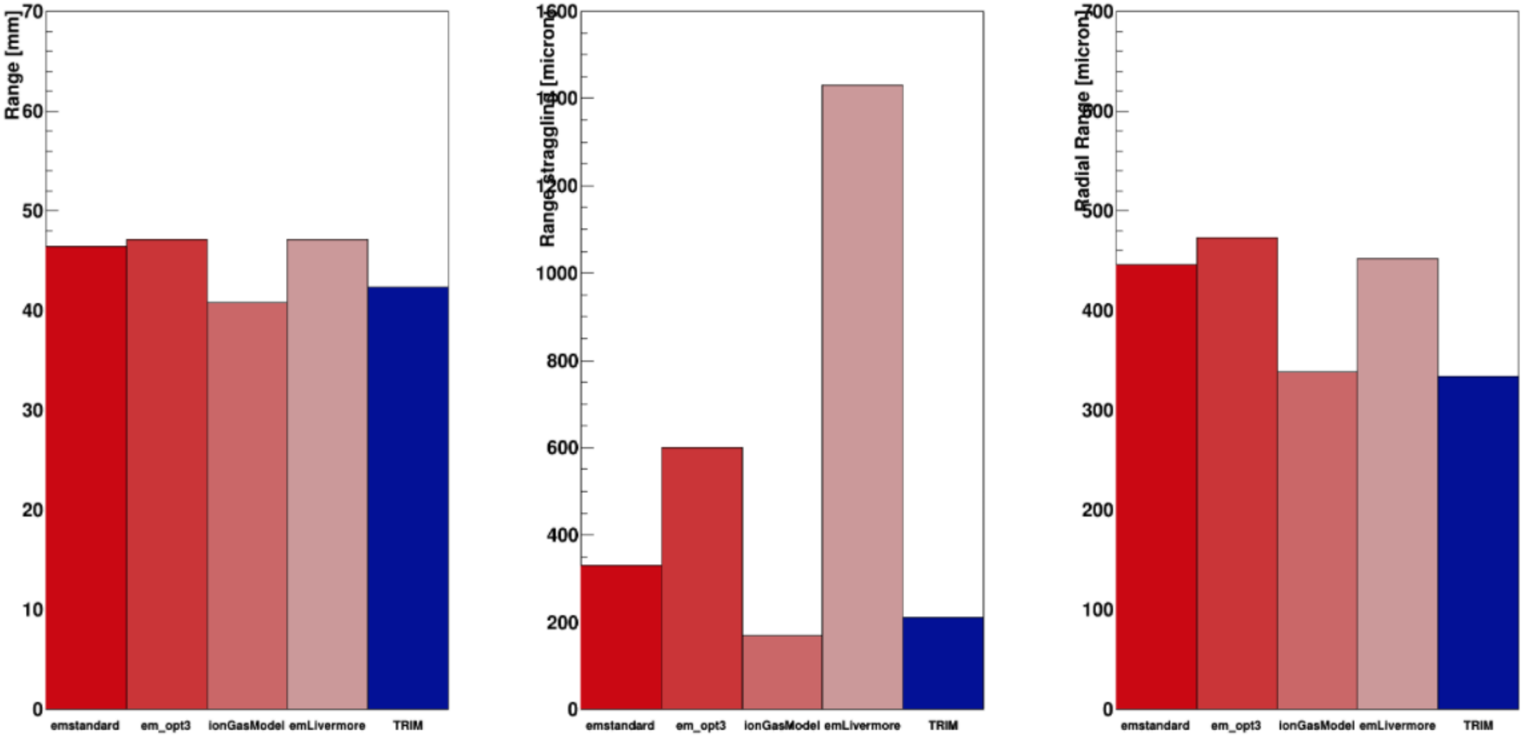
in H2_STP (0.084 mg/cm3)



D2 STP (0.167mg/cm^3)

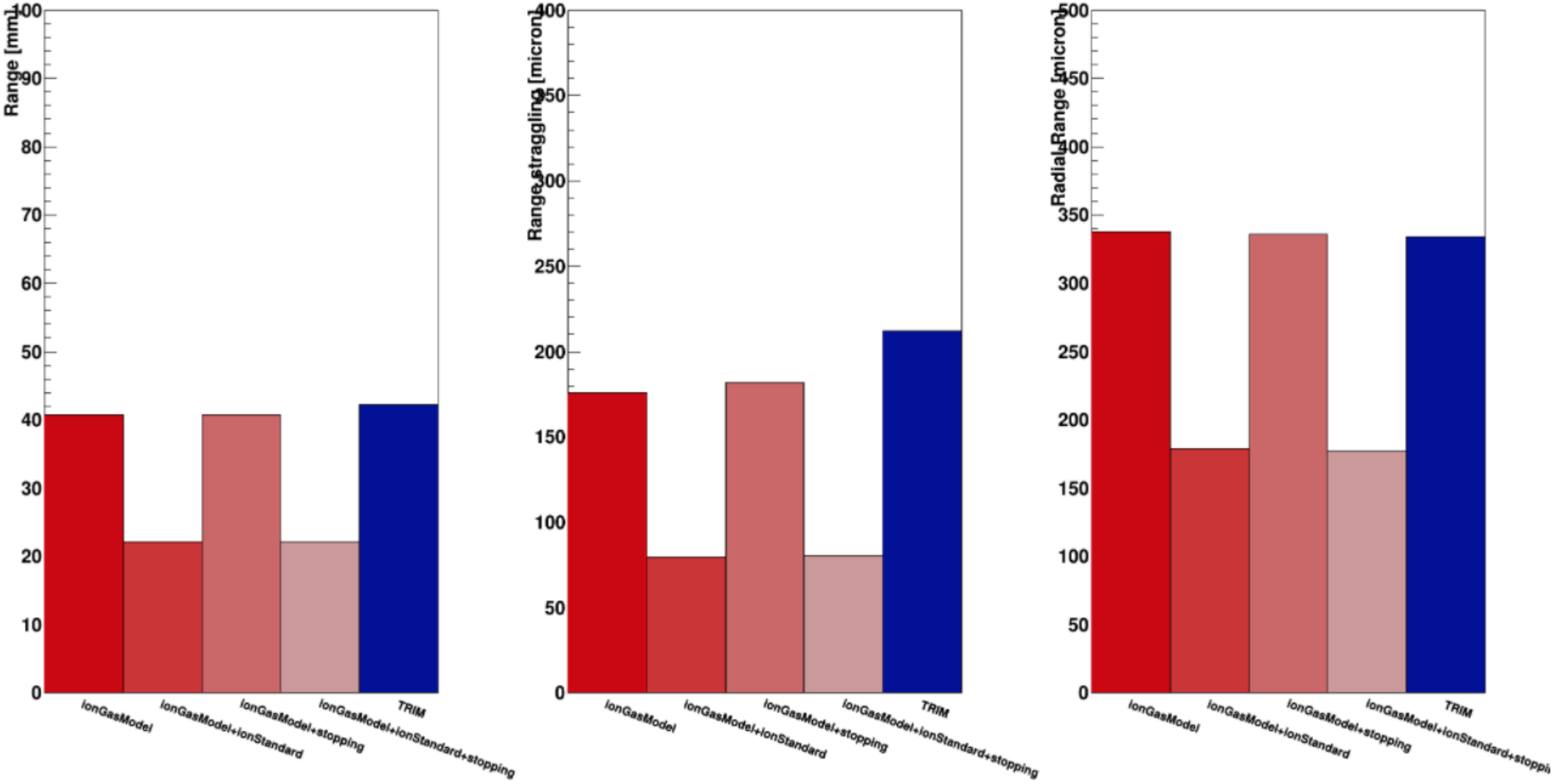


iC4H10 STP (2.67mg/cm^3)



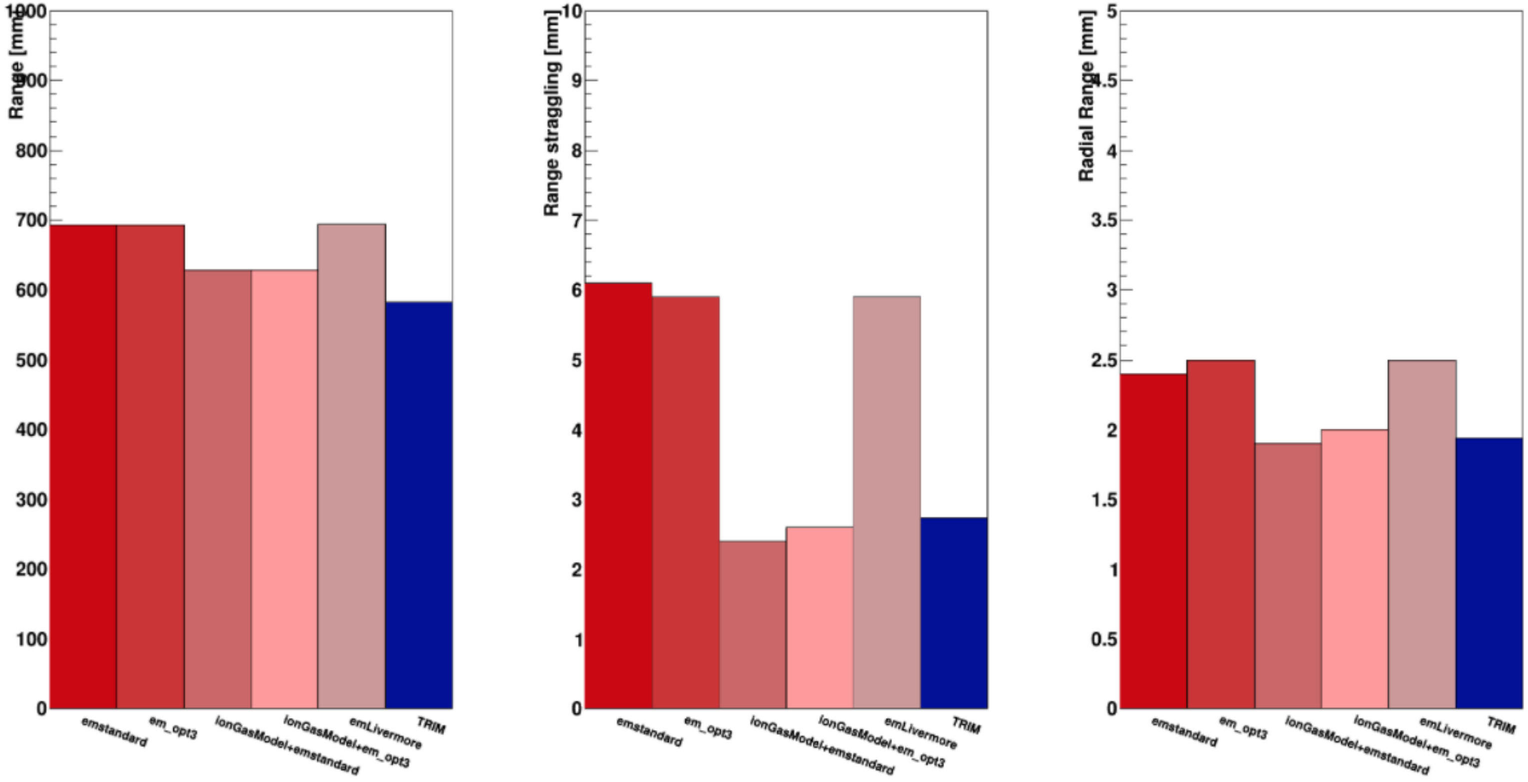
As the ActarSim physics libraries are based on Gamma therapy example, I noticed that in addition to the electromagnetic library one can add a specific ion library (ionstandard which load the HadrontherapyIonStandard library) and a stopping library (G4StoppingPhysics).

I tested these extentions with ionGasModel in iC4H10 and it seems that ionStandard library doesn't work fine.

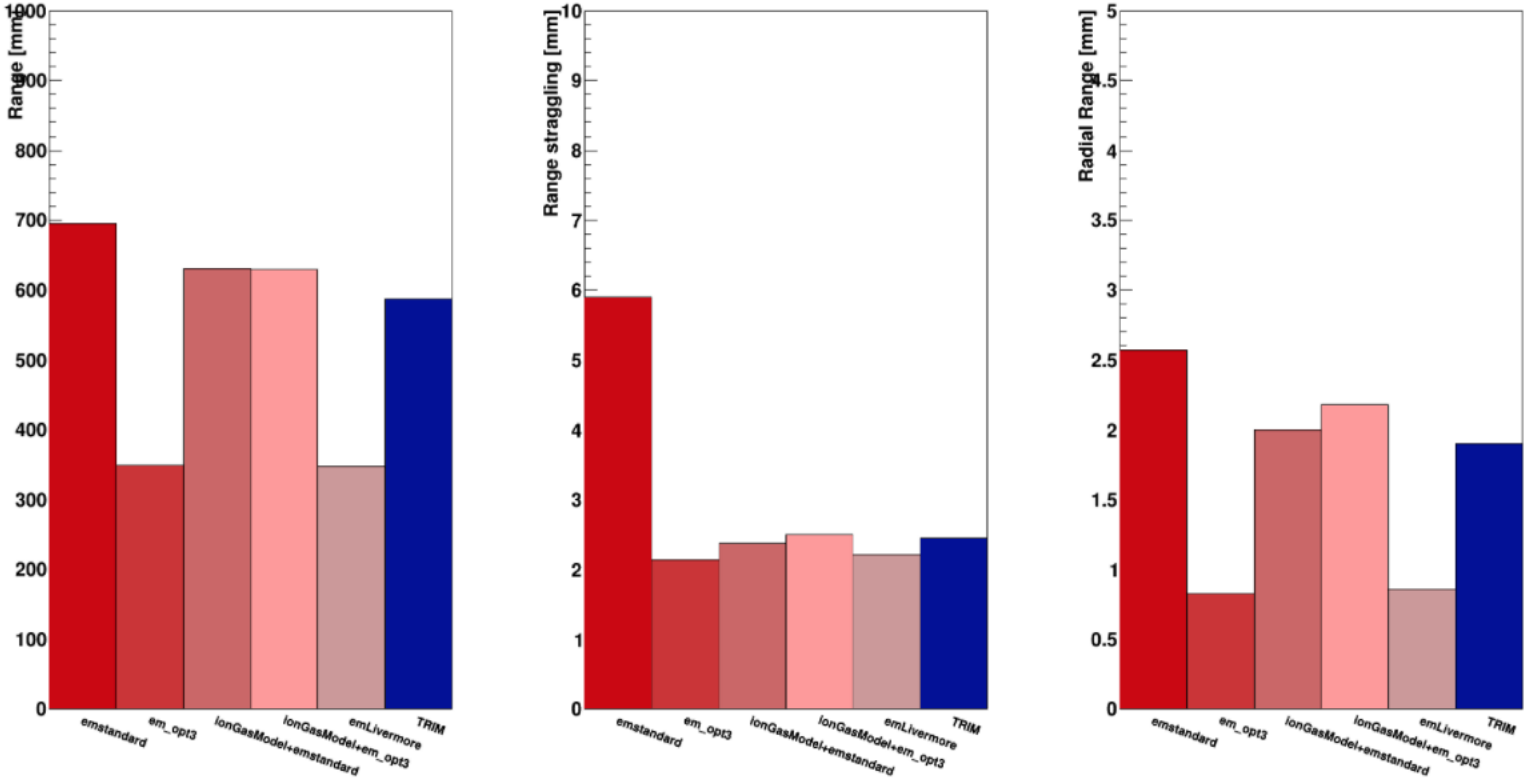


Ok so I updated the plots with the combination emstandard_opt3 + ionGasModel

For H2STP :



D2 STP (0.167mg/cm^3)



iC4H10 STP (2.67mg/cm^3)