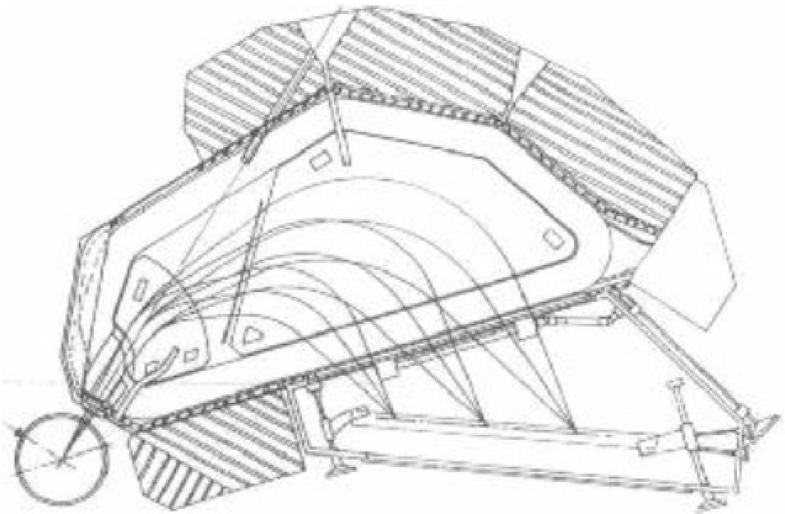
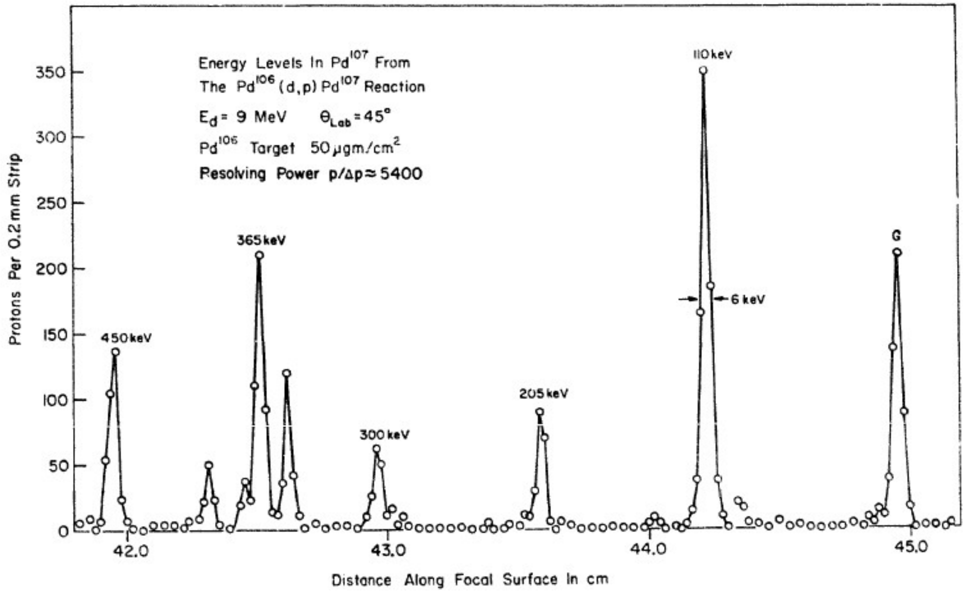
ACTAR TPC: an active target and time projection chamber for nuclear physics

Past: structure of nuclei close to stability in direct kinematics, use of magnetic spectrograph

- Good resolution (few keV)
- High beam intensity
- Stuck with stable isotopes from which a target can be made

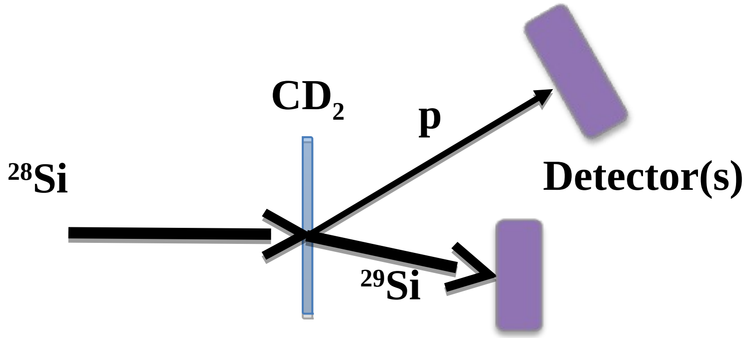


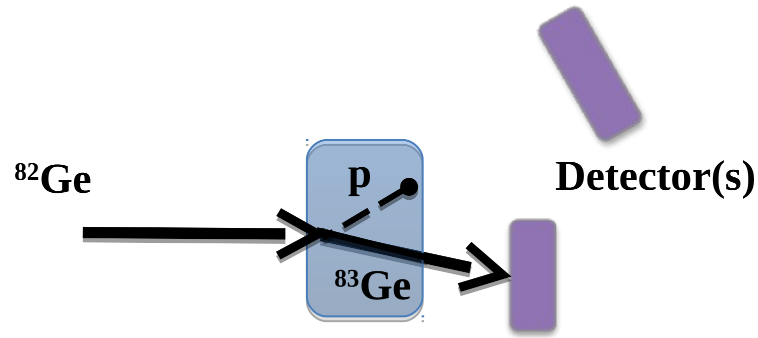


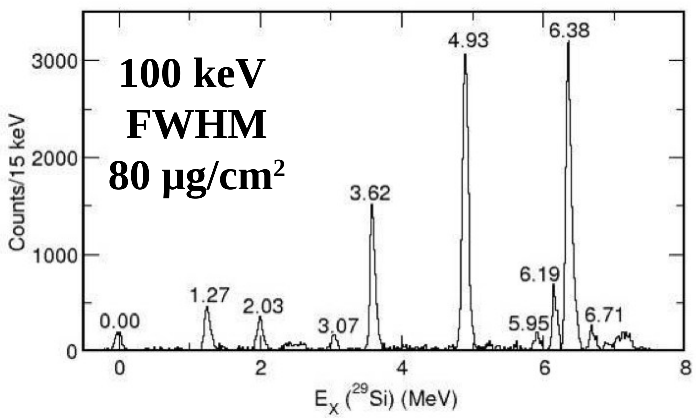
*J.E. Spencer and H.A. Enge, NIM **49,** 181 (1967)*

Now: structure of exotic nuclei in inverse kinematics

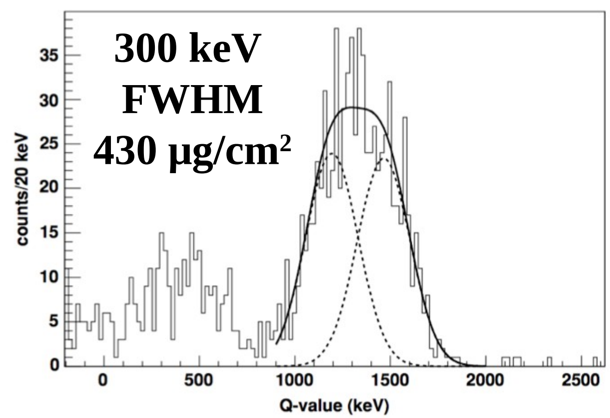
- Study of nuclei with short half-life
- Low beam intensity
- Resolution strongly depends on target thickness







J.C.Lighthall et al., NIM A ***622*** *97 (2010)*



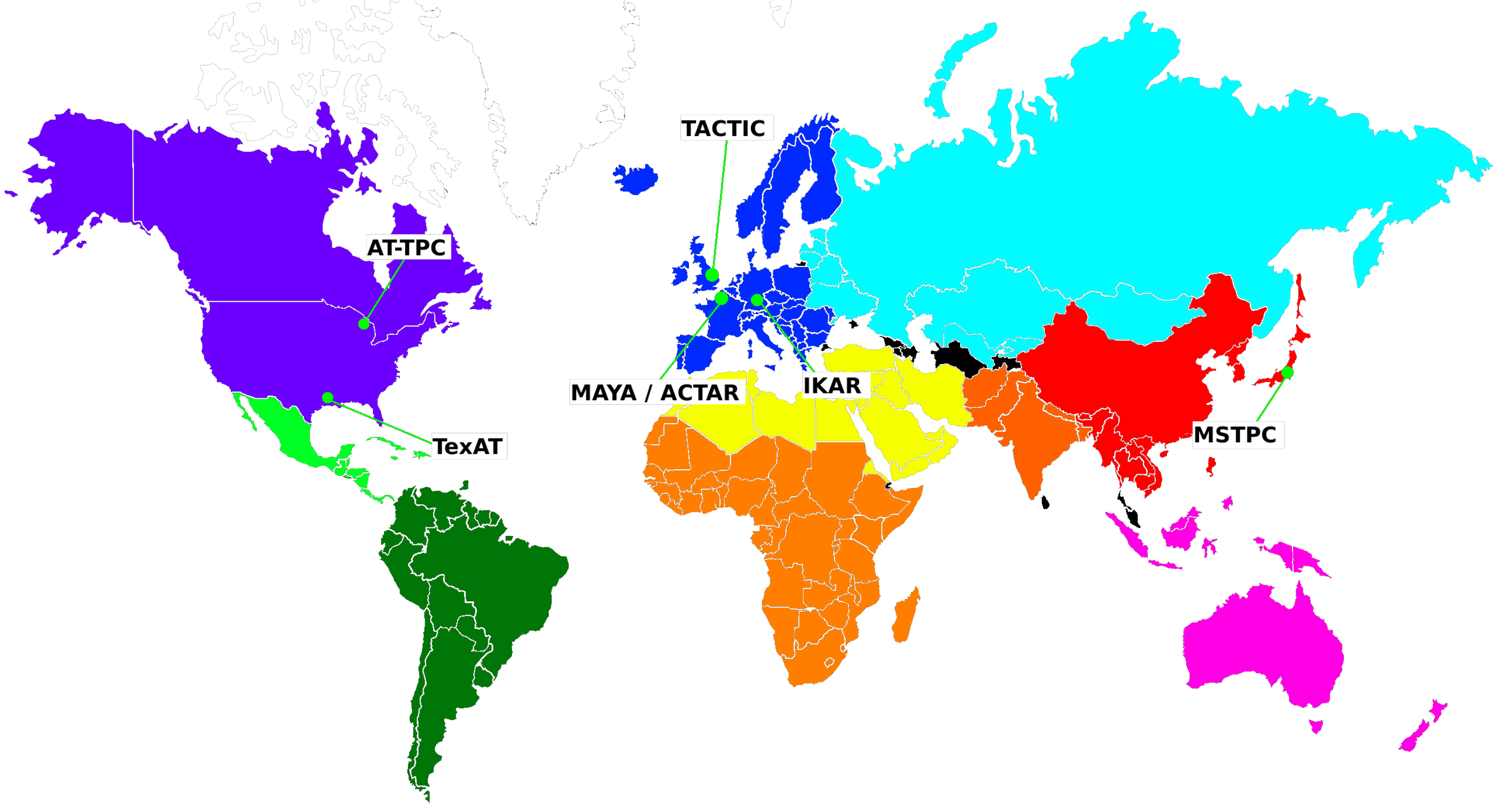
J.S. Thomas et al., PRC ***71,*** *012302 (2005)*

Need thick targets *and* excellent resolution

Now: ACTIVE TARGETS

- Study of nuclei with short half-life, produced with small intensity
- Use of thick target without loss of resolution
- Detection of very low energy recoils

Active target: (Gaseous) detector in which the atoms of the gas are used as a target

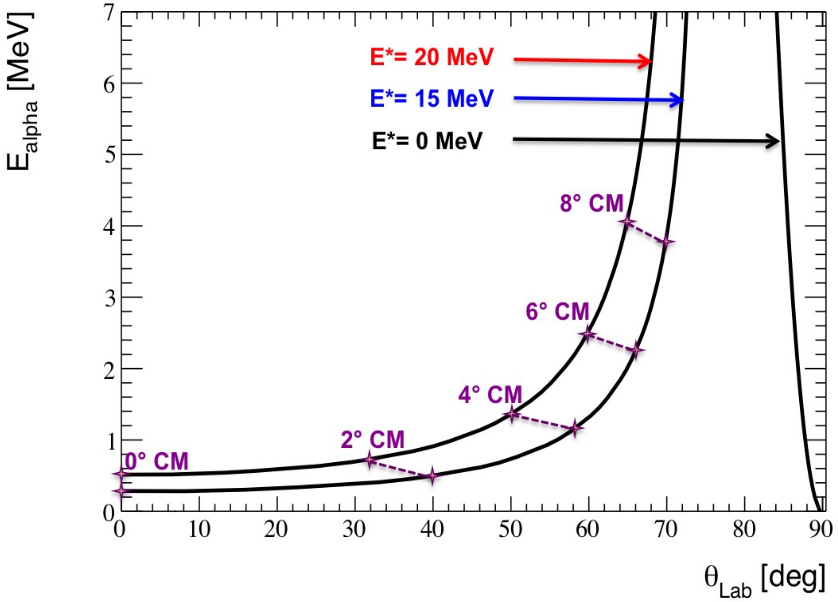


When should active targets be used?

- Reactions with very negative Q-value in inverse kinematics
  - → recoil stops inside the target

^{68}Ni(α,α') @ 50*A* MeV → GMR

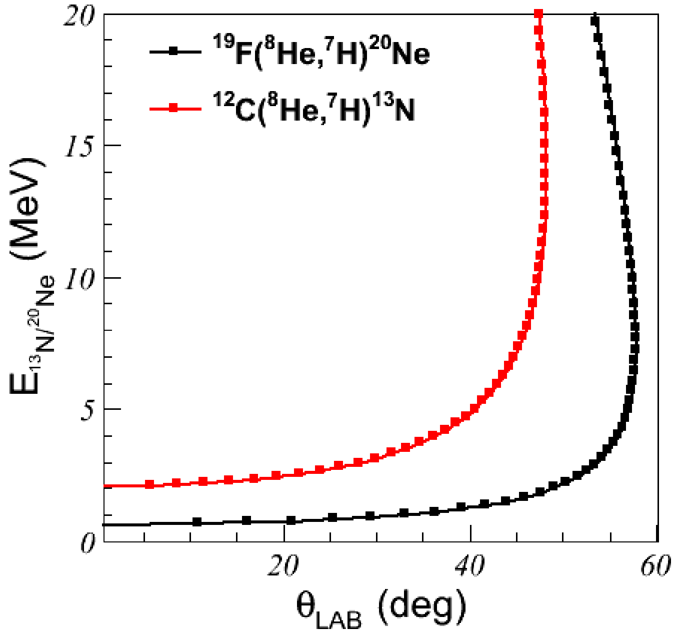
Q ≈ -15 MeV



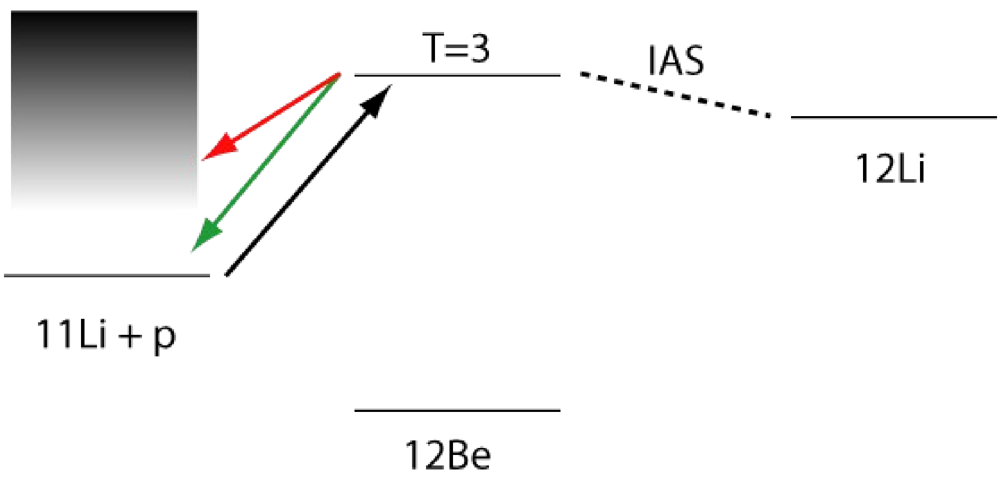
M. Vandebrouck, PhD thesis, Université Paris-Sud XI (2013)

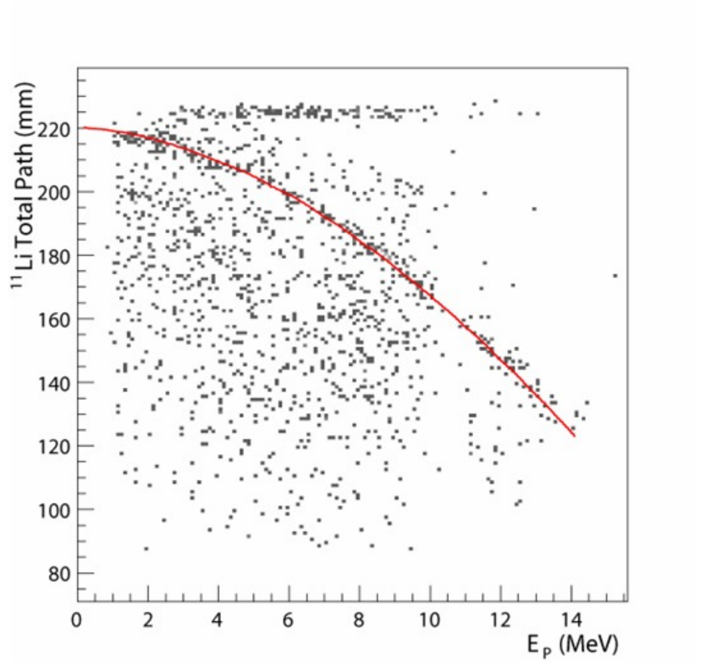
^{8}He(^{19}F, ^{20}Ne) ^{7}H @ 15*A* MeV

Q ≈ -13 MeV



- Reactions with very negative Q-value in inverse kinematics
  - → recoil stops inside the target
- Study of excitation functions
  - → thick target, need to differentiate the reaction channels





T. Roger, PhD thesis, Université de Caen (2009)

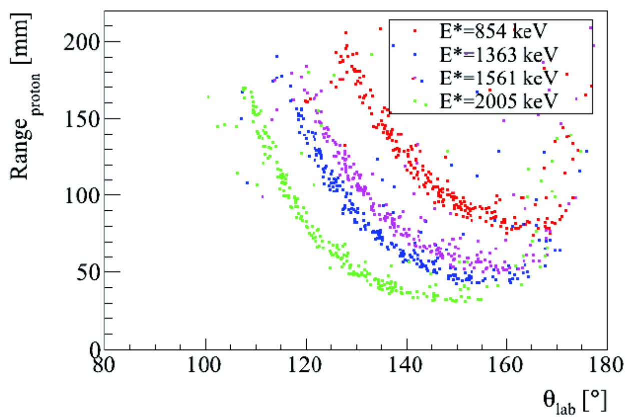
- Reactions with very negative Q-value in inverse kinematics
  - → recoil stops inside the target
- Study of excitation functions
  - → thick target, need to differentiate the reaction channels
- Reactions with very low intensity beams
  - → thick target, possibly no ^{12}C contamination

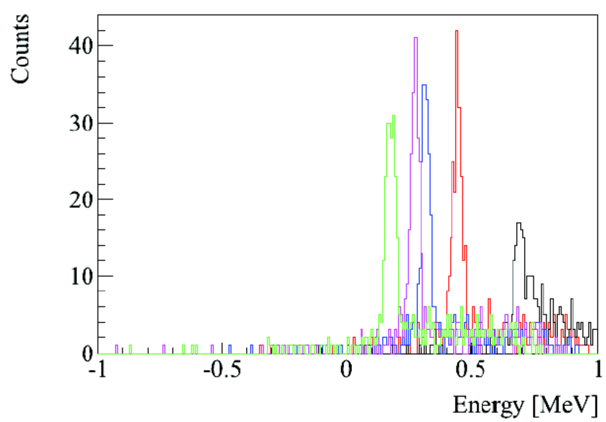
Example: $^{132}Sn(d,p)$ reaction

→ For the same energy loss in the target, about 3x more deutons in D_2 gas than in solid CD_2 target

→ Vertexing: possibility to increase the target thickness without loss of resolution

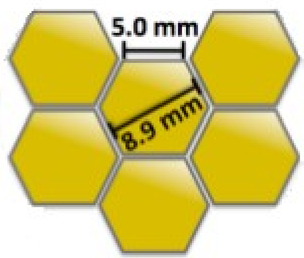
→ Overall gain of D_2 gaseous target: factor up to 100!

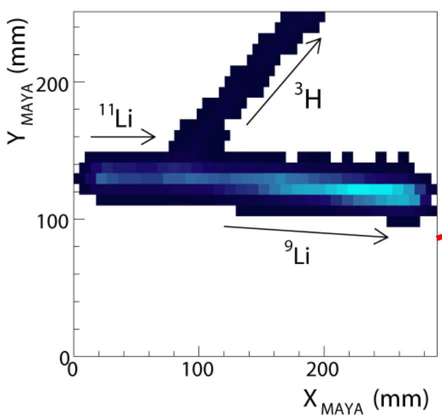




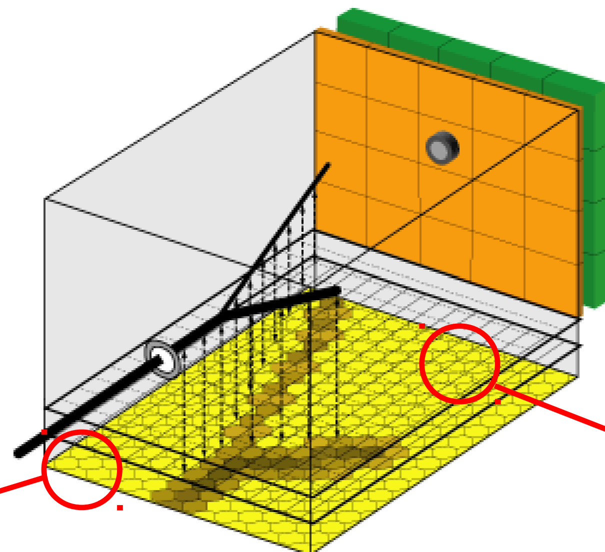
ACTARsim report: http://pro.ganil-spiral2.eu/spiral2/instrumentation/actar-tpc/actarsim-2013-report/view

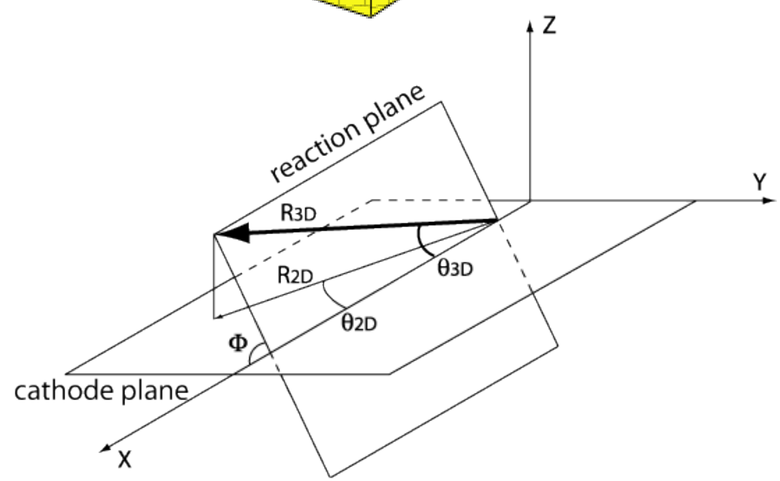
MAYA: A two dimensional charge – one dimensional time projection chamber

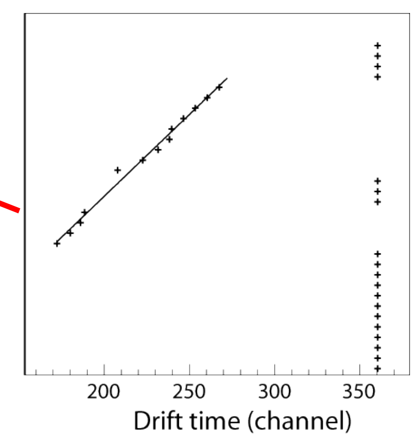




Cathode recorded pattern
→ 2 dimensions
(32x32 pads)





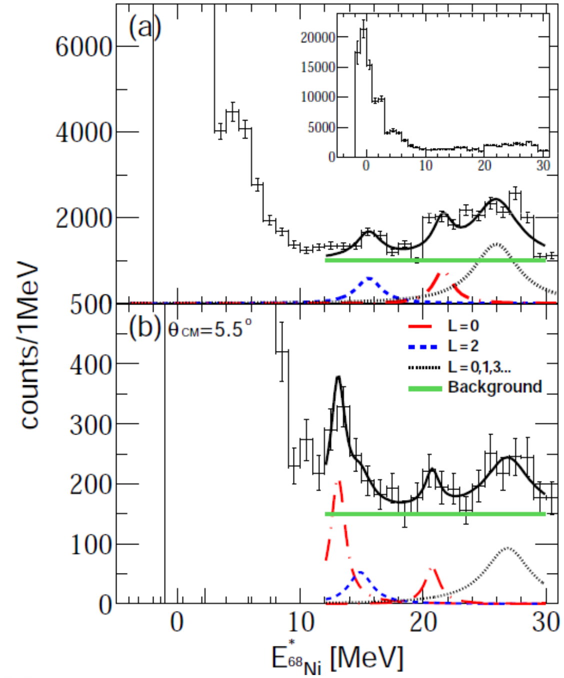


Wire recorded time
→ 3rd dimension
(32 wires)

*C.E. Demonchy et al., NIM A **583,** 341 (2007)*

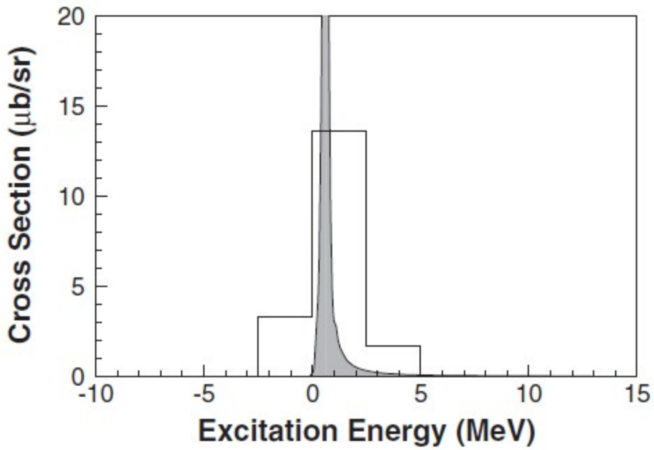
- 1st observation of Giant Resonances in radioactive nuclei: ^{56}Ni & ^{68}Ni

  *C.Monrozeau et al. Phys. Rev. Lett. **100**, 042501 (2008)*
  *M. Vandebrouck et al. Phys. Rev. Lett. **113**, 032504 (2014)*
  *M. Vandebrouck et al. Phys. Rev. C **92**, 024316(2015)*
  S. Bagchi et al. Submitted to Phys. Lett. B (2015)



- Observation of the "most exotic" nucleus ^{7}H

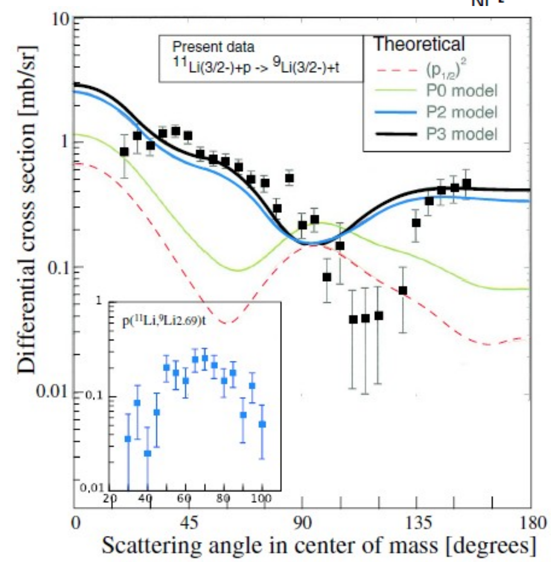
  *M.Caamano et al. Phys. Rev. Lett. **99**, 062502 (2007)*



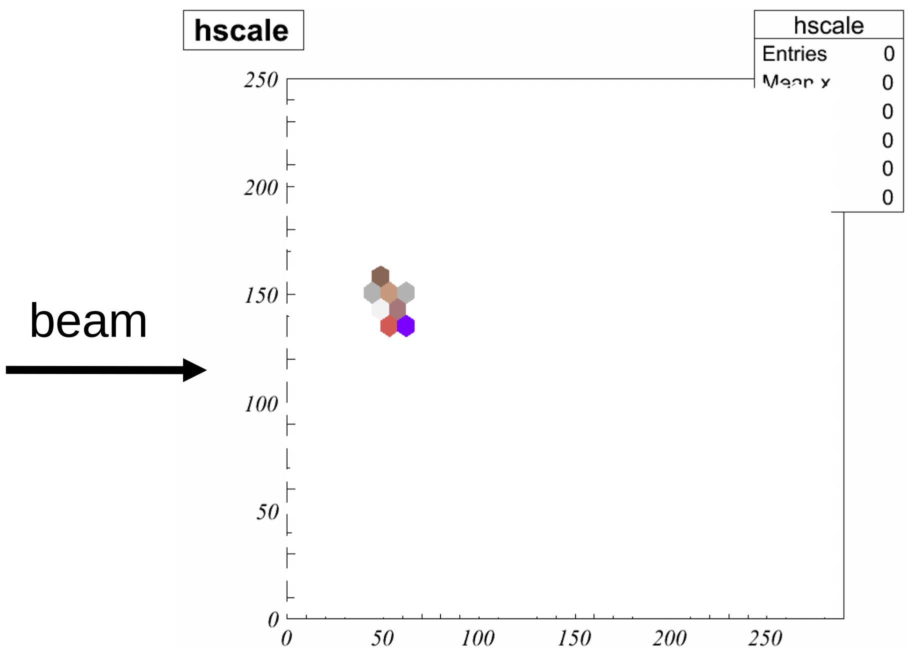
- 1st study of the ^{11}Li 2-neutron halo via a transfer reaction

  *I.Tanihata et al. Phys. Rev. Lett. **100**, 192502 (2008)*

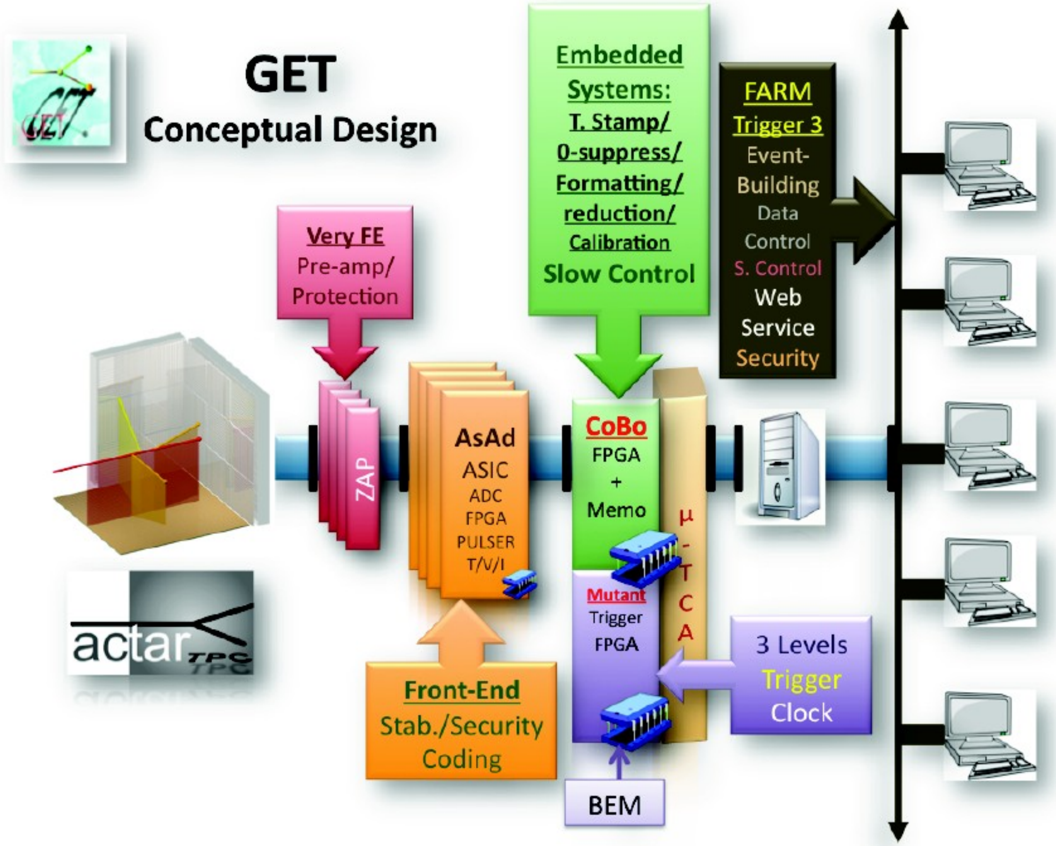
  *T. Roger et al. Phys. Rev. C **79**, 031603 (2009)*



- 3rd dimension from wires
  - → Mostly stuck to binary reactions
- Gassiplex electronics
  - → Poor detection dynamics (~20)
  - → Huge dead-time (>2 ms for 2000 pads)
- 5 mm side pads (8 mm pitch)
  - → Hard to reconstruct trajectories if range < few cm.

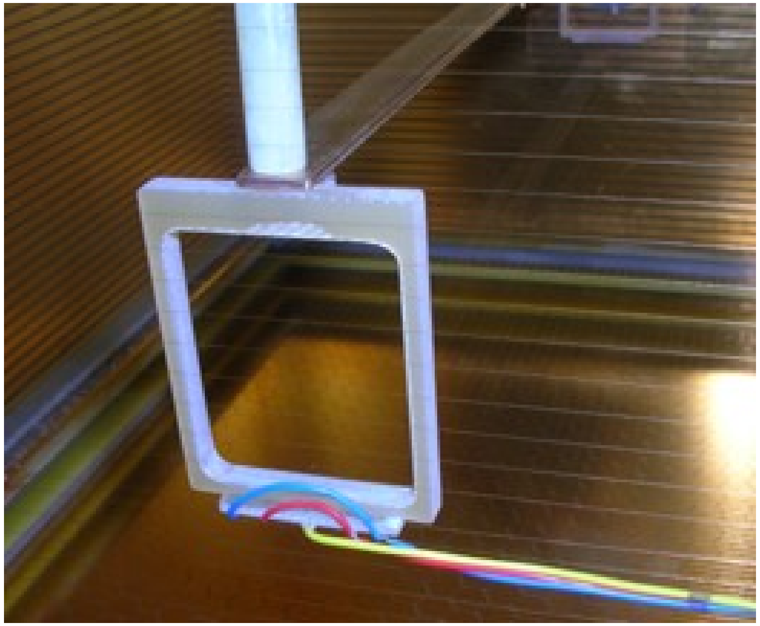


- Improved detection dynamics
  - → Use GET electronics: theoretical dynamical range of ~1000 + digitized electronics
  - → Possibility of pads polarization: reduces locally the amplification

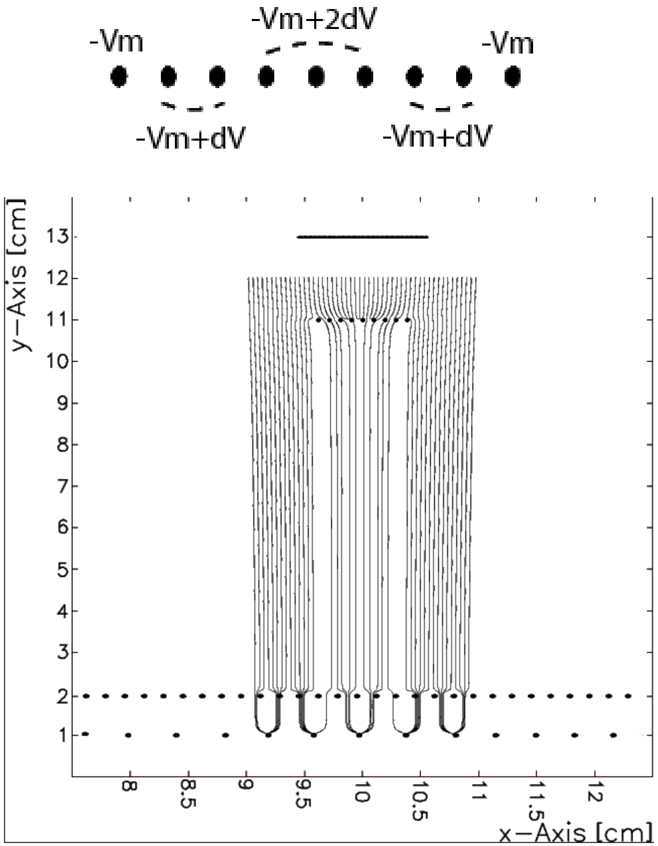


E.C. Pollaco et al., Physics Procedia ***37,*** *1799 (2012)*

- Improved detection dynamics
  - → Use GET electronics: theoretical dynamical range of ~1000 + digitized electronics
  - → Possibility of pads polarization: reduces locally the amplification
  - → Use a semi-transparent mask to reduce the number of primary electrons



*J. Pancin et al., JINST **7**, P01006 (2012)*

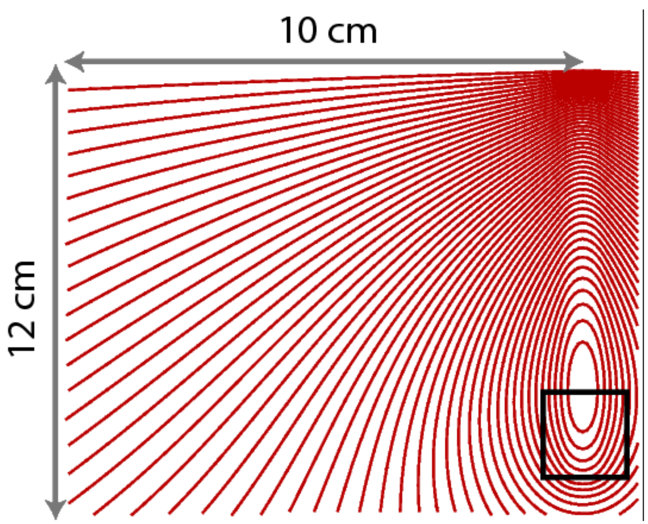


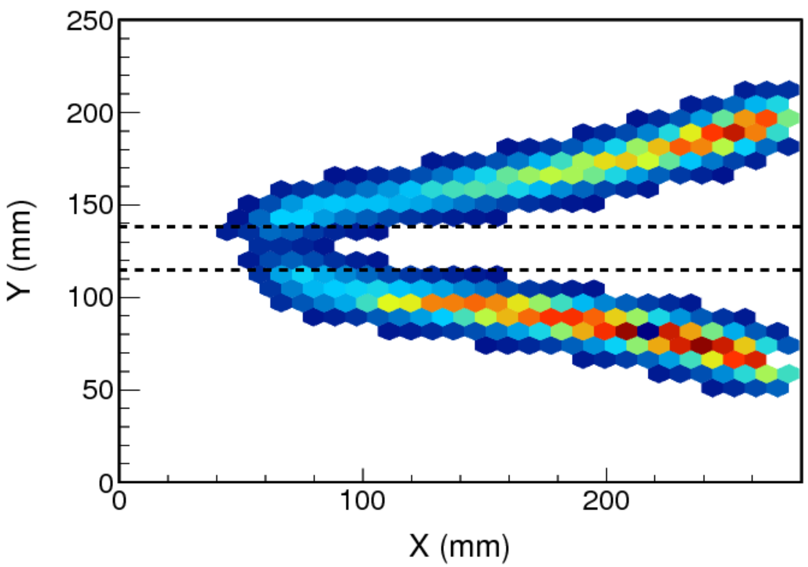
- Improved detection dynamics
- Improved incoming beam intensity / heavy-Z beams
  - → Use a mask + field cage (Tactic-like)

➔ E653 experiment: Angular distribution of fission fragment in transfer-induced fission using MAYA

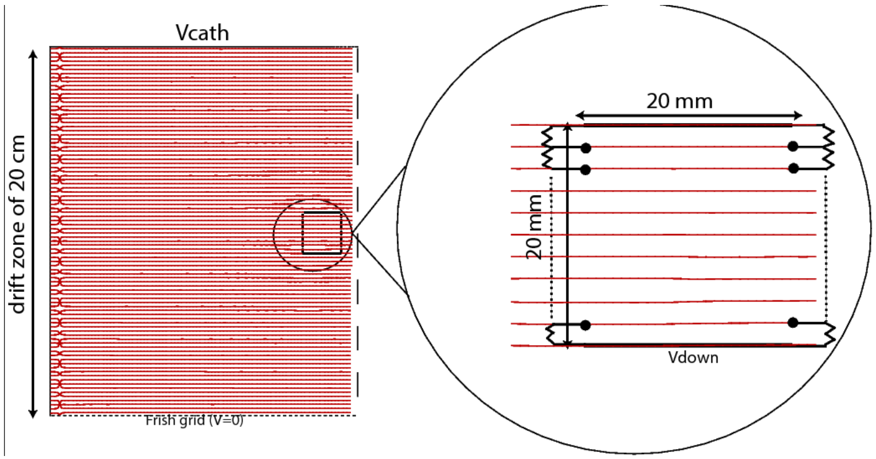
➔ Principle: use a 10^6 Hz ^{238}U beam @ 6*A* MeV in isobutane

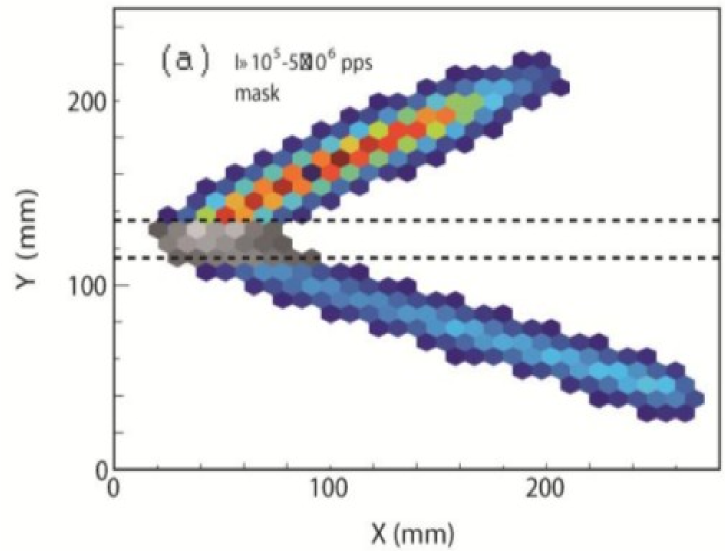
- → Energy deposit ~ 1 PeV/s
- → Primary ions electric field: ~ 80 V/cm compared to drift field ~ 15V/cm



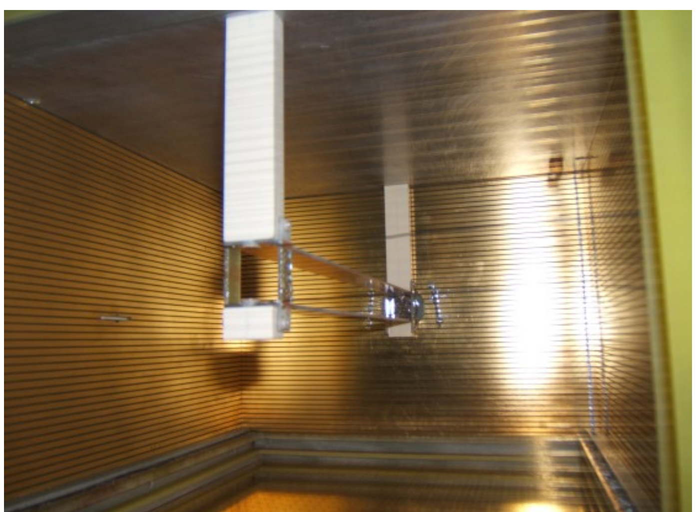


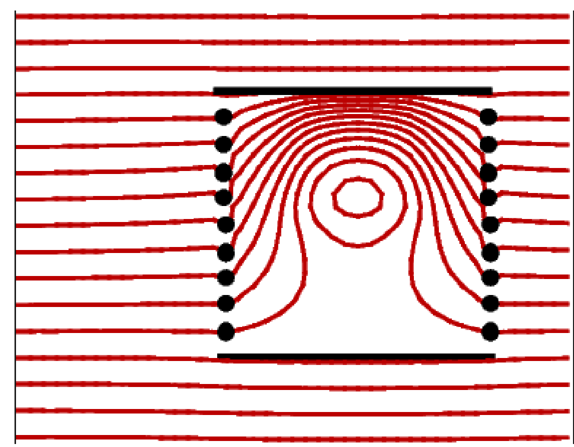
- Improved detection dynamics
- Improved incoming beam intensity / heavy-Z beams
  - → Use a mask + field cage (Tactic-like)



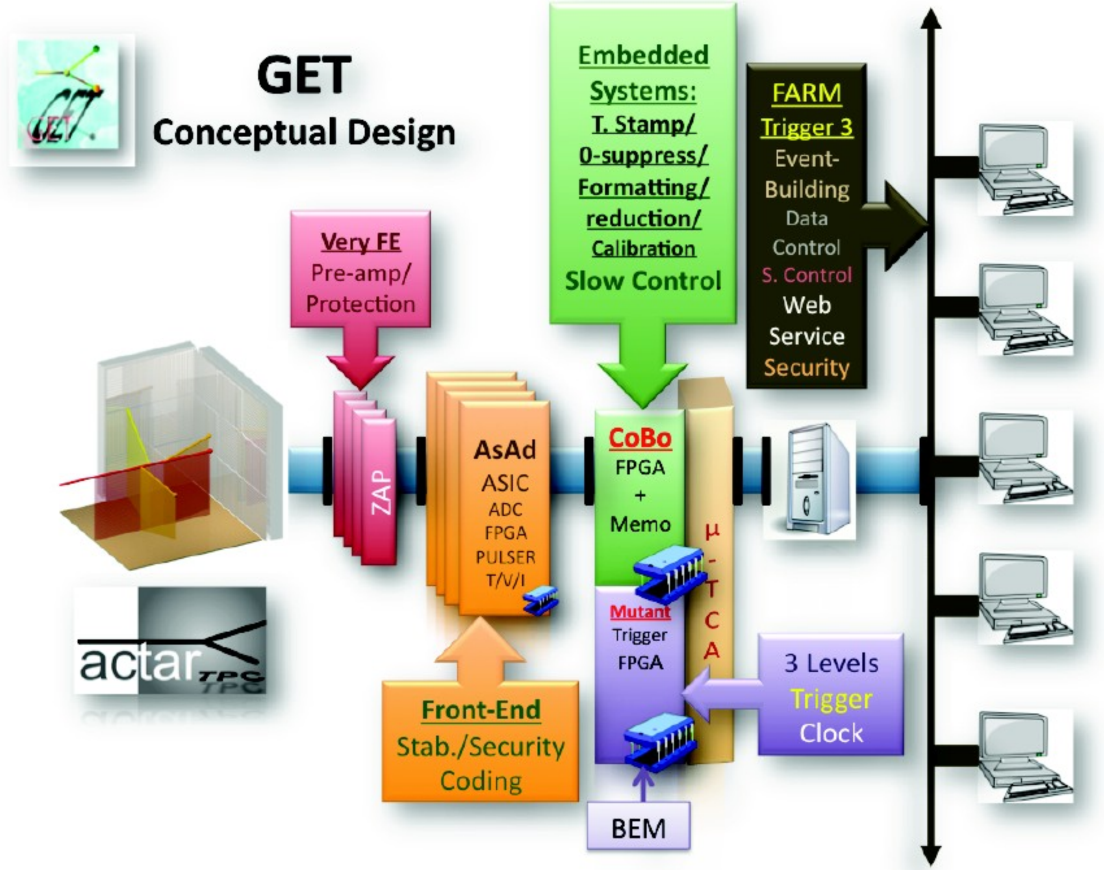


C. Rodriguez-Tajes et al., NIM A ***768***, 179 (2014)





- Improved detection dynamics
- Improved incoming beam intensity / heavy-Z beams
  - → Use a mask + field cage (Tactic-like)
  - → Use L2 triggers & CPU farms to reduce the number of accepted triggers

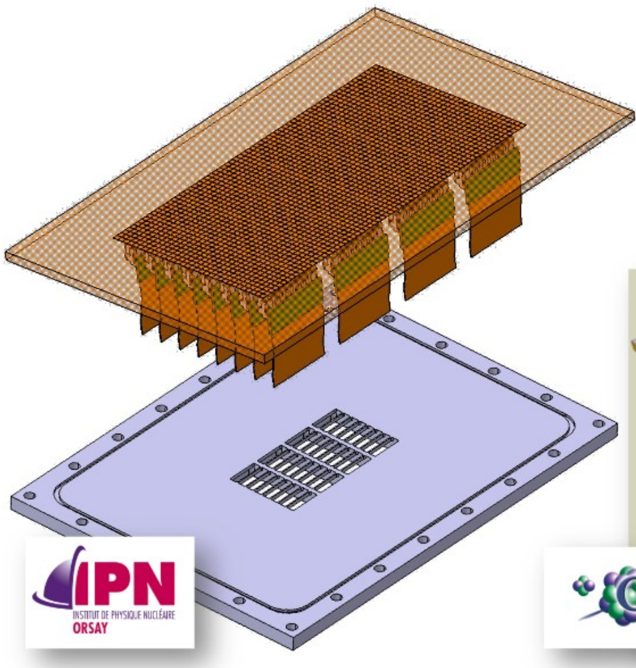


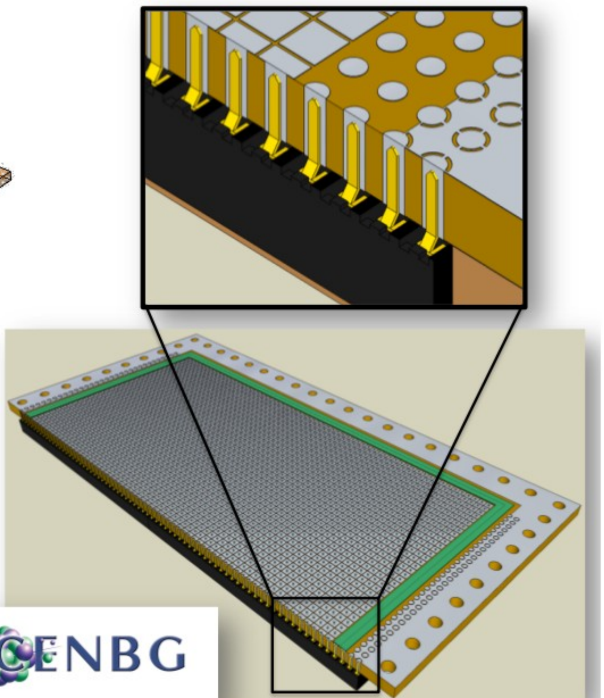
- Improved detection dynamics
- Improved incoming beam intensity / heavy-Z beams
- Improved granularity: ACTAR TPC
  - → 16384 pads, 2x2 mm²
  - → GET electronics: digitized signals on each pad
  - → Funded by ERC starting grant (G. Grinyer)

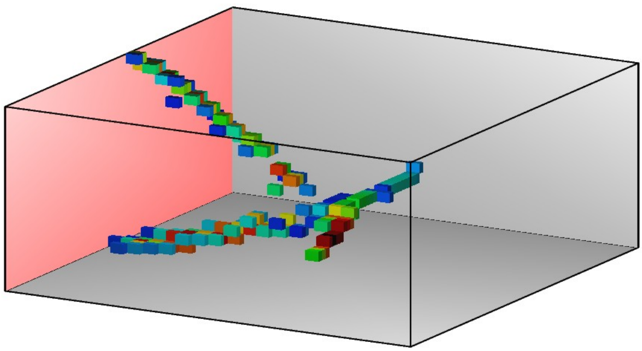
European Research Council

Established by the European Commission

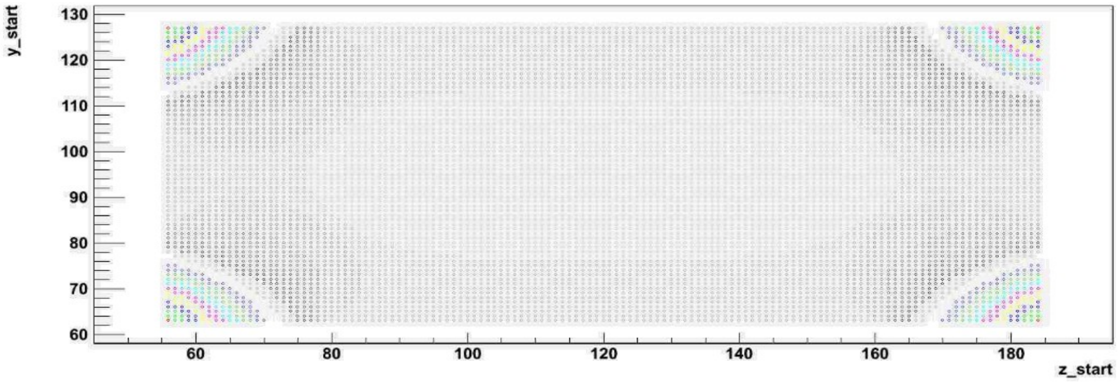
➔ About 8 millions voxels!

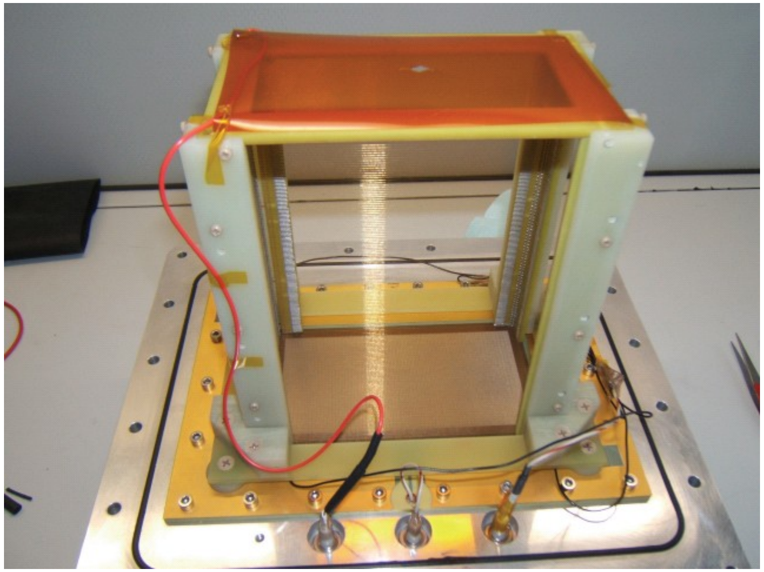


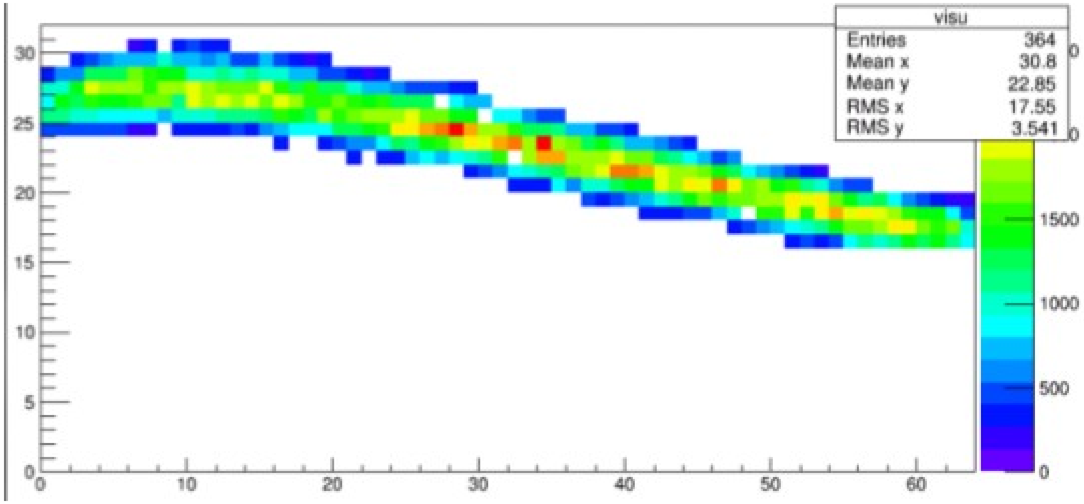




- Drift region:
  - → Demonstrator: 1 mm pitch single wire field cage
  - → Final chamber: double wire cage with pitch > 2mm
  - → Simulations ongoing

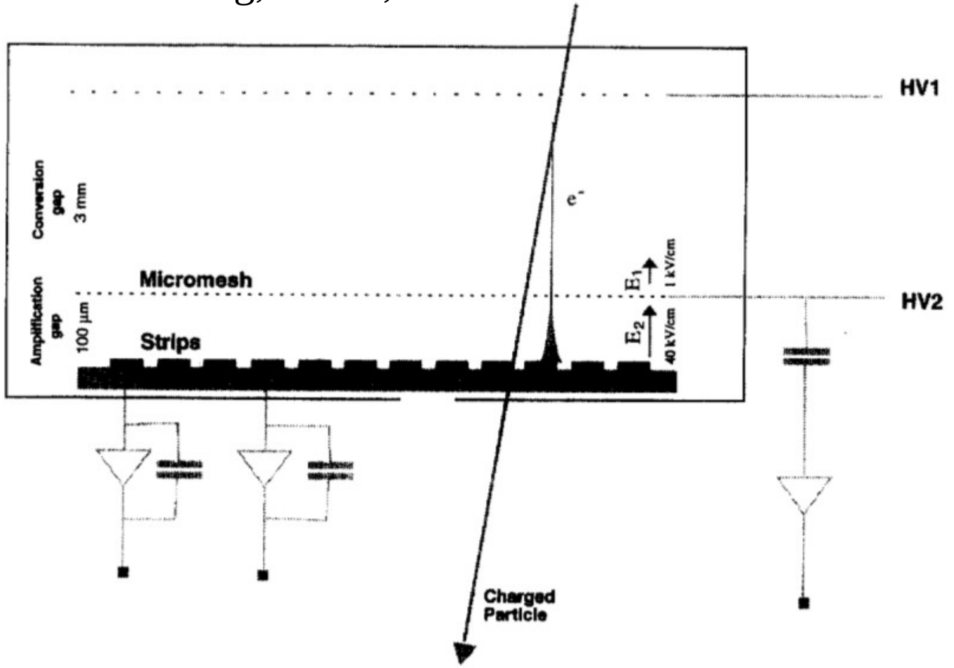


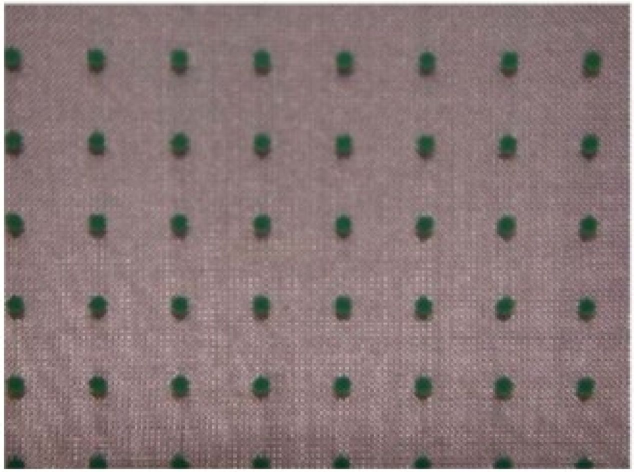


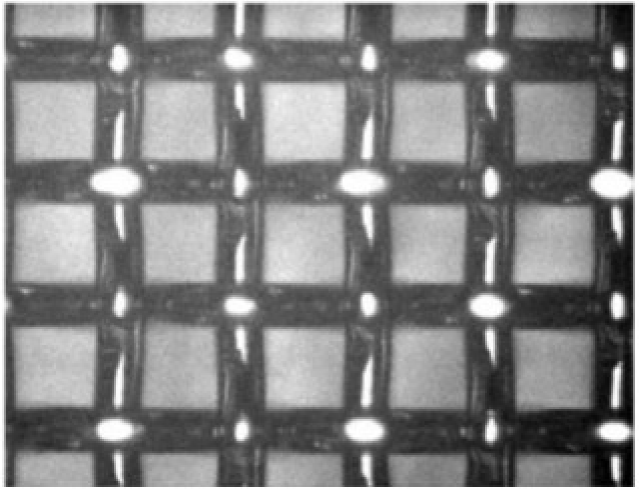


- Drift region:
  - → Demonstrator: 1 mm pitch single wire field cage
  - → Final chamber: double wire cage with pitch > 2mm
  - → Simulations ongoing

- Amplification region:
  - → Micromegas, 220 µm gap: OK for low pressure
  - → Fast timing, robust, cost effective



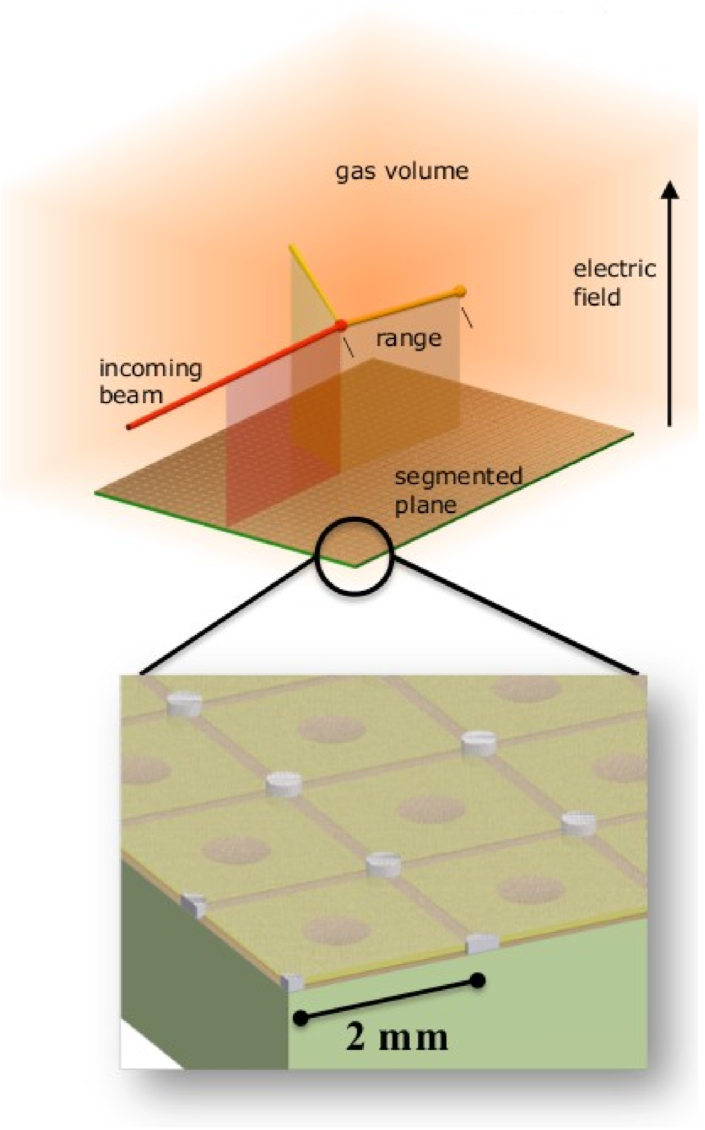




Y. Giomataris et al., NIM A ***560,*** *405 (2006)*

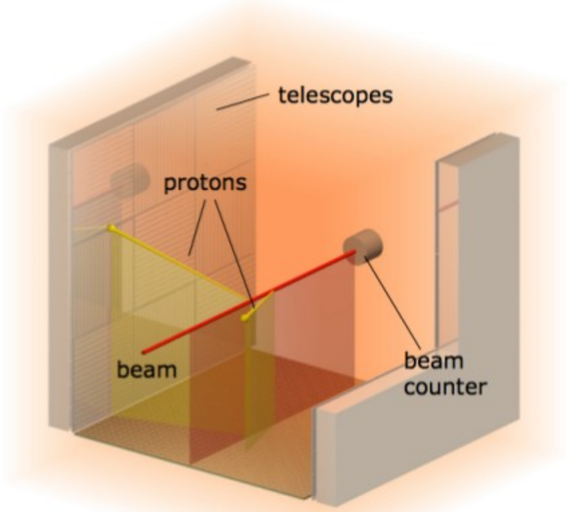
ACTAR TPC: Detector design

- Drift region:
  - → Demonstrator: 1 mm pitch single wire field cage
  - → Final chamber: double wire cage with pitch > 2mm
  - → Simulations ongoing
- Amplification region:
  - → Micromegas, 220 µm gap: OK for low pressure
  - → Fast timing, robust, cost effective
- Segmented pad plane:
  - → Very high density: 2x2 mm² (= 25 channels/cm²)
  - → Total 16348 electronics channels, digitized (GET system)
- Auxiliary detectors:
  - → Telescopes for escaping particles (Si+Si or Si+CsI)
  - → $LaBr_3$ or $CeBr_3$ for γ rays (SpecMAT ERC – R. Raabe)

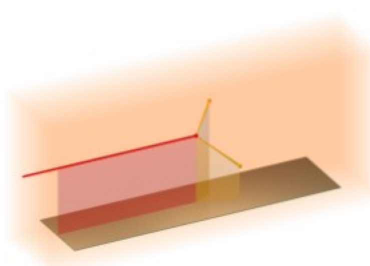


ACTAR TPC: Versatile design

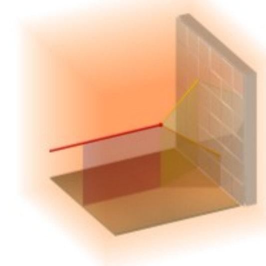
- Design goal (1): Reconfigurable
  - → Auxiliary detectors for particles and/or γ rays
  - → Configurable – Installation on any side
  - → Depends on the kinematics of the experiment
- Design goal (2): Versatility
  - → Perform reaction and decay experiments
  - → Two separate chambers will be designed
- Design goal (3): Portability
  - → Take advantage of unique beam production capabilities at each facility
- Design goal (4): Synergies with other projects
  - → SpecMAT ERC, PARIS and all potential users
  - → GANIL/LISE future plans



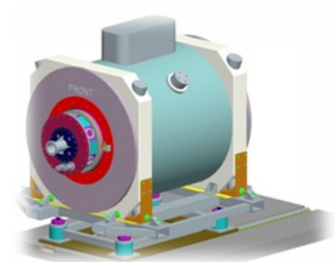
High-energy & Decay: LISE

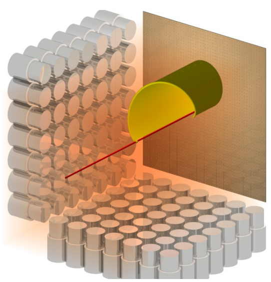


Low-energies: SPIRAL



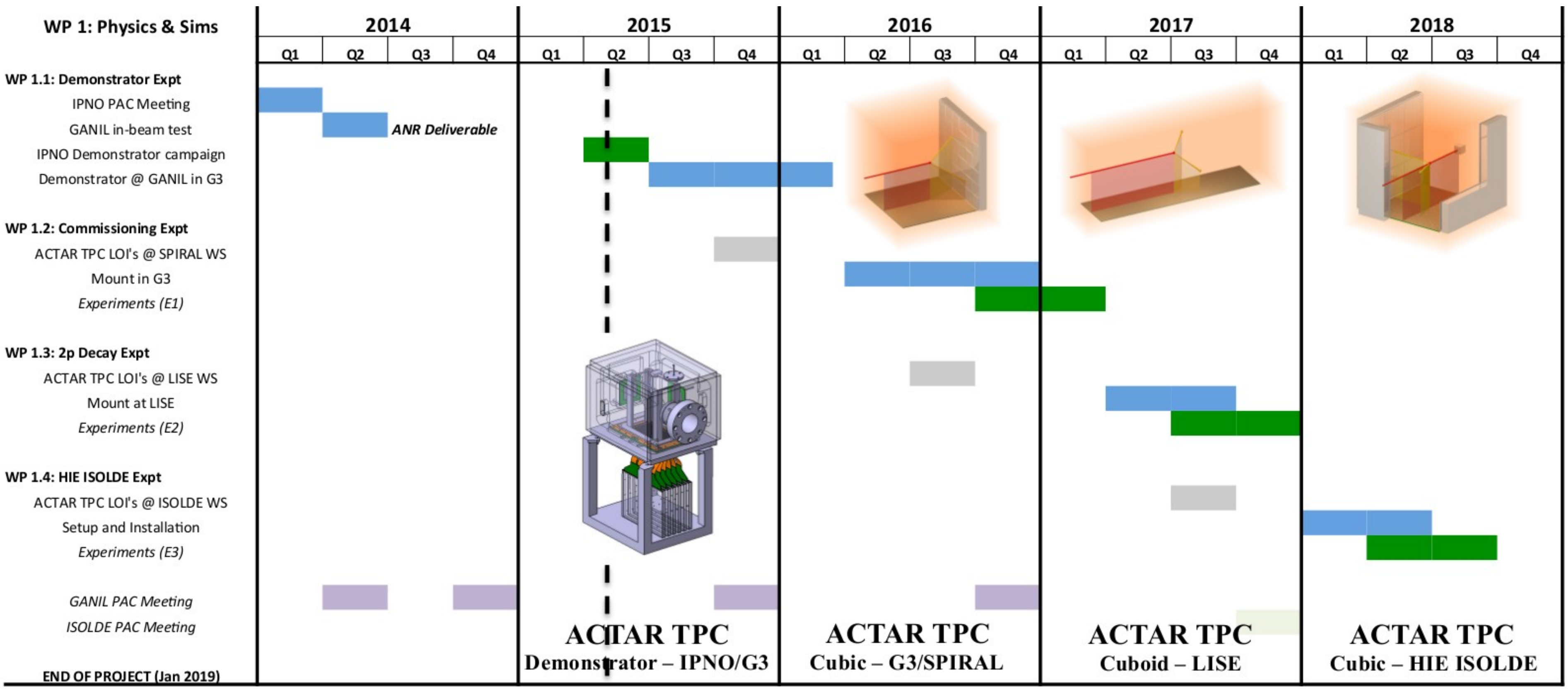
SpecMAT: $LaBr_3$ + B Field



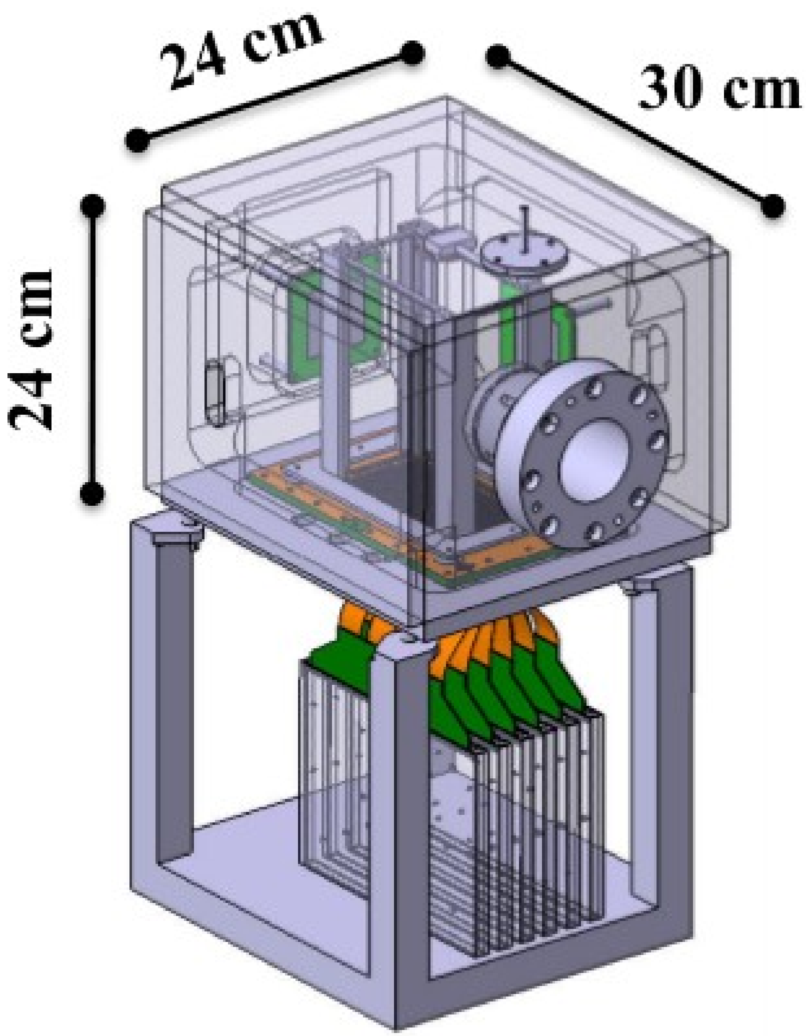


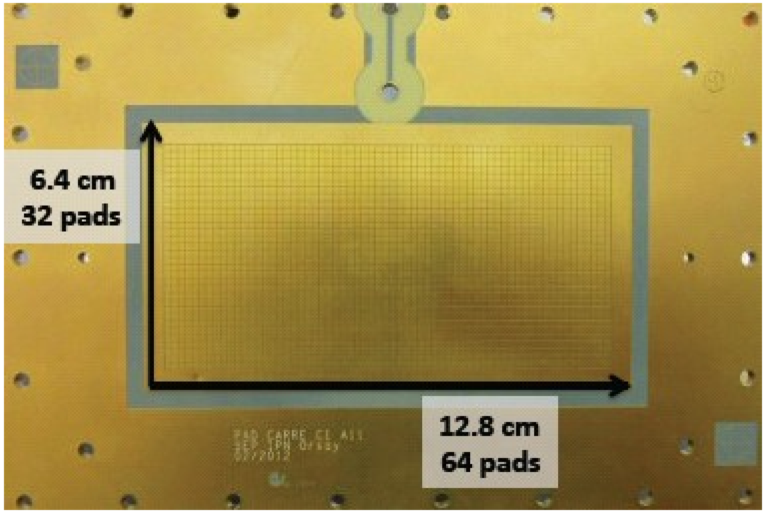
ACTAR TPC: ERC planning

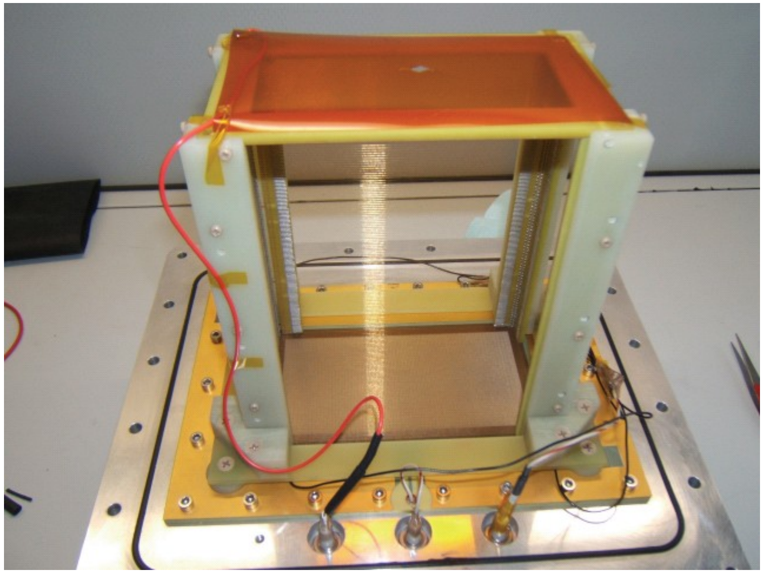
- ACTAR TPC ERC Project Planning
  - → Experiments at GANIL/G3 (2016/2017), GANIL/LISE (2017), HIE-ISOLDE (2018)
  - → Demonstrator experiments at IPNO (July 2015)



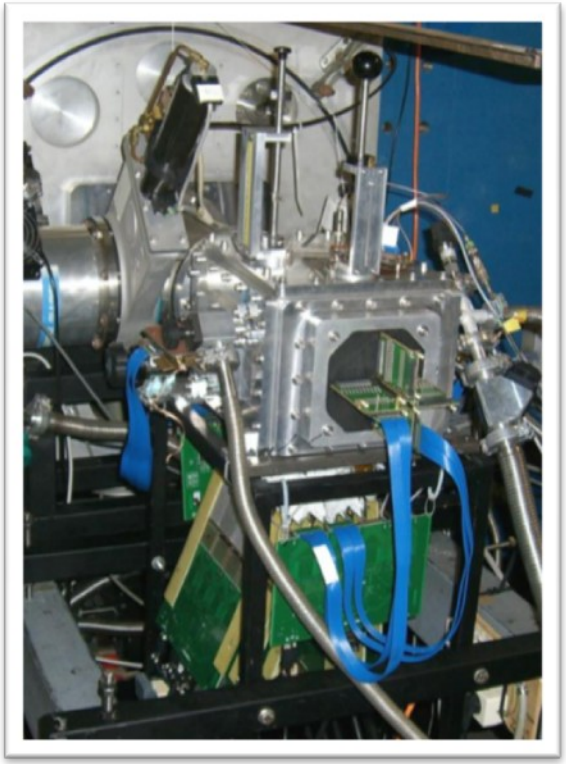
- 2048-channel pad plane

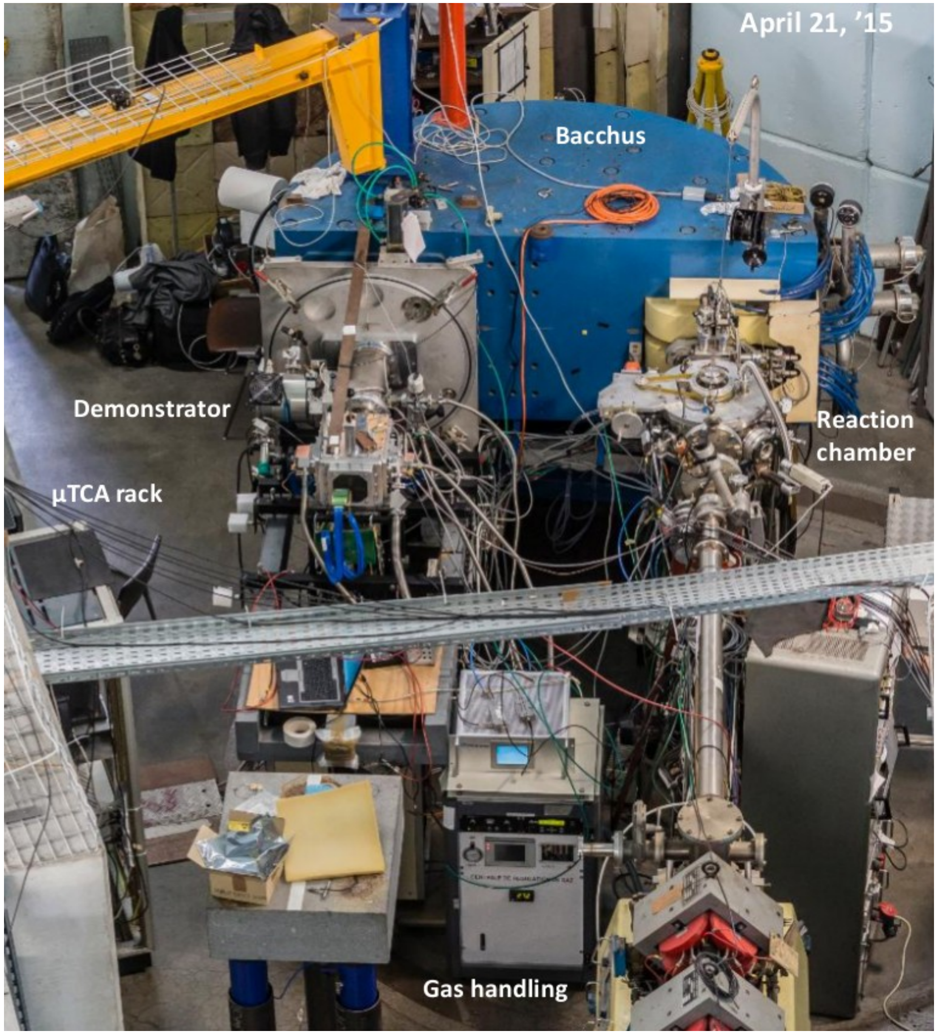




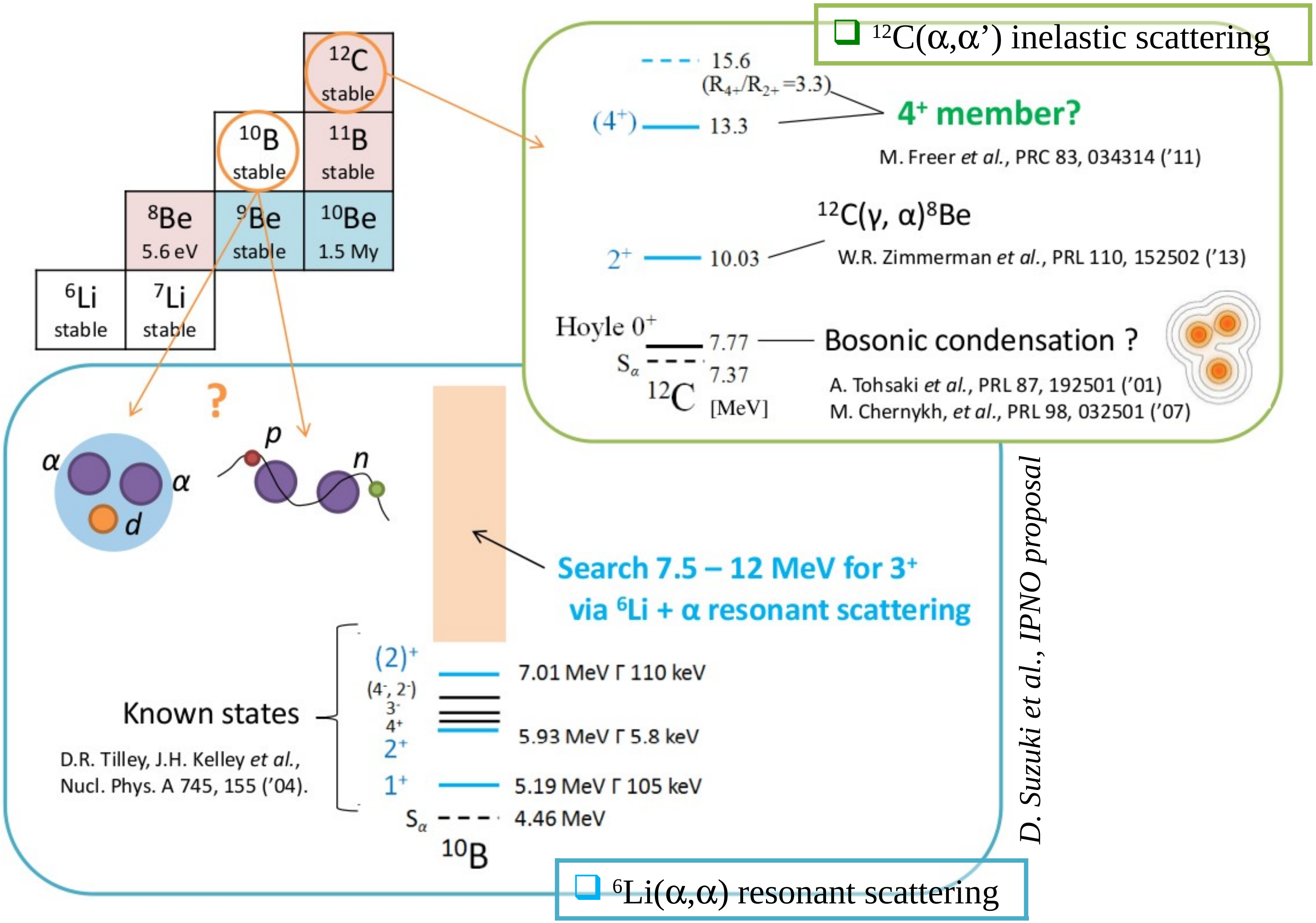


- 2048-channel pad plane
    - → Used at IPNO in July 2015 (BACCHUS beam line)

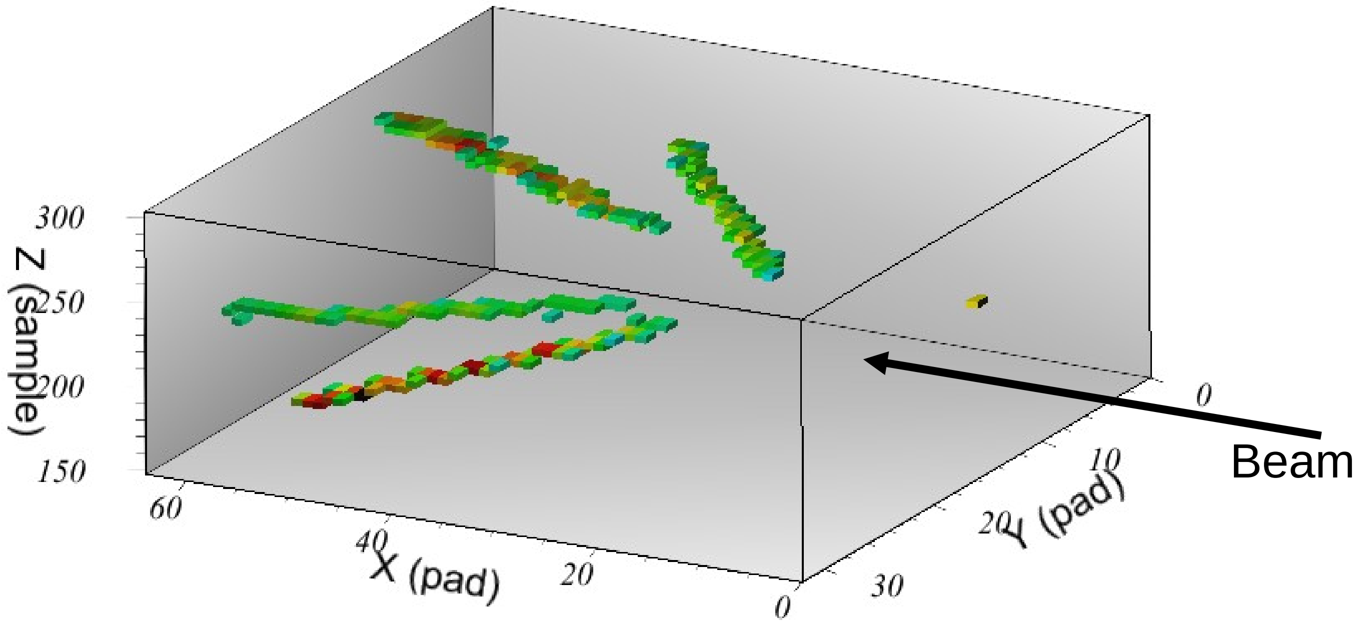


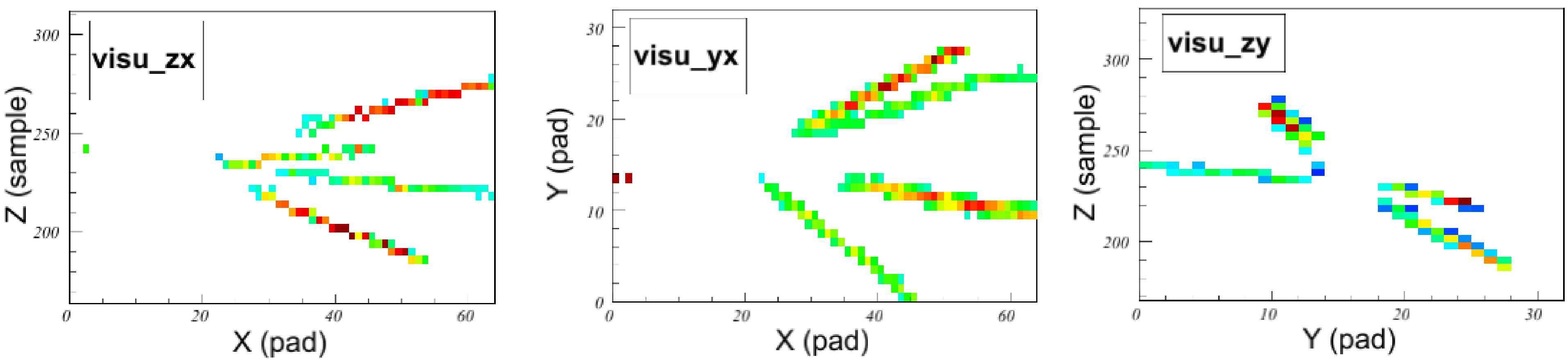


- Two experiments performed at IPNO: α-clustering in light nuclei



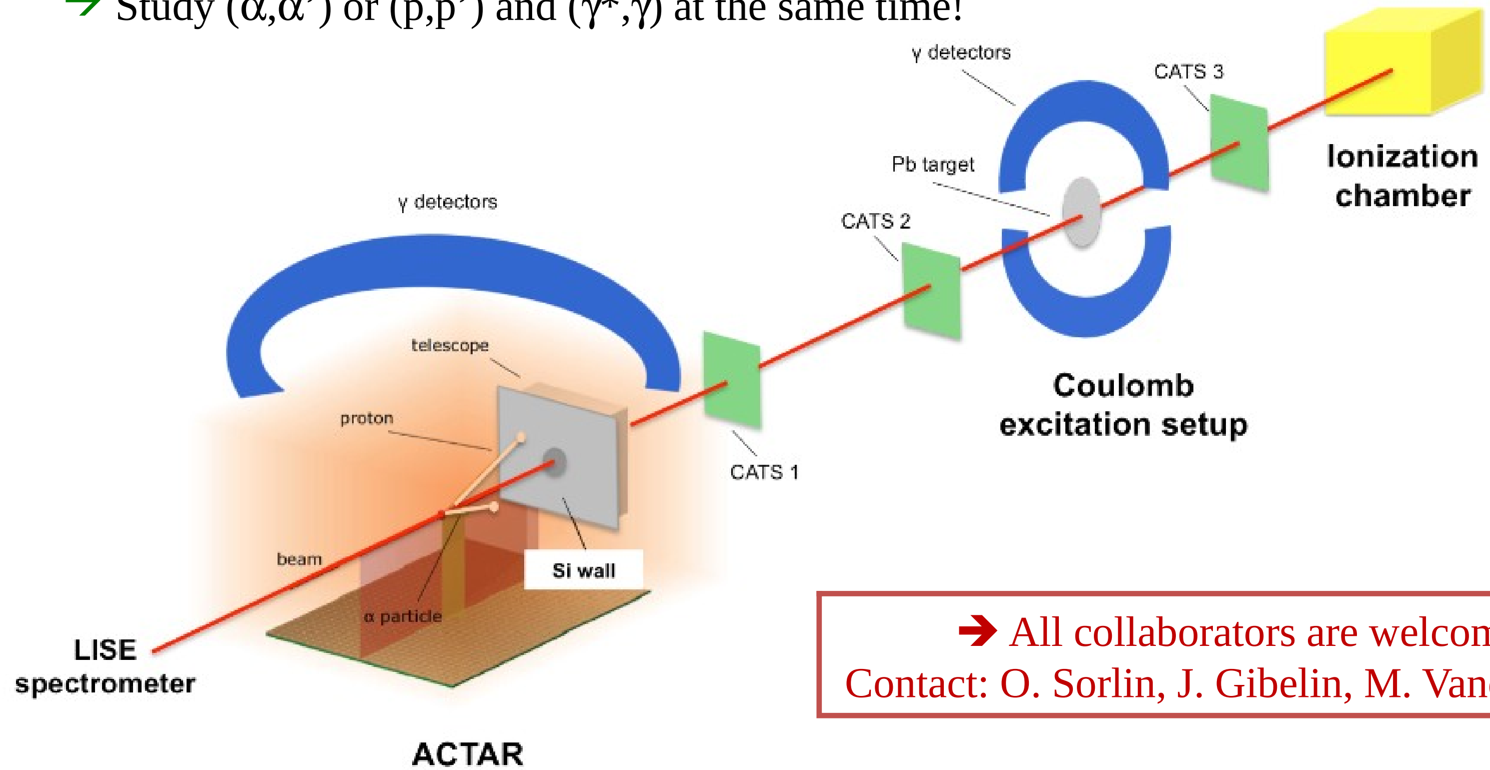
- Two experiments performed at IPNO: α-clustering in light nuclei





- Document on the exploitation of LISE in the horizon of 5 years currently written
  - → Working groups constituted: shell evolution, collective modes, nuclear astrophysics…
  - → Presentation at the next GANIL SAC in October

- Preliminary conclusions of the "collective modes" working group:
  - → Possibility to combine ACTAR TPC and "classic" solid target + Château de Cristal setup
  - → Study (α,α') or (p,p') and (γ*,γ) at the same time!



→ All collaborators are welcome!
Contact: O. Sorlin, J. Gibelin, M. Vandebrouck

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G.Fremont	F.Renzi	A.Maroni		B.Fernández
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T.Roger	G.Wittwer			
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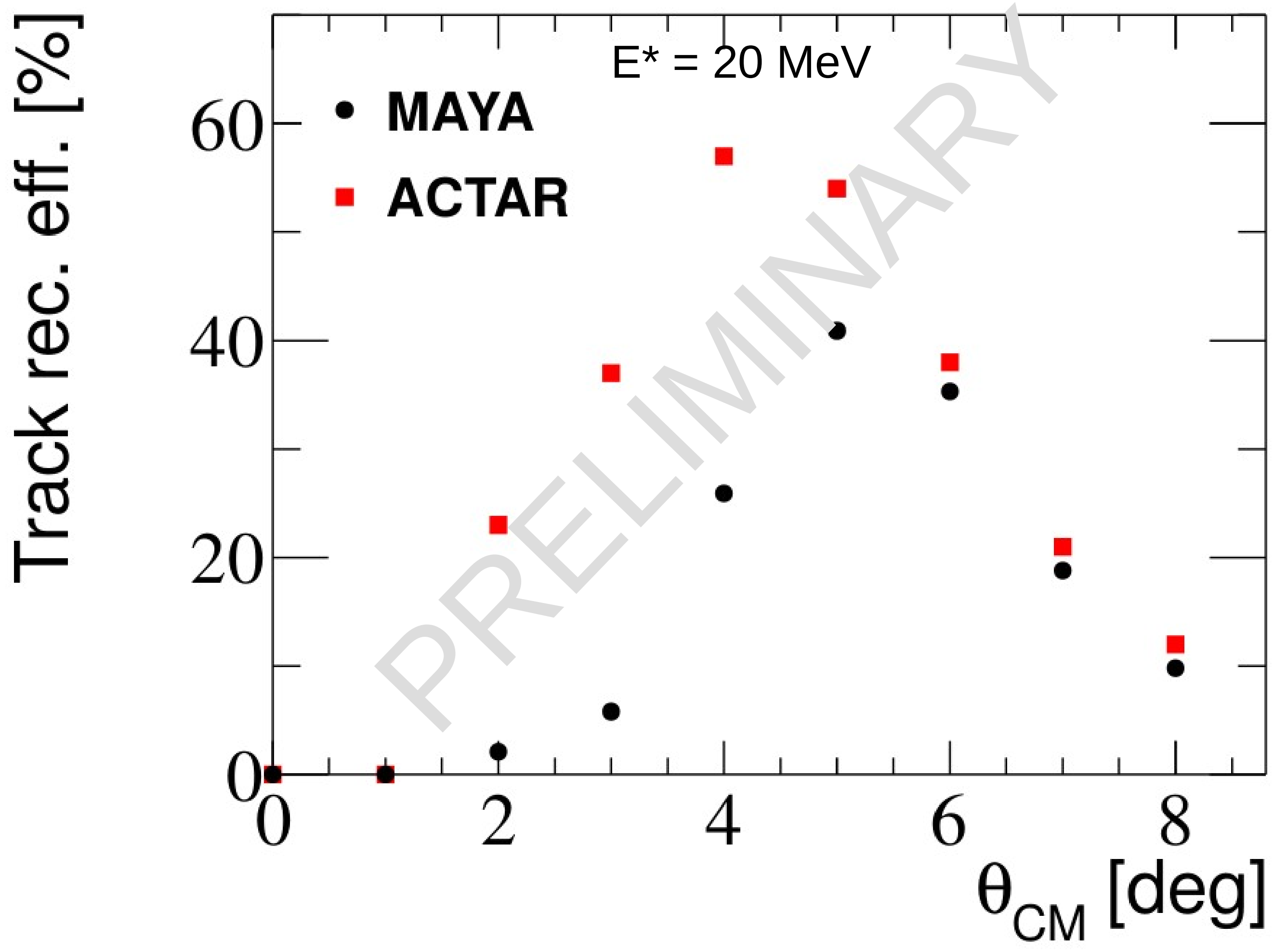
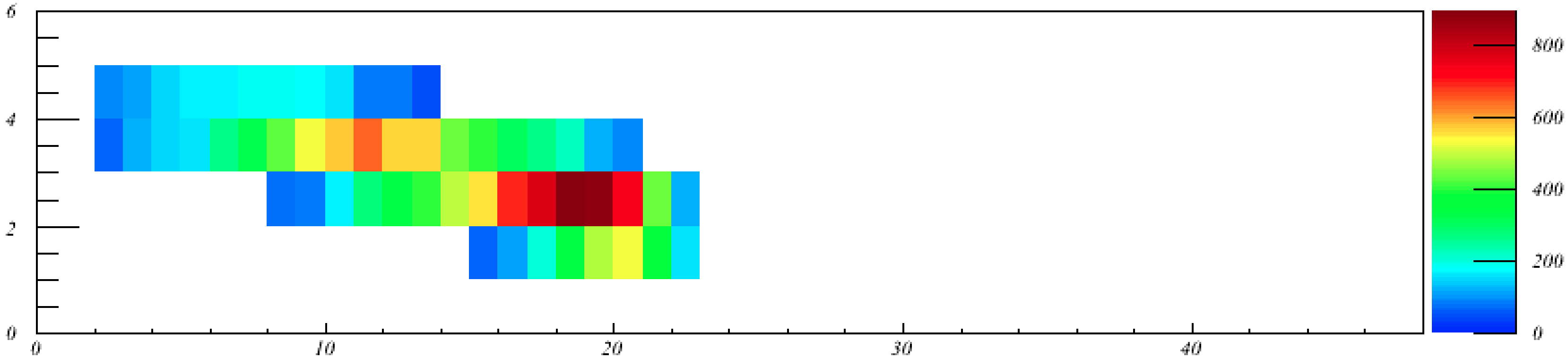
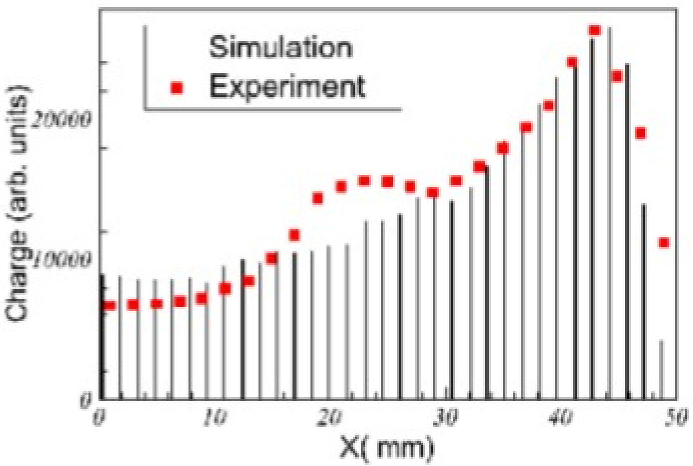
● Students ● Postdocs *Alumni

^{68}Ni(α,α') tracking efficiency comparison between MAYA & ACTAR TPC (**Courtesy M. Vandebrouck**)



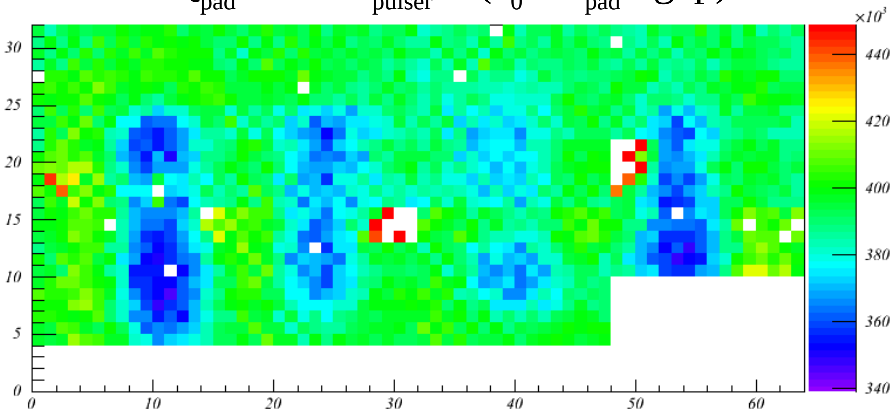
If the micromesh gap is not homogenous:





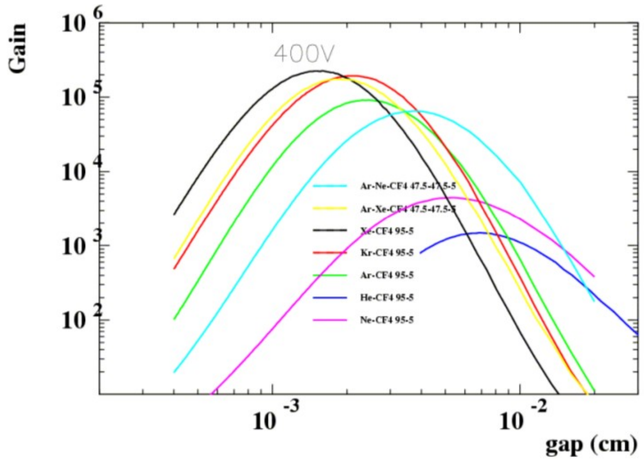
Step 1: inject a pulser on the mesh : get the gap

→ $Q_{pad} = C \times V_{pulser} = (\varepsilon_0 \times S_{pad} / gap) \times V$



Step 2: calculate a correction depending on the gas

→ Garfield simulations



Step 3: verify the correction (using cosmic rays)