an active target for radioactive beam physics

actar

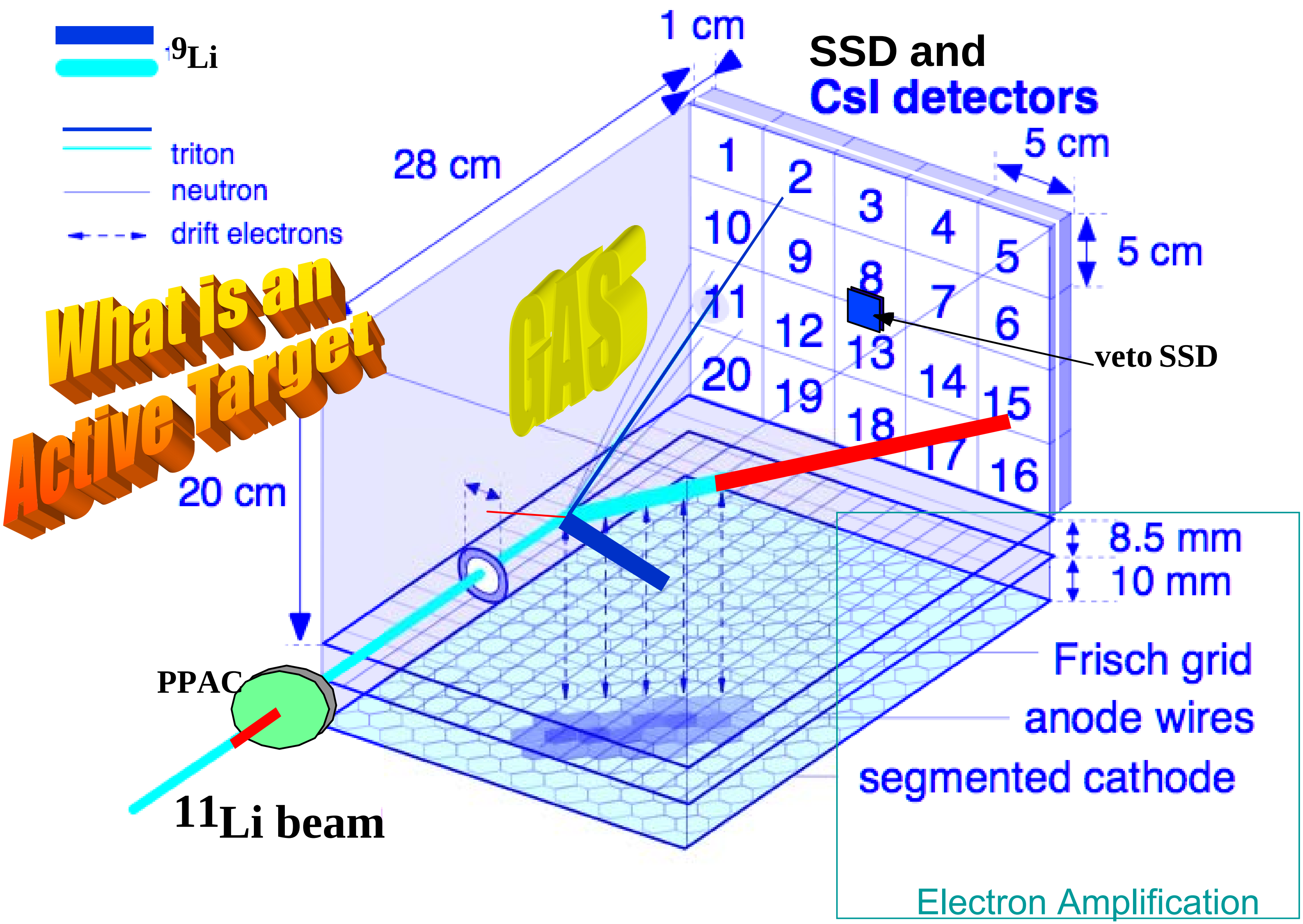
Emanuel POLLACCO IRFU/SPhN

Goal of talk:-

- To describe a current project for an **active target** ➔ target material is also that of the detector.
  - Status ➔ understanding & lack of it.

- To launch a possible interest in your participating in building an/the active target for ISOLDE and/or making use of ACTAR at ISOLDE.

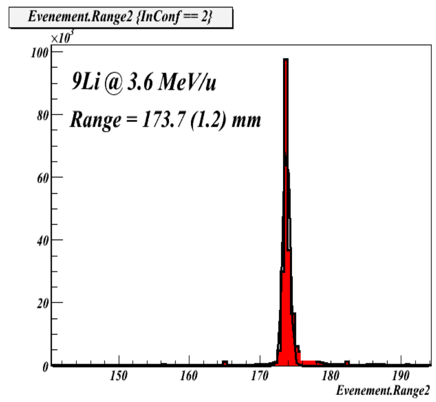
- Direct me as I go!

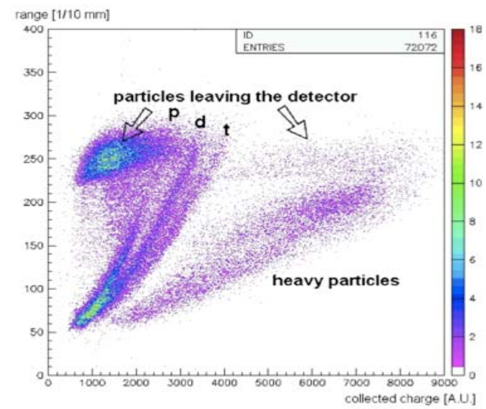


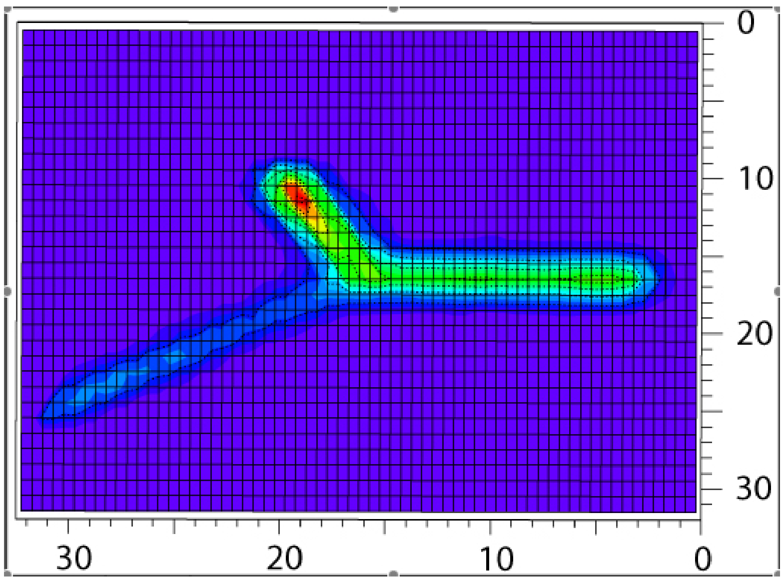
MAYA target-detector

For particle stopping inside MAYA, identification is given by the charge deposit and its Range :

Range ∝ E^2/MZ^2







- 'Target' ~ 10E21/cm²
- Energy resolution
  - Range resolution ≈ 1mm
  - ΔR/R ≈ 1mm/R (≈ 1% for Range = 100mm)
  - ΔE/E = 0.5*1/R (≈ 0.5% for Range = 100mm)
  - Need (3% for most lengths!)
- Charge resolution ~ 10 % (need 25%)
- Vertex resolution ~ 3 mm (need 0 mm)
- Angular resolution
  - Δθ ≈ Δx/R (0.6 deg for R=100m) (at all lengths)

Work to be done

Hervé Savajols & Thomas Roger – GANIL

Why an active target?

- Measure {dσ(Z,A,E)/dΩ} at low ejectile energies (Low Thresholds)
- High & Pure Luminosity (BeamXTarget)
  $\sim 10^{5+21}$ $cm^{-2}.sec^{-1}$ ➔ $\sigma \sim$ 10-100μb
- Wide angular cover (4π ➔π)
- Versatility in the experimental method.
- Active Target is not an all-round soln.
  – Limited cover (B=0 Solenoid)
- ACTAR – attempting a versatile soln.

Participants of the ACTAR R&D & Schedule & Budget

- **FP6 program – 2005→2008 - ACTAR**
  - Physics
  - Detector Physics & Electro-Mechanics
  - Simulation
  - FEE & DAQ
  - Analysis of Active-Target data (MAYA)

Work to be done

GANIL / IRFU / CENBG
CCLRC DARESBURY
U. LIVERPOOL/ GSI
U. SANTIAGO DE COMPOSTELA
INP CRACOW

- **ACTAR and the FEE & DAQ – program GET**
  - Participants under:- Multi-lab - Multi-Project

GANIL / IRFU / CENBG
MSU/RIKEN

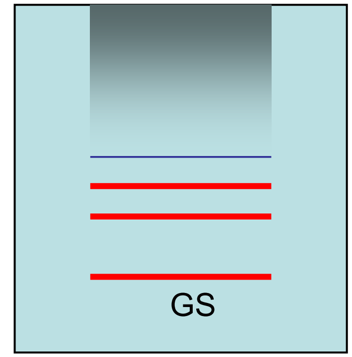
  - **A 4 year exercise: T0=Sept 2008**
    - Phase I -Two year R&D for the geometry, gas-amplification and FEE & DAQ with tests of pro-types/demonstrators
    - Phase II - Two year construction
  - **Budget**
    - 30-35€/channel- System of 15kchannels (0.5M€). R&D and instrument included except Auxiliary Detectors. Material Cost/channel~11€
  - **MoU**
    - By Mid 2009 (10March 2009)
    - **To include other labs**

ACTAR are not alone to build a TPC for Nucl. Phys.

- MSU (US) – Direct reaction & Astro & EoS
  - *AT-TPC*
- CENBG (FR) – (GANIL/SPIRAL2, RIKEN)) – 2p & 3p decay
  - *2p-TPC*
- FSU – LSU (US) – (FSU & MSU) - (α,p), (p,p’),(d,p)… Astro
  - *ANASEN*
- York University - (Triumf) - (α,p), (p,p’)… Astro
  - *TACTIC*
- LBL (US)– Fission
  - *FISSION-TPC*
- Saclay – (GSI/NUSTAR) (FR) - Spallation
  - *R3B-TPC*
- Kyoto – (RIKEN) Japan - EoS
  - *SAMURAI-TPC*

Physics Program addressed:-

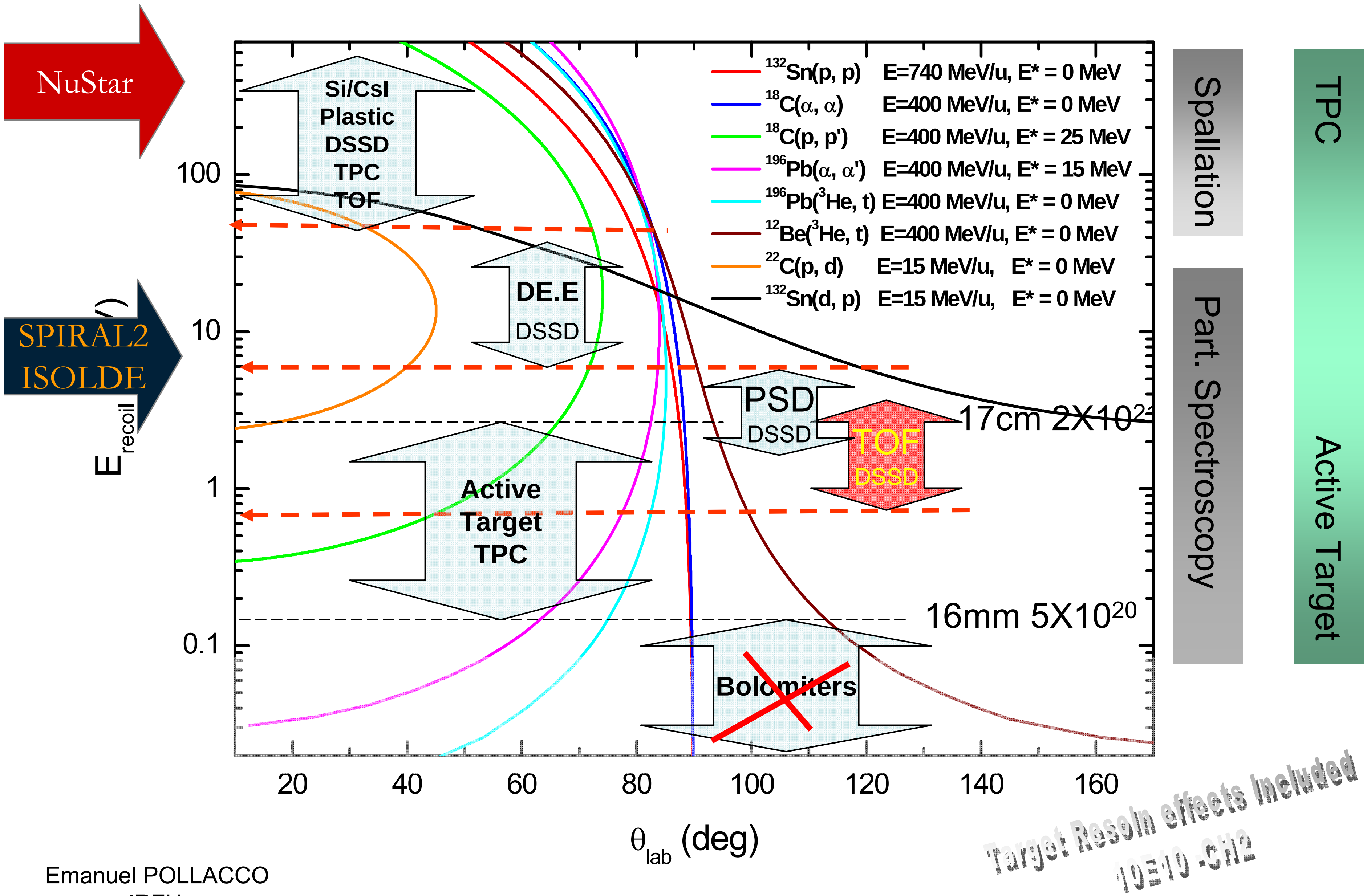
- Direct reaction program – **Active Target**
  - Inverse Kinematics 10MeV>E_B > 5MeV.A
  - n ➔ (d,p), p➔(^{3}He,d), (α,t) (S,J^π,Ex)
  - d ➔ (d,α) (np pairing)
  - Inel➔ (p,p'), (α,α'), (d,d'), (EoS, β,J^π,Ex)
  - Charge Exchange ➔(d,2p)
  - **Low energy quasi-target recoil: Z, A, E_x, θ**



- Resonant scattering – **Active Target**
  - Inverse Kinematics E_B < 5MeV.A
  - (p,p) Elastic & Inelastic Resonant Scattering
  - (α,p) Inelastic resonant Scattering
  - **Quasi-target recoil & beam-like Z, A, E_x, θ High rates**
- Radio Activity – **Active stopping volume**
  - p, 2p, 3p … decay or more exotic decay
  - **High dynamic range low sequential events dead-time**
- Induced Fission – **Active stopping volume**
  - A(n,f) Fission fragments X-sections
  - **Very high rates**

- Shell evolution far from stability
- Giant resonances
- Matter density distribution
- Cluster structures
- Isobaric analogue states
- Nuclear astrophysics

Methods to cover an energy dynamic range & yield



Emanuel POLLACCO
IRFU

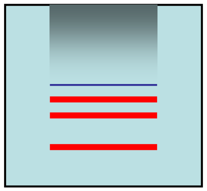
Target Contribution to Engy Resol^{n}.

- **Ex. Energy resolution required**
  - 200keV is OK
  - **100keV is the best**
  - 50kev is a dream

- **Solid Target**
  - dE/dx for p in C_3H_6 (1.2mg/cm²) for **10^{20} H_2**
    - p=0.75MeV; ΔE = 620keV
    - **p=1.00MeV; ΔE = 410keV**
    - p=2.00MeV; ΔE = 230keV
  - Resolution ΔE+ (Det + Elect) + Kinematics
  - Det ~ 50 keV (5% at 1MeV)

- **Gas Target** (depth 30cm with 20cm active: H_2 **10^{21})**
  - Position resolution for the vertex 3mm
    - p=0.75MeV; ΔE = 25keV
    - **p=1.00MeV; ΔE = 15keV**
    - p=2.00MeV; ΔE = 10keV
  - Resolution ΔE+ (Det + Elect) + Kinematics + Analysis
  - DET ΔE/E ~ 0.5% if range is **100mm**
  - **Micromegas resol^{n} 1.5-2% for a single pad in P10 … to explore.**

R&D needed to establish Working values as a fn of energy, … - A POTENTIAL=PHYSICS?



Target Contribution to Angular Resol.

- **Resolution required**
  - **For the physics 2.0° is OK**
  - **0.5° is V.good**
  - For energy correction Kinematics $dE/d\theta$

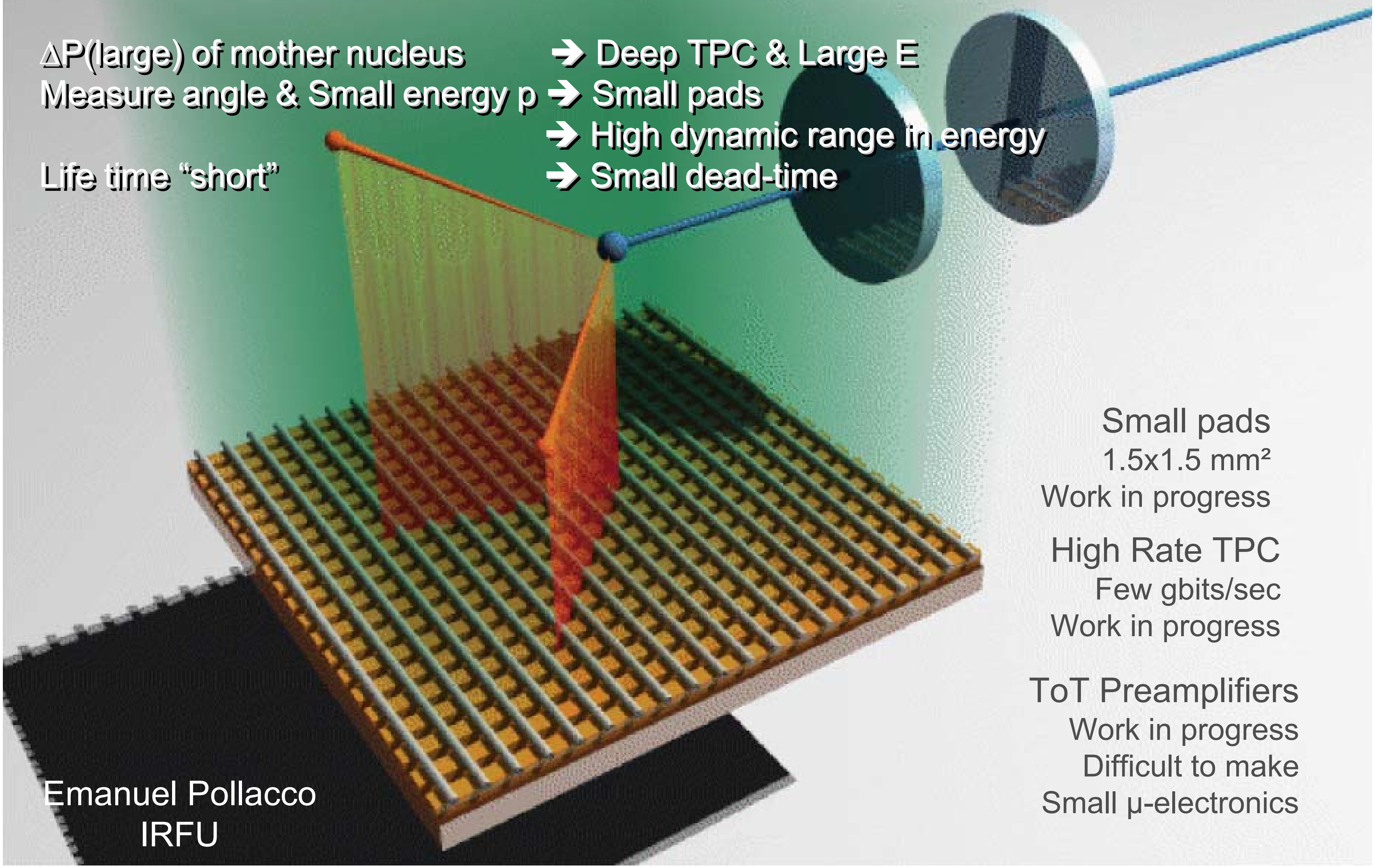
    $\Delta\theta = 1$ is poor to OK

    $\Delta\theta = 0.3°$ is V. good

- **Solid Target**
  - dE/dx for p in C_3H_6 (1.2mg/cm²) for 10^{20} H_2
    - p=0.75MeV; $\Delta\theta = 5°$
    - **p=1.00MeV; $\Delta\theta = 4°$**
    - p=2.00MeV; $\Delta\theta = 2°$
  - Resolution $\Delta\theta$ + Det (0.3°)
- **Gas Target**
  - Position resolution for the vertex 3mm Target $10^{E}21$ H_2
    - p=0.75MeV; $\Delta\theta = 0.6°$
    - **p=1.00MeV; $\Delta\theta = 0.5°$**
    - p=2.00MeV; $\Delta\theta = 0.2°$
  - Resolution $\Delta\theta$+ Det + Elect + Analysis
    - Det resoln 50 mm ➔ 0.7° ➔ **vertex+det < 1°**

CENBG 2-p decay TPC

ΔP(large) of mother nucleus ➔ Deep TPC & Large E
Measure angle & Small energy p ➔ Small pads
➔ High dynamic range in energy
Life time “short” ➔ Small dead-time



Small pads
1.5x1.5 mm²
Work in progress

High Rate TPC
Few gbits/sec
Work in progress

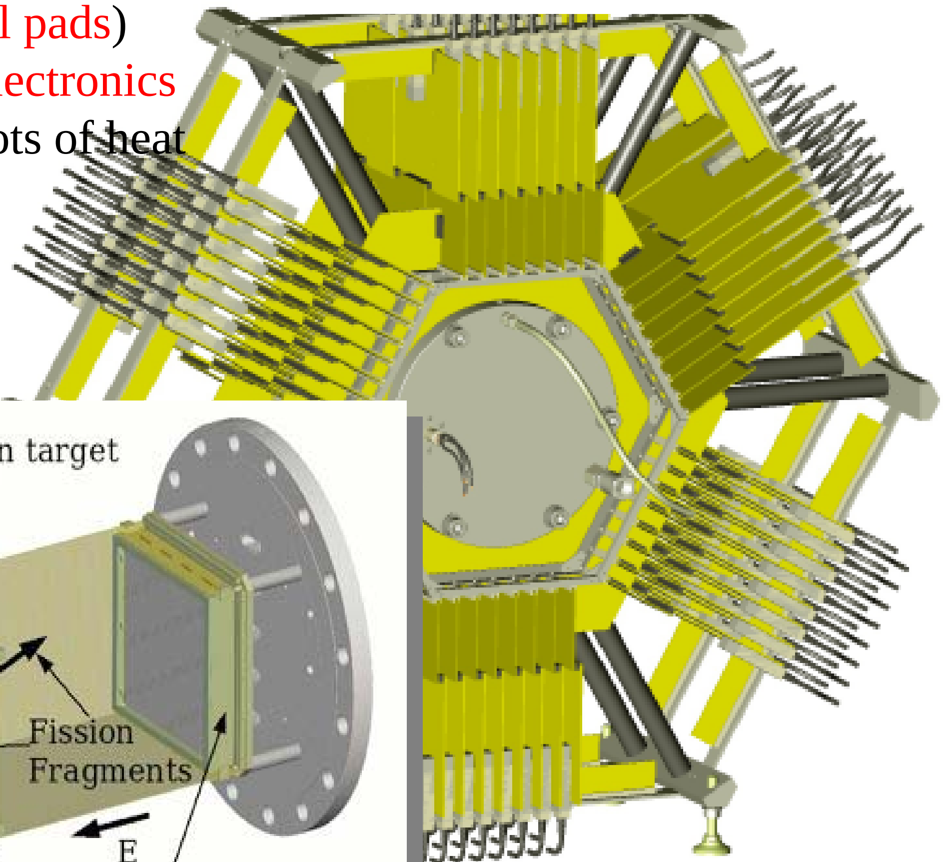
ToT Preamplifiers
Work in progress
Difficult to make
Small μ-electronics

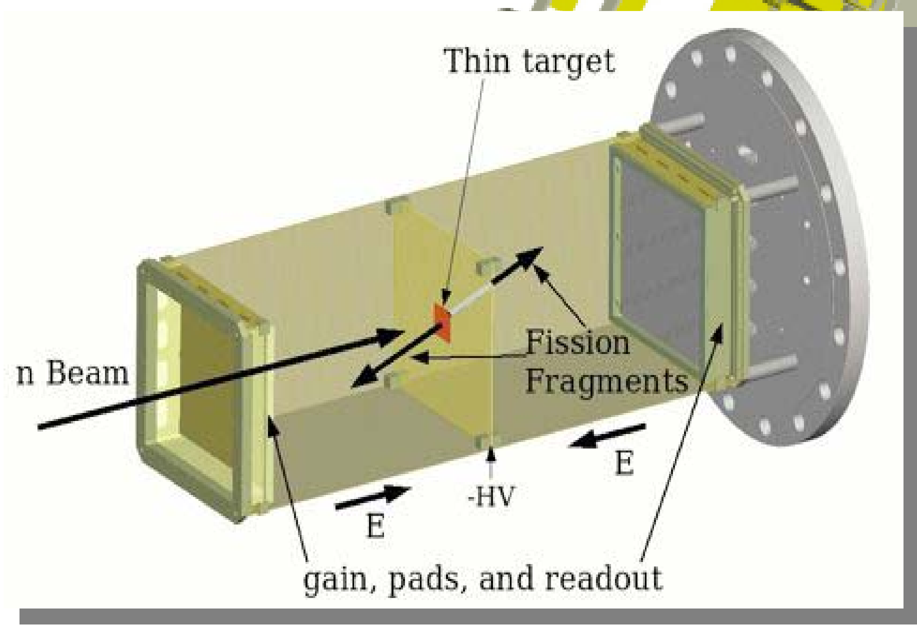
Emanuel Pollacco
IRFU

The Fission TPC – Electronics Mounting

Study of Fission x-sections

- Eg ^{239}Pu(n,f)
- 3K Channels (small pads)
- High throughput Electronics
- Radiation Hard – lots of heat





Small pad size

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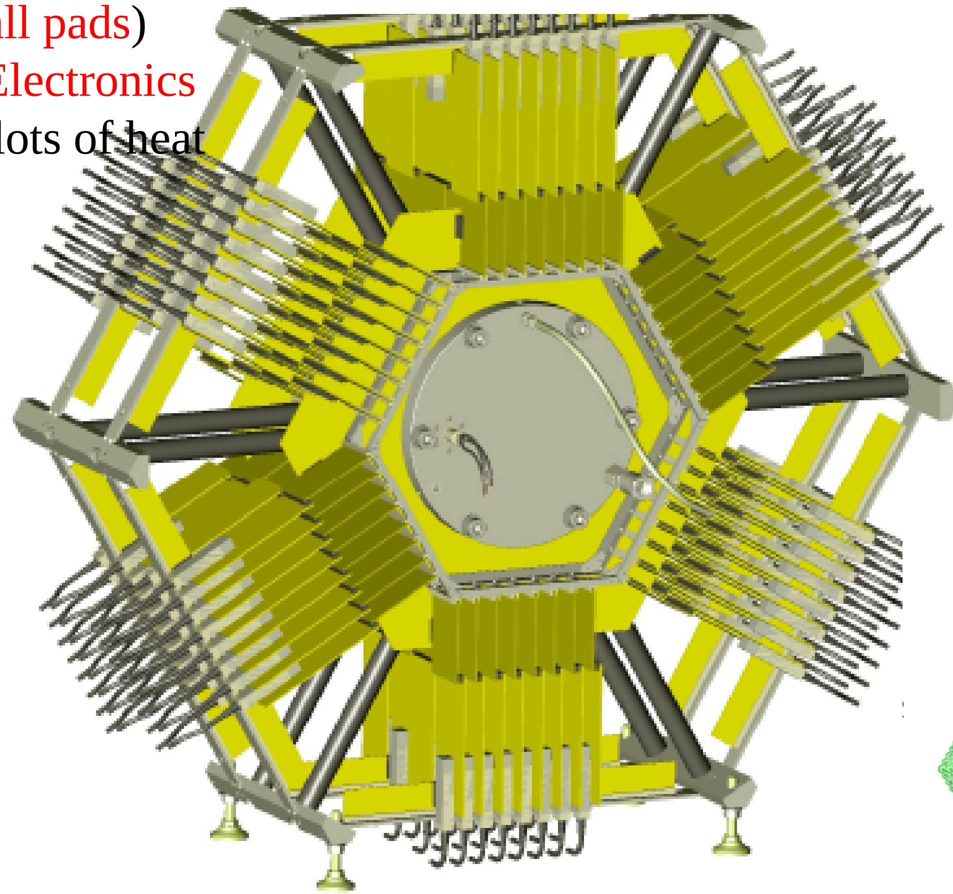
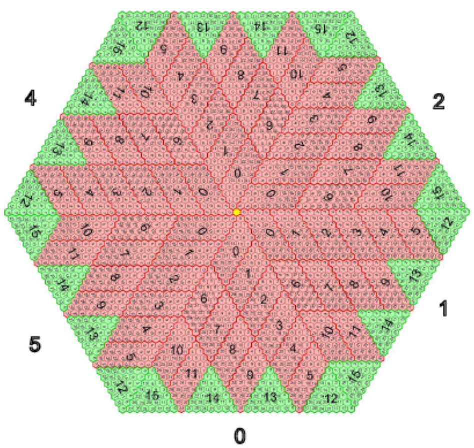
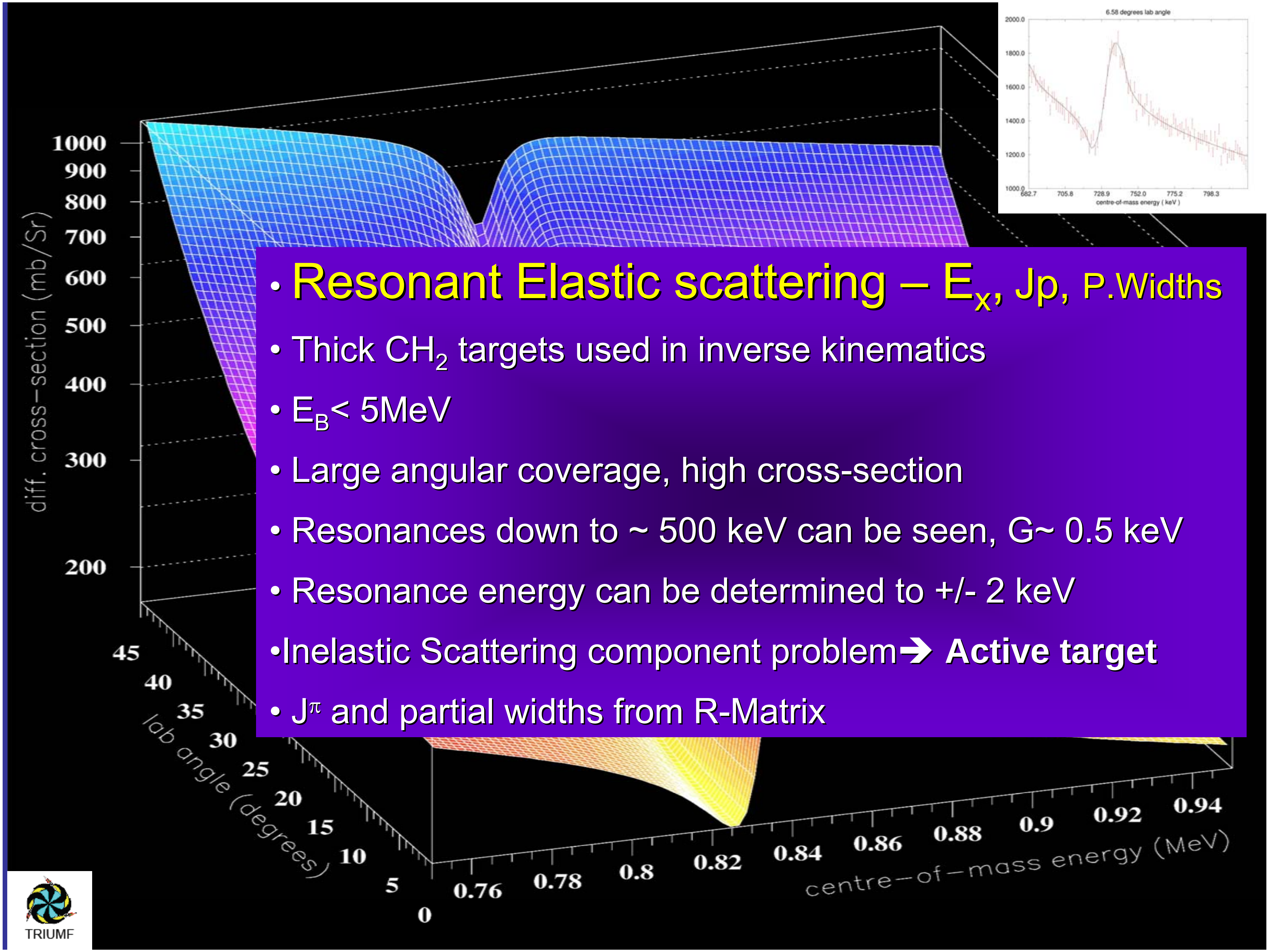


Small pad size

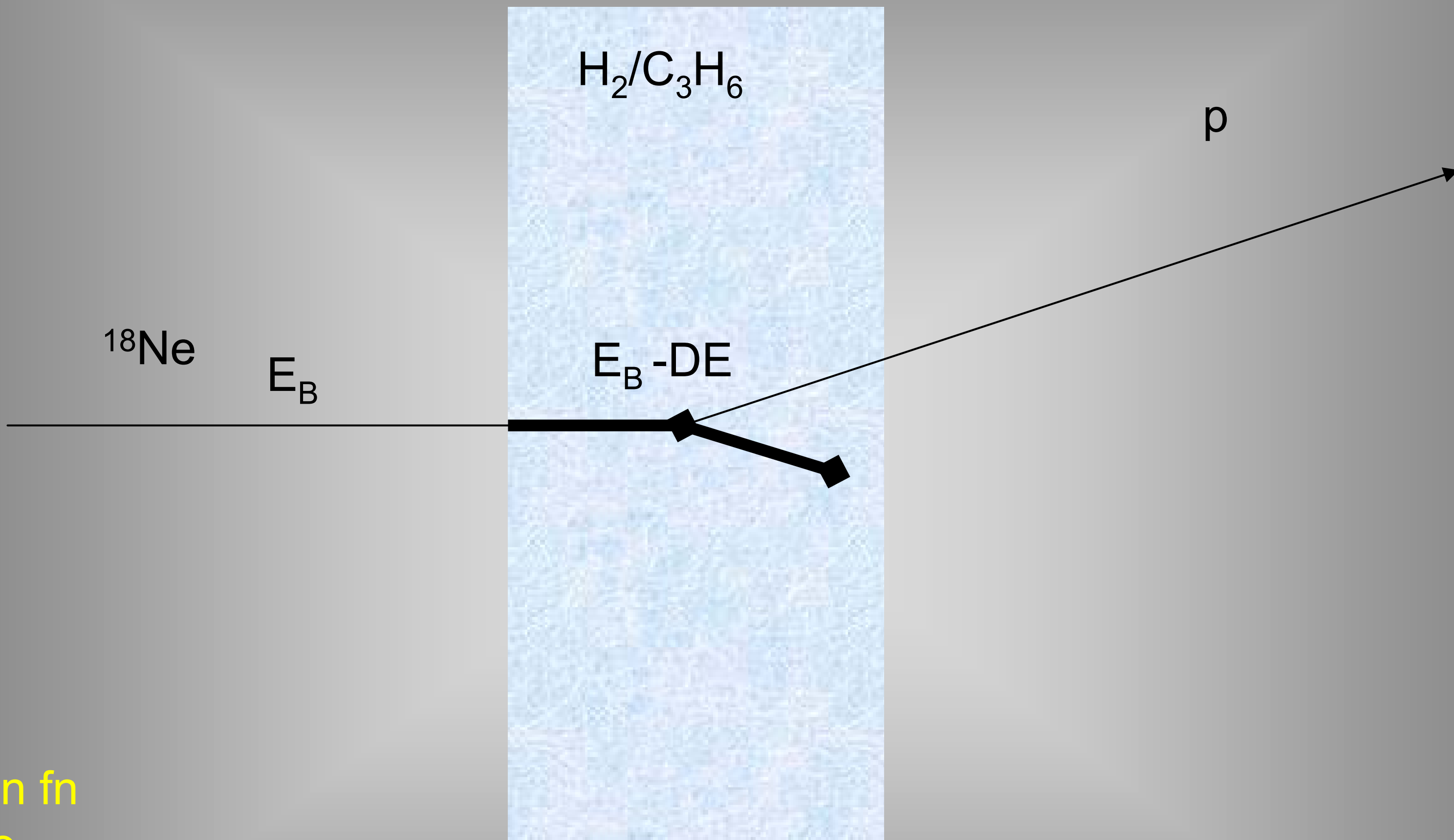




• Resonant Elastic scattering – E_x, Jp, P.Widths

- Thick CH_2 targets used in inverse kinematics
- E_B< 5MeV
- Large angular coverage, high cross-section
- Resonances down to ~ 500 keV can be seen, G~ 0.5 keV
- Resonance energy can be determined to +/- 2 keV
- Inelastic Scattering component problem➔ **Active target**
- J^π and partial widths from R-Matrix

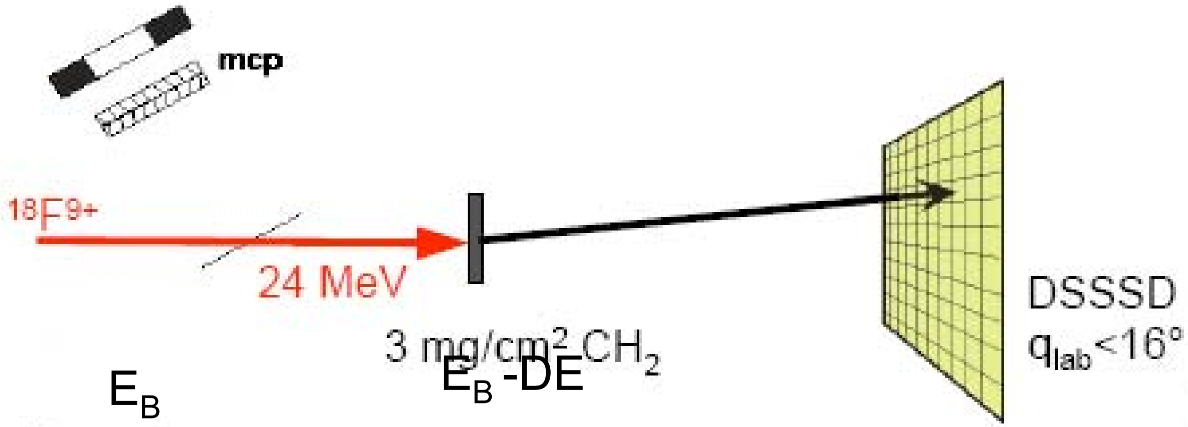
TRIUMF



Excitation fn
in one go
if no inelastic

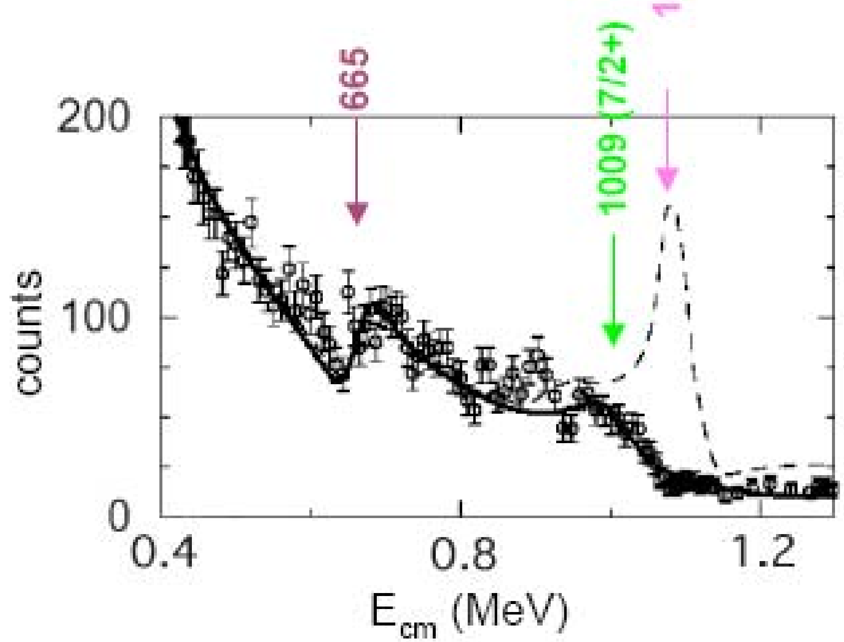
Proton elastic scattering II

D.W. Bardayan et al., Phys. Rev.C 70 (2004).



- Very thick target
- Highly pure beam required
- Large energy range simultaneously measured
- E_p+angle → E_{cm} for event
- Angle is well determined
- Backgrounds are an issue (reactions on carbon), especially with heavier beams
- Pure H_2 target would increase yields ~ 3x & less background

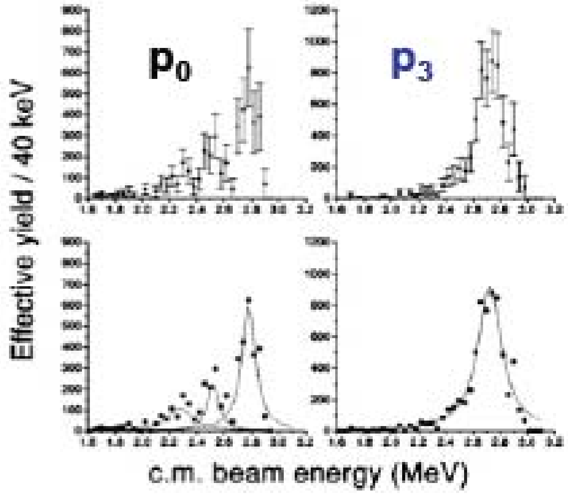
Excitation fn
in one go
if no inelastic

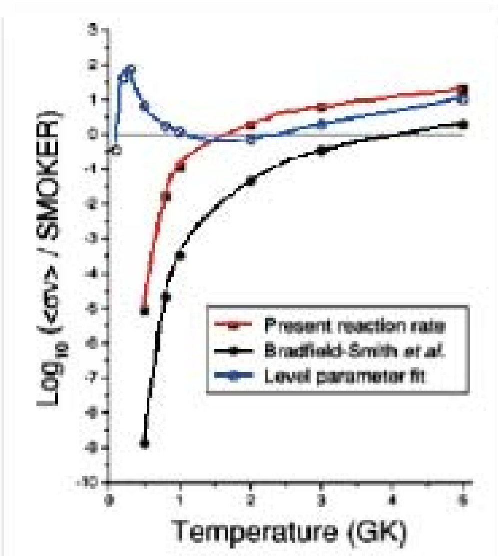


Jeff Blackmon, LSU

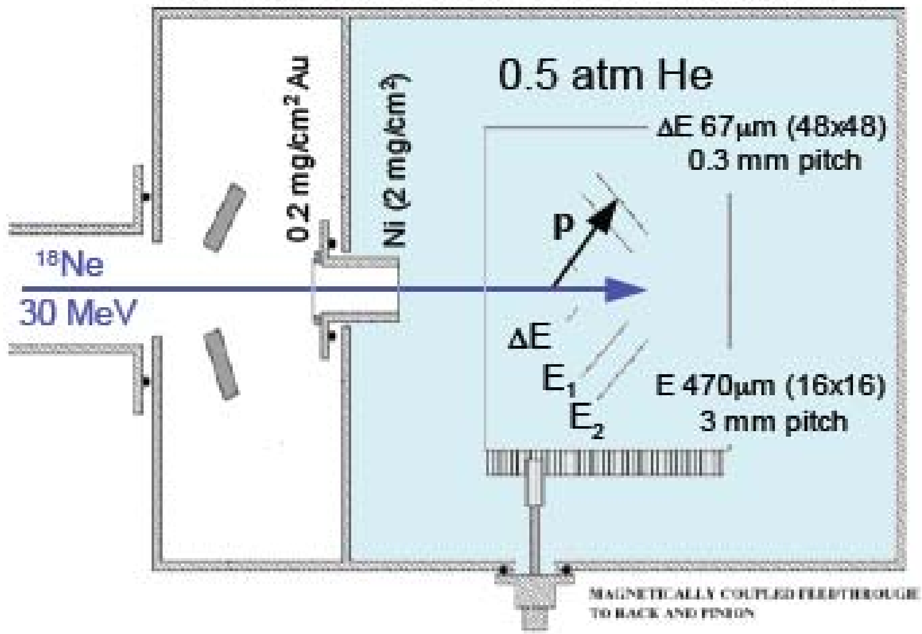
http://www.cyc.ucl.ac.be/

$^{18}Ne(\alpha,p)^{21}Na$ at CRC at Louvain-le-Neuve





D. Goombridge *et al.*, PRC **66** (2002) 055802.



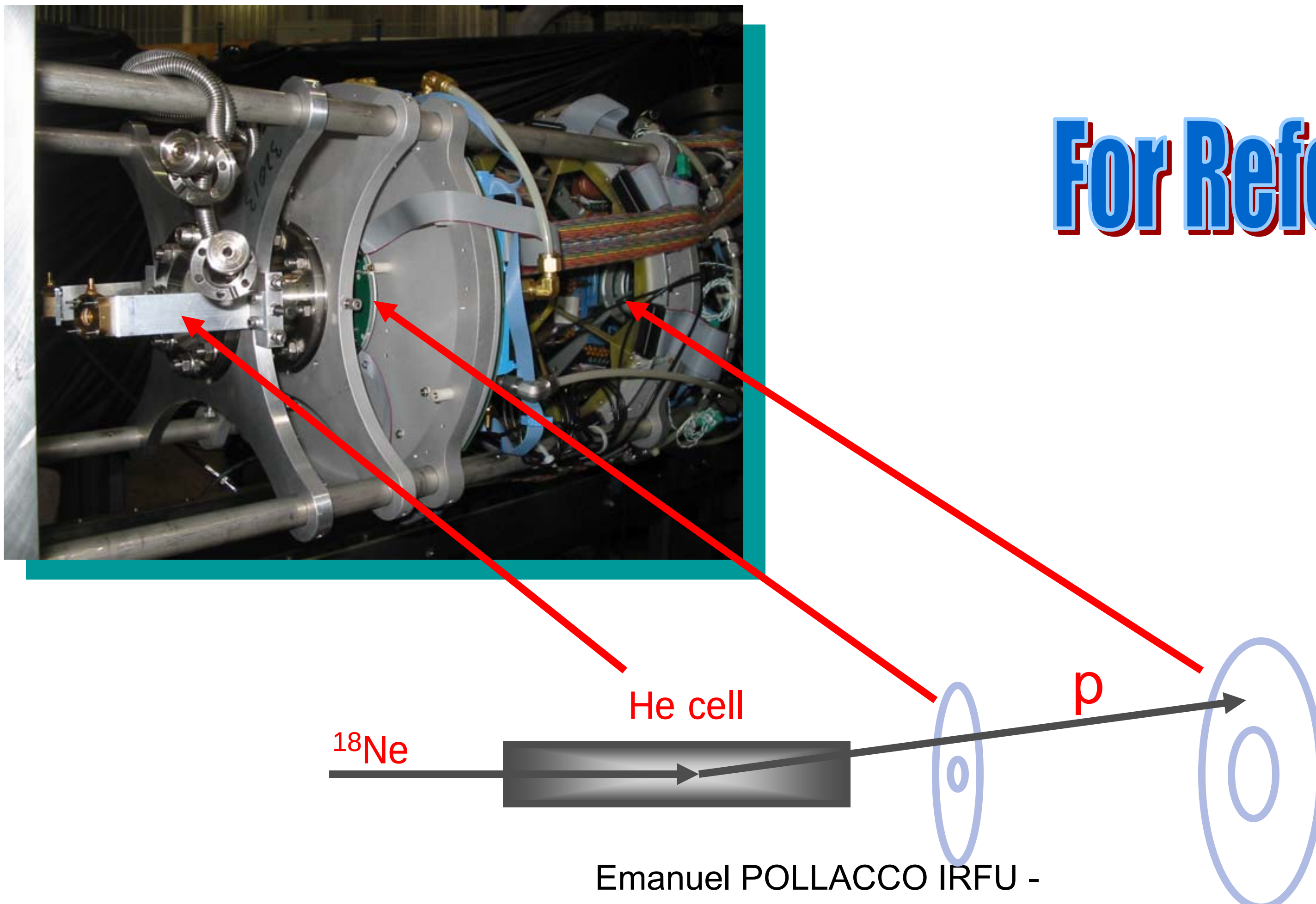
- Proton angle is determined by tracking through 2 layers of ***silicon-strip detectors***
- Resulting energy resolution not as good as one would like
- Need measurements to lower E_{cm}
- Statistical rates not accurate enough

Jeff Blackmon, LSU

TRIUMF

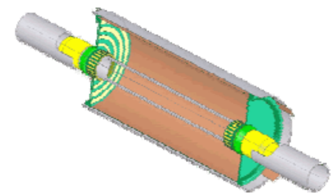
e.g. $^{18}Ne(\alpha,p)^{21}Na)$

For Reference



TRIUMF

THE UNIVERSITY *of York*



(α,p) with an active target

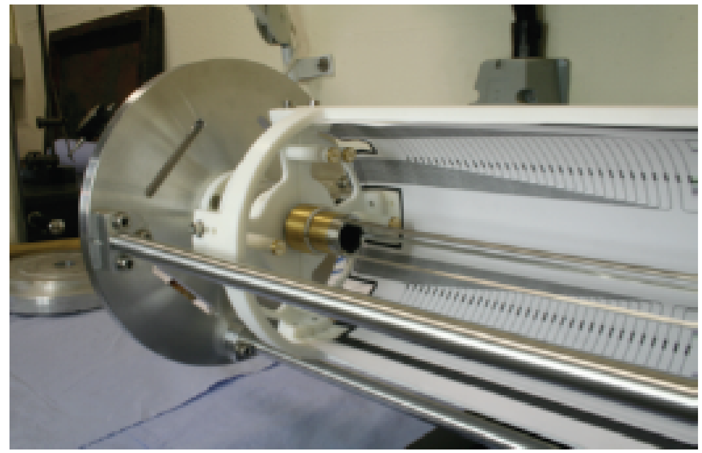
TACTIC

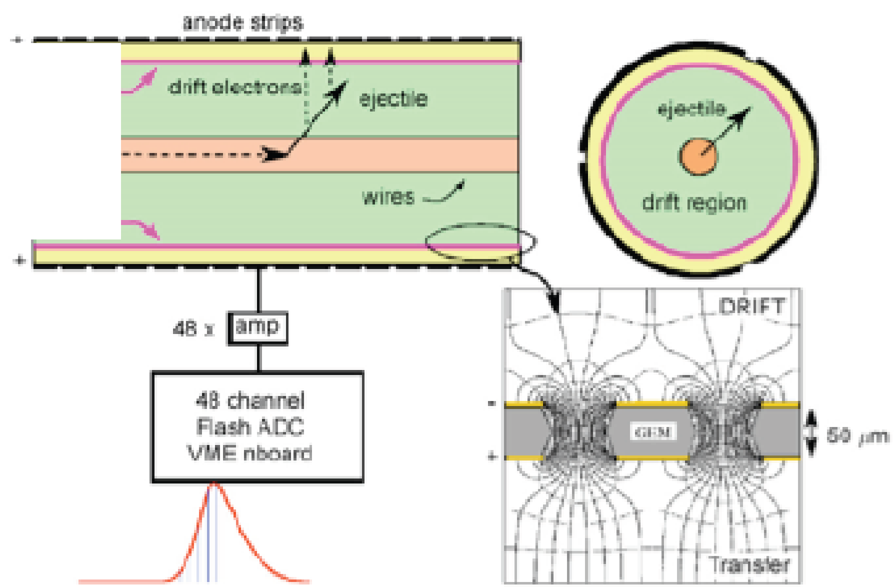
A. M. Laird, NIM A 573 (2007) 306.

- TPC-like device
- Cross sections are small
- Need >> 10^5 pps
- Region around beam is isolated from detector elements allowing high incident beam intensities
- Track of ejected particles is reconstructed from segmented anodes fed into flash ADCs

Radial Field
Beam in 'Faraday-Cup'

For reference

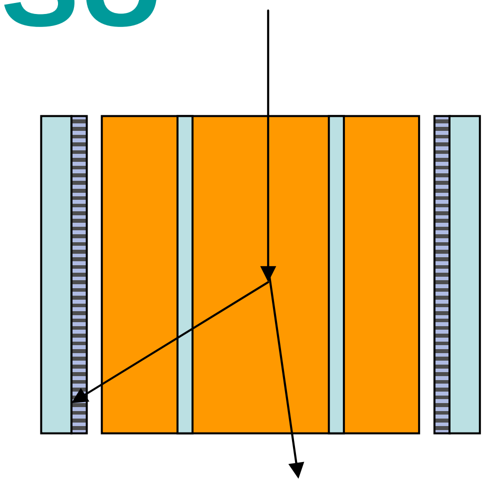


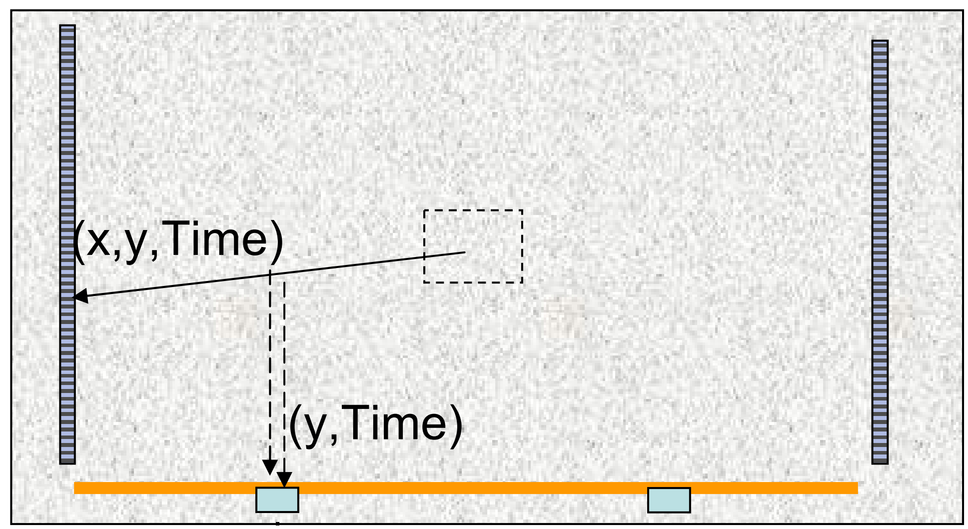


Jeff Blackmon, LSU

ANASEN –FSU & LSU

- Blackmon et al. LSU
- (p,p), (p,p’), (a,p), (d,p) …
- Active target (Extended drift-chamber)
- DSSD + CsI array 48 – 500 channels
- Beam FSU & MSU (re accelerated beams)
  - windowless
  - Beam Tracking MCP



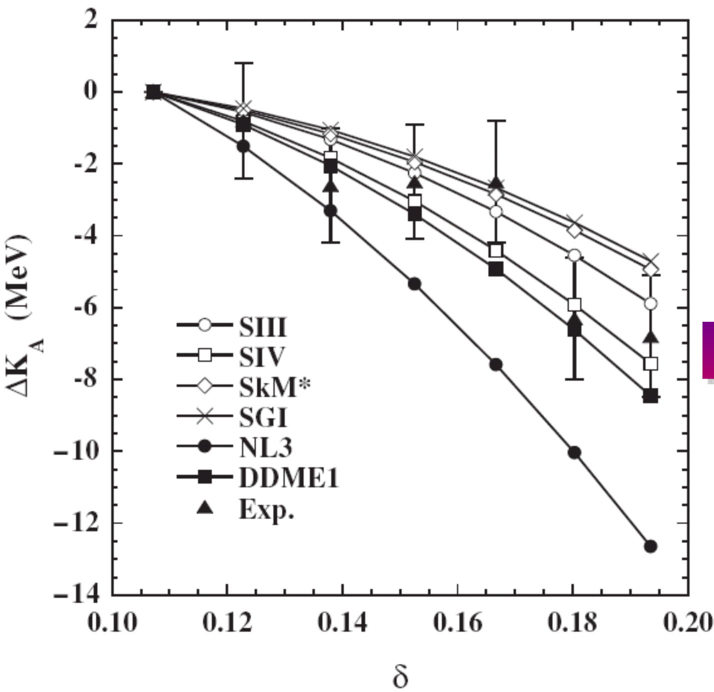


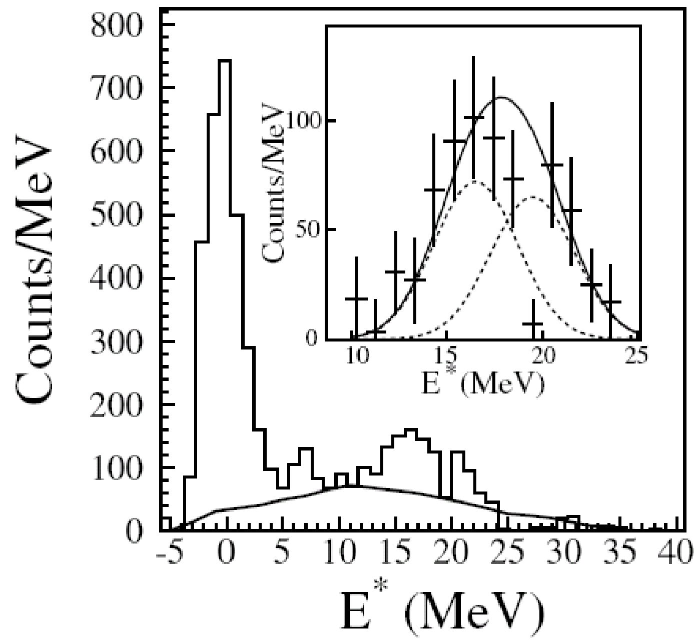
For reference

Physics cases for active targets

Isospin dependence of the EOS: GMR

$$K^A = K^\infty + K^{surf} A^{-1/3} + K^{coul} A^2/Z^{4/3} + K^{sym} ((N-Z)/A)^2$$

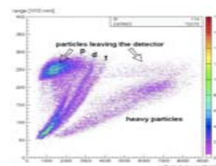


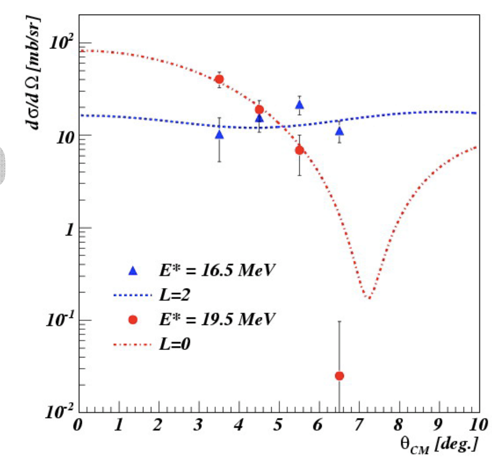


Mass Resoln at

low d or alpha energies?

Cylindrical Geometry



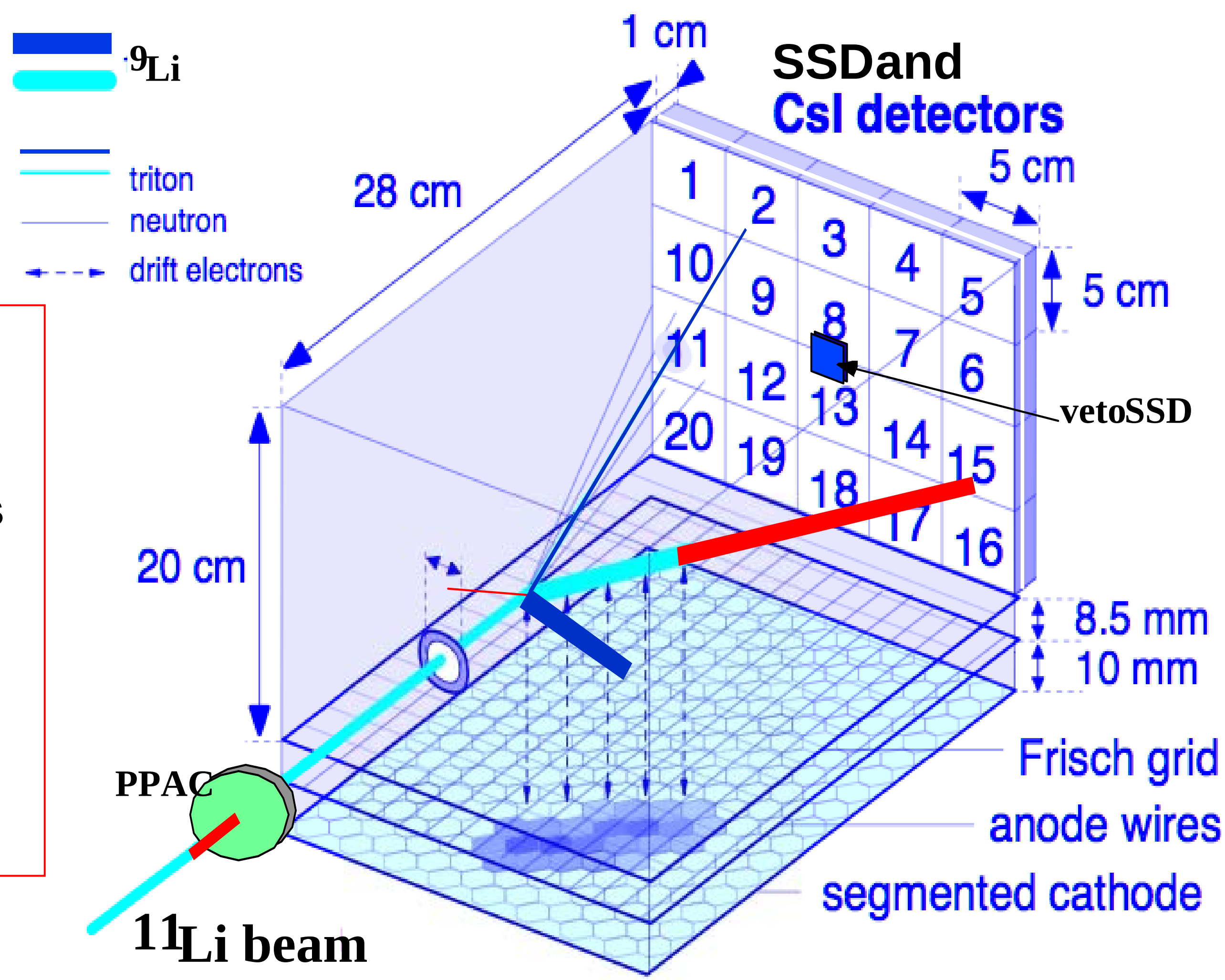


C. Monrozeau et al., Phys. Rev. Lett. 100, 042501 (2008)

To Modify what?

Decrease pad size
Wire➔ GEM/Momegas
Electronics
- Self Trigger Mode
- Trigger levels
- Dyn. Range
- Counting rate

Si Telescope cover



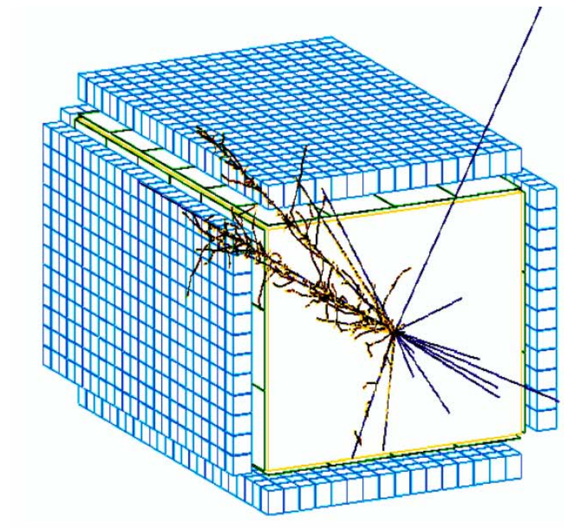
MAYA target-detector

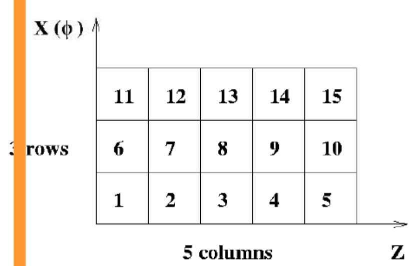
Simulations (H. Alvarez-Pol, E.A. Benjamin, D.Y. Pang)

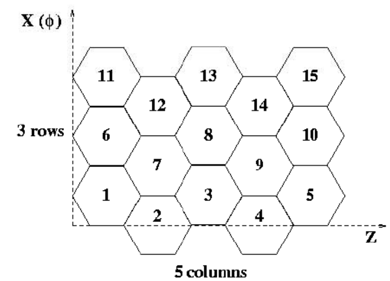
ActarSim http://www.usc.es/genp/

A Geant4+ROOT simulation tool

- Stores position and energy deposited for each track
- Calculates drift and diffusion of electronic clouds
- Calculates induction in the pads plane
- Uses pad signals for reconstruction
- Modular and configurable
  ⇒ test of geometry, gas parameters, amplification technology, reconstruction algorithms





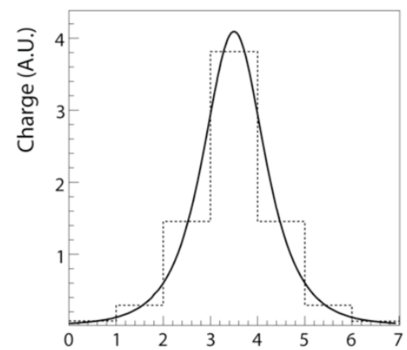


Tracking and reconstruction algorithms (T. Roger)

- Identification of track projection
- Method to measure drift velocity of electrons
- Range measurement from charge profile Threshold effects

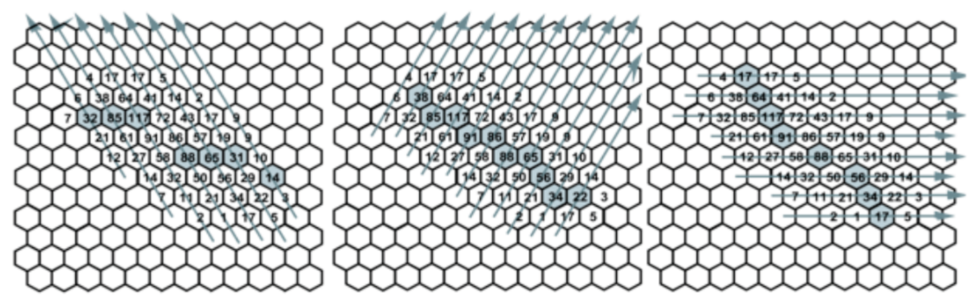
Extended R&D to Comply with new Development

Hyperbolic secant squared method



$$\Delta_R = \frac{w}{2}\frac{ln(\frac{1+a_1}{1-a_1})}{ln(a_2+\sqrt{a_2^2-1})}$$

$$a_1 = \frac{\sqrt{\frac{Q_0}{Q_+}}-\sqrt{\frac{Q_0}{Q_-}}}{2\,sinh\,a_2} \text{ and } a_2 = \frac{1}{2}(\sqrt{\frac{Q_0}{Q_+}}+\sqrt{\frac{Q_0}{Q_-}})$$



axis 1
7 maxima found

axis 2
10 maxima found

axis 3
8 maxima found

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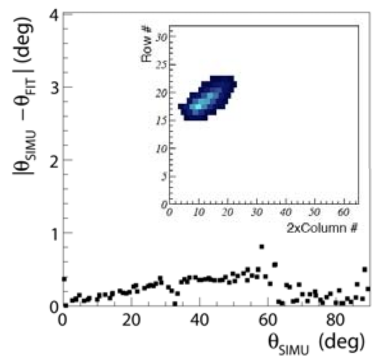
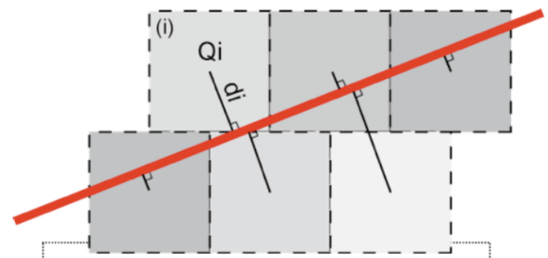
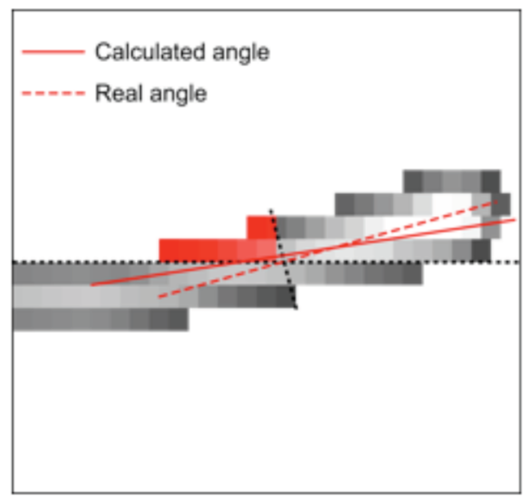


Orthogonal distance regression



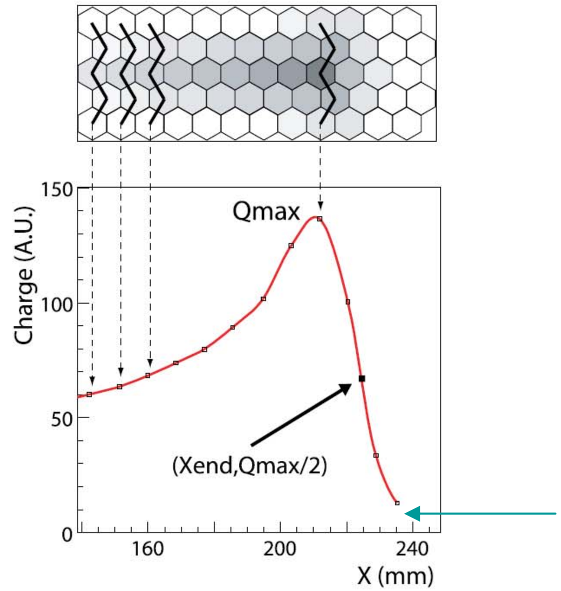
$$\chi^2 = \sum_{n=0}^{Npts} Q_n \frac{(ax_n + b - y_n)^2}{a^2 + 1}$$



Angle measure should be improved by smaller pads.
Note – <u>charge spread is smaller.</u>
Resln ➔?
Tests & simulations to be done.

Tracking and reconstruction algorithms (T. Roger)

- Identification of track projection
- Method to measure drift velocity of electrons
- Range measurement from charge profile
  Threshold effects



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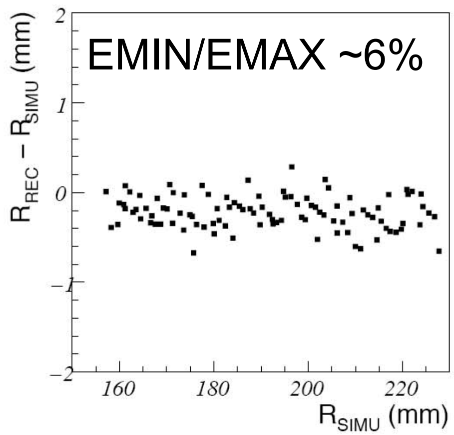
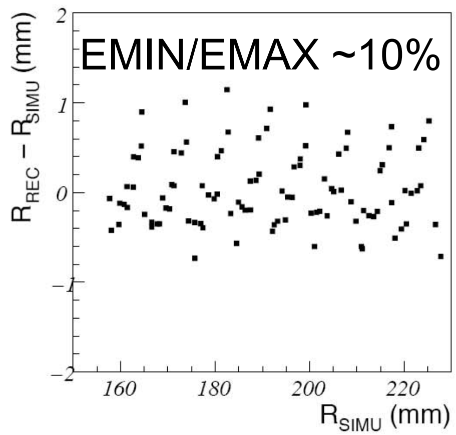
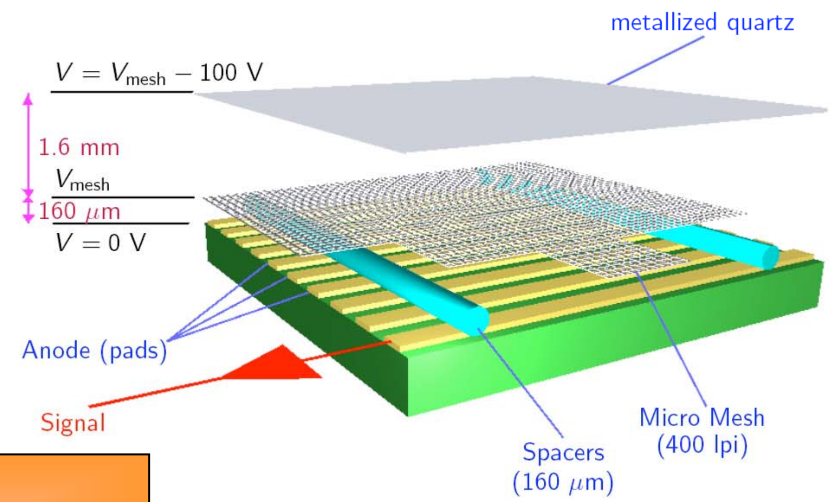




Amplification (T. Zerguerras, D.Y. Pang) Riccardo Raabe

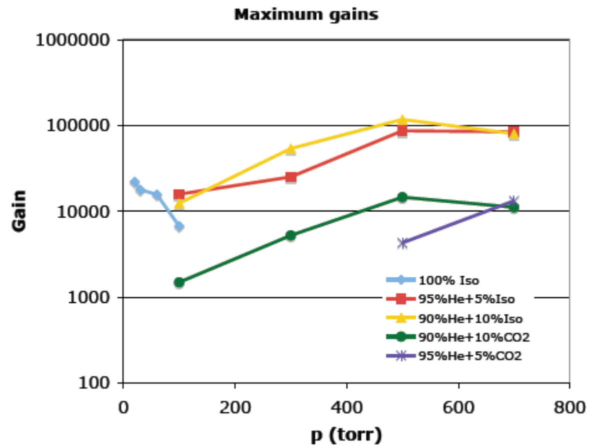
Technology

- Wires
  Fragile, aging, space charge, gain instability at high rates
- Micromegas
  Micro-mesh gaseous detector
- GEM: Gas Electron Multiplier



Test are being done:-
Gas H_2 & He, tensions, gains …
GEM/Micromegas
DE/E, DA/A, DR/R, DAngle/Angle,
Pads(4mm²) ➔ analysis criteria
Small Pad electro-mechanics

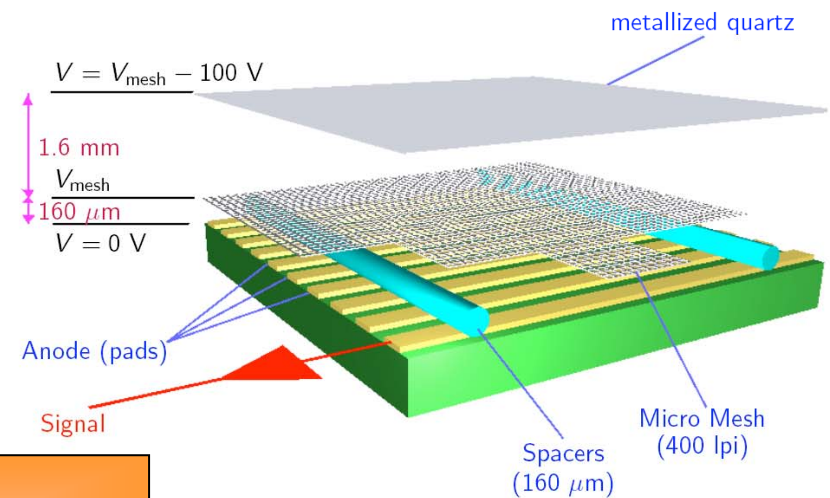
Tests IPN Orsay



Amplification (T. Zerguerras, D.Y. Pang) Riccardo Raabe

Technology

- Wires
  Fragile, aging, space charge, gain instability at high rates
- Micromegas
  Micro-mesh gaseous detector
- GEM: Gas Electron Multiplier



Test are being done:-

Gas H_2 & He, tensions, gains …
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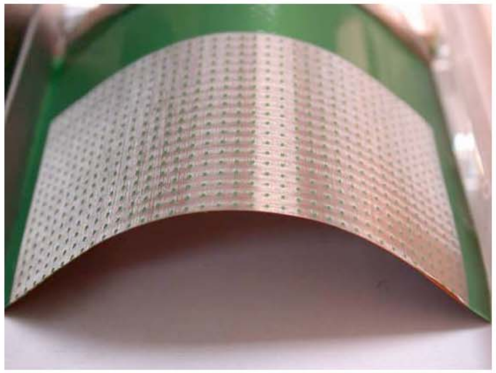
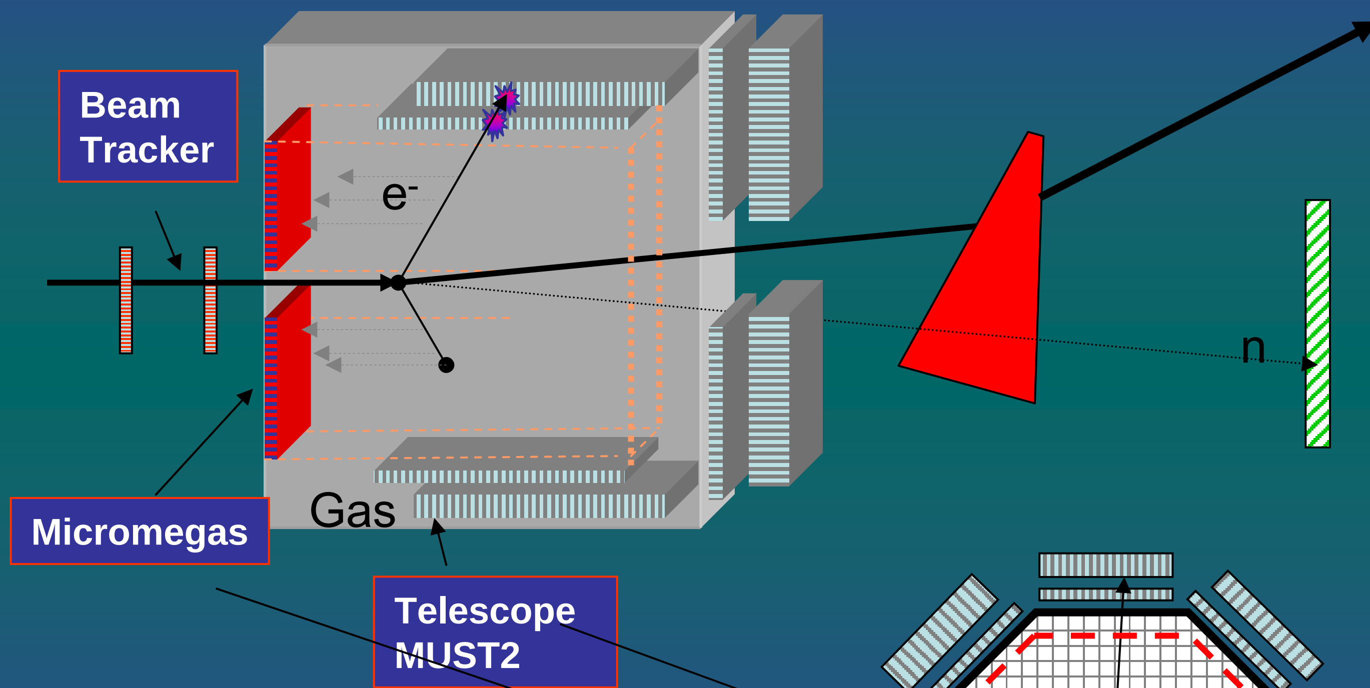
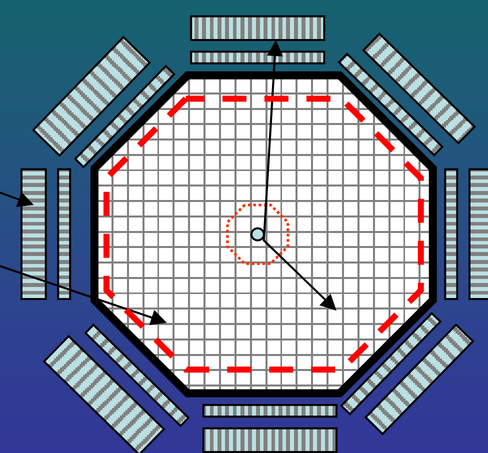
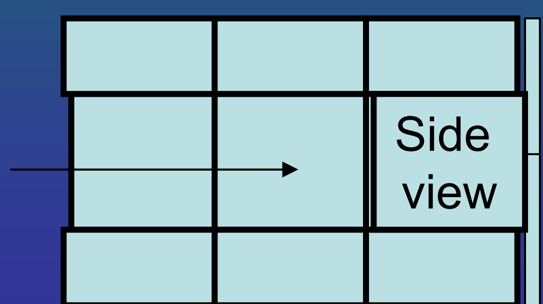


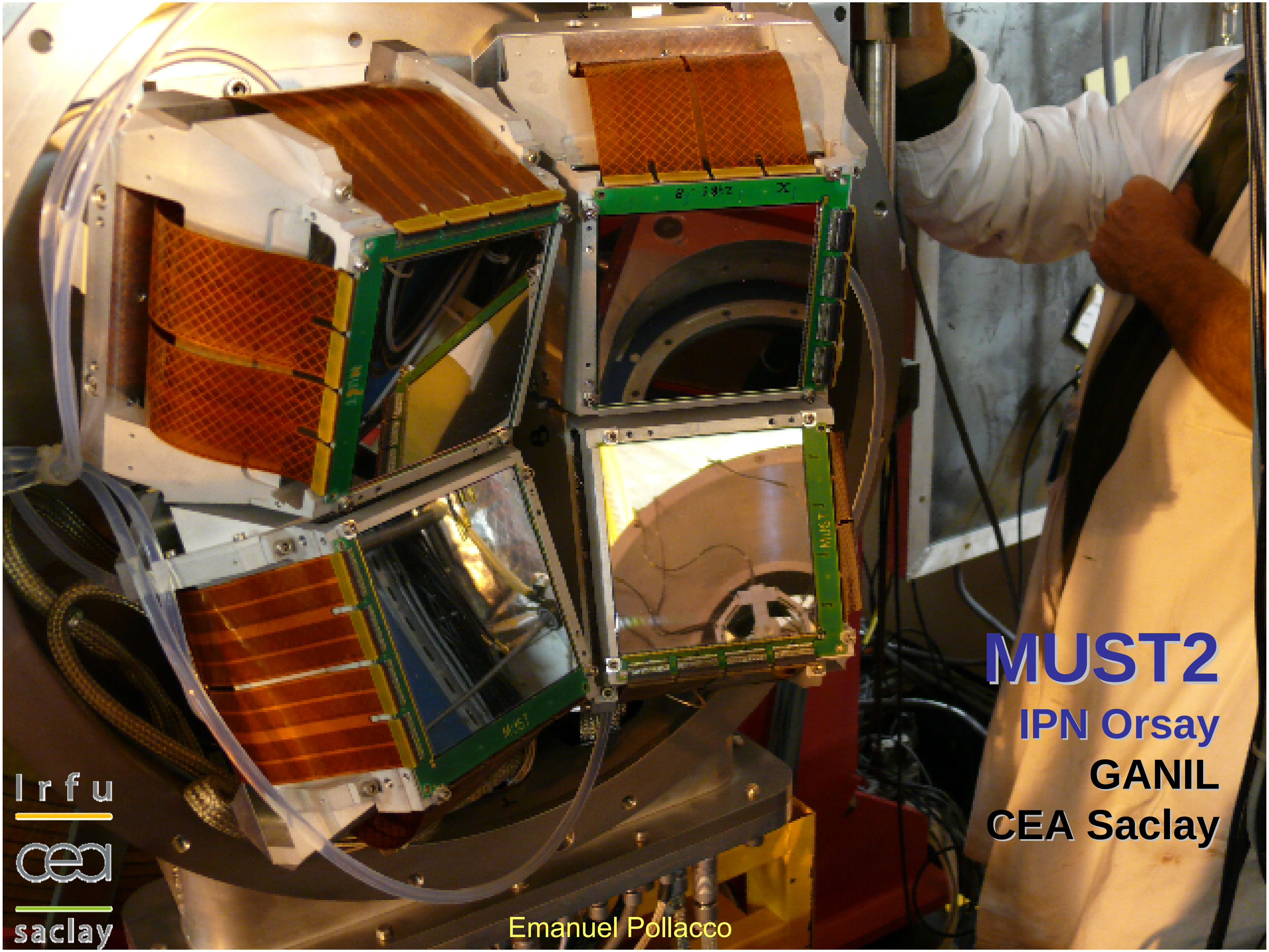
A possible Instrument Geometry For ACTAR





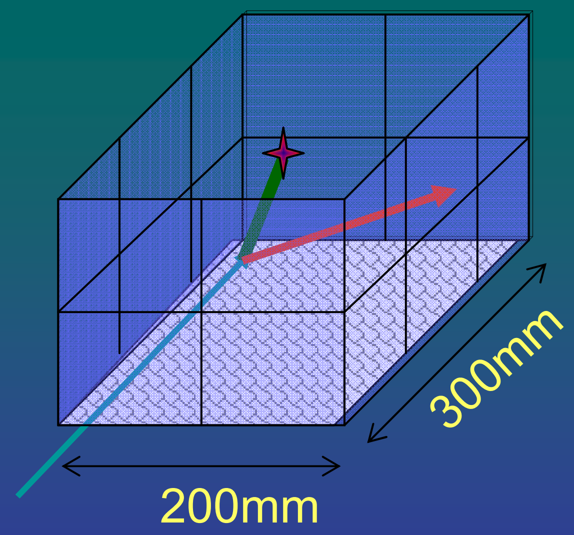


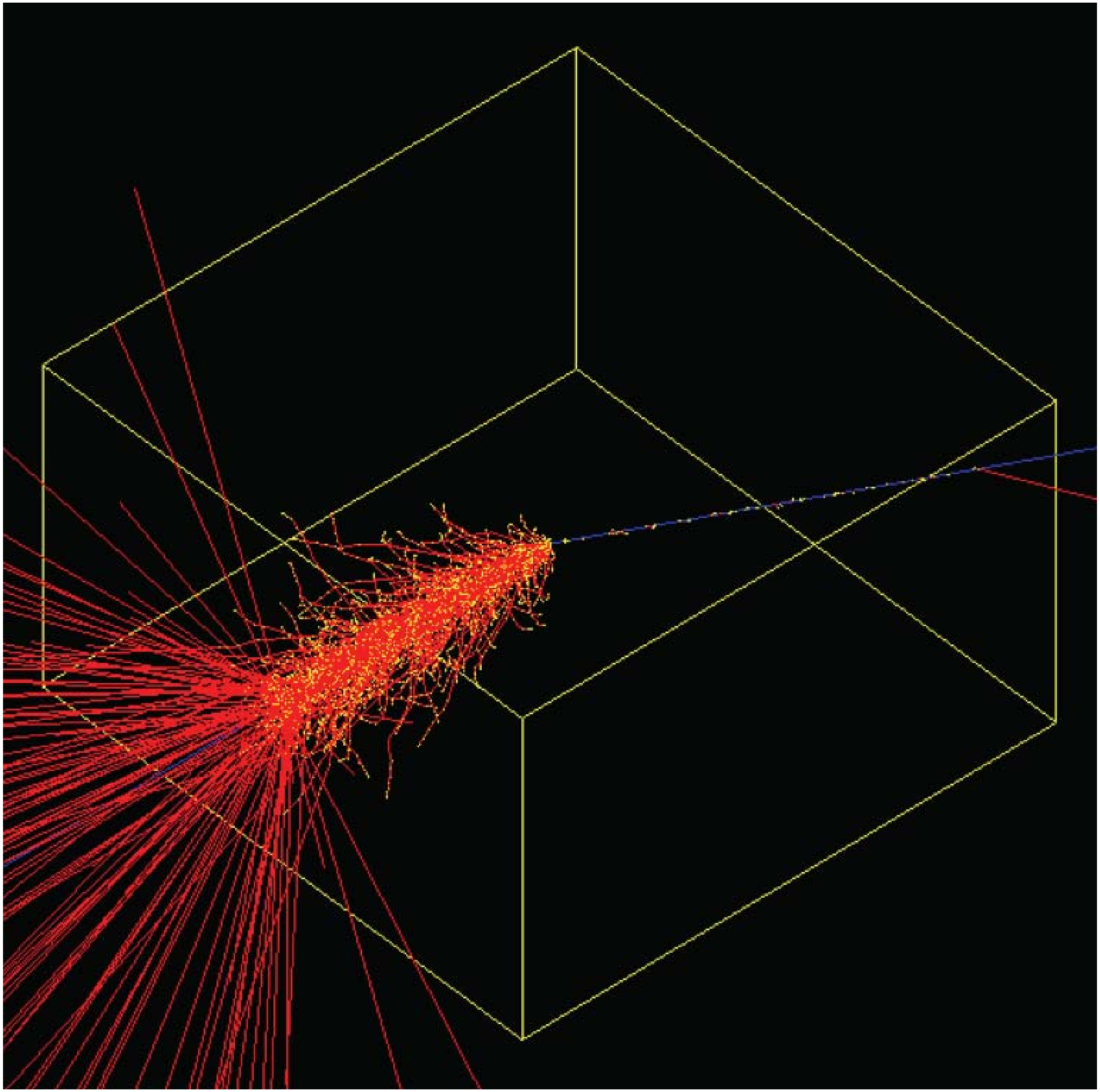
~ 28 MUST2 telescopes
100cm² each
Diameter 30cm
Length 30cm


MUST2
IPN Orsay
GANIL
CEA Saclay
Irfu
cea
saclay
Emanuel Pollacco

A possible Instrument Geometry

- 15,000 channels 2x2mm² pads (30,000 pads ➔ 300mmx400mm)
- 760 Torr gas @ STP
  - p in H_2
    - 100mm➔ 0.98MeV (1.25MeV)
    - 300mm➔ 1.80MeV
  - He in He
    - 100mm➔ 3.1MeV (4.8MeV)
    - 300mm➔ 6.5MeV
- **Full Si Telescope cover**
  - 1200cm² ➔ 12 MUST2
  - 800cm² ➔ 8 MUST2
  - MUST2 ➔ DSSD+Si(Li)+CsI
- **Efficiency of such a device**
  - Solid angle cover
    - ~30% **- Poor**
  - Dynamic Range
    - 0.1(300Torr) - 100MeV p **V.Good**
  - **X-section - simulations**





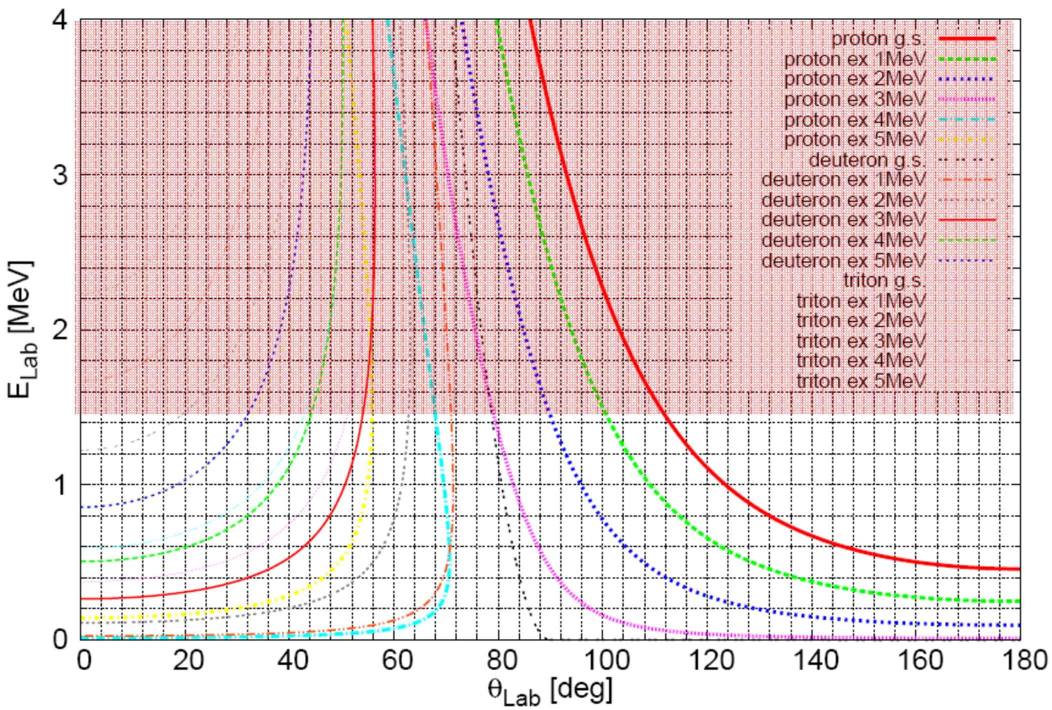
$^{2}H(^{78}Ni,^{79}Cu)p$

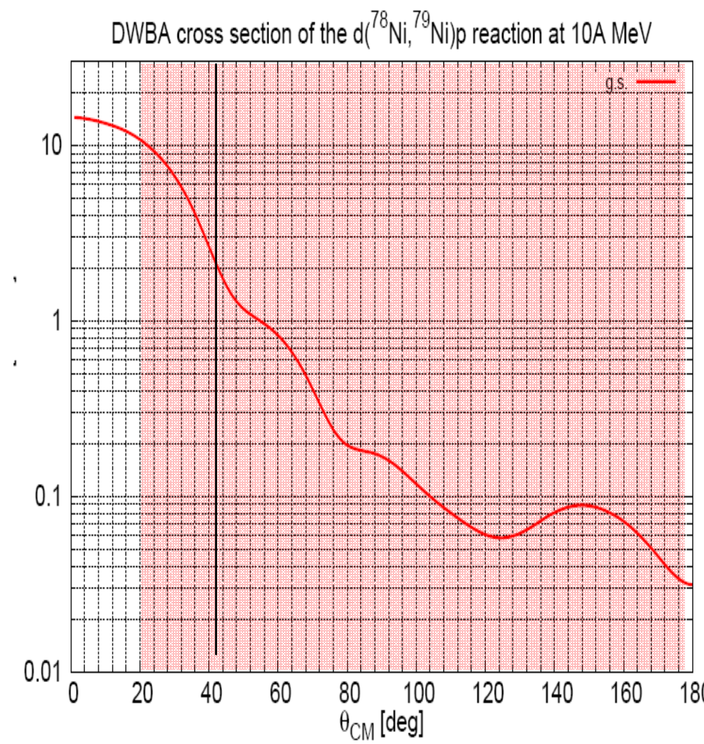
3He

The conditions:

The reaction: $d(^{78}Ni,^{79}Ni)p$ at 10A MeV.

θ_{CM} angle coverage: from 2 to 70 degrees with steps of 2 degrees.





Simulation:: Efficiency:: Definition

For a first approximation, the efficiency of detecting protons is:

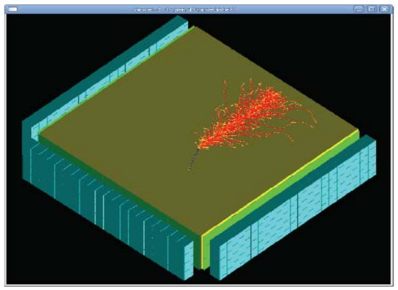
- For a proton stopped in the gas, it is effective if:
  1. its projected range length in gas is larger than 3 cm,
  2. its θ_{Lab} angle relative to the beam line in the Lab system is larger than 5° (to avoid the beam).

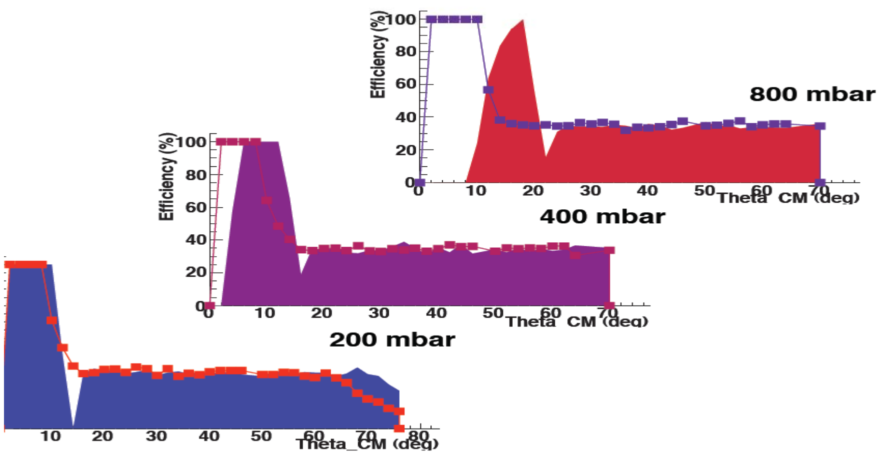
- For protons escaping the gas chamber:
  1. its residual energy (energy at reaction vertex − energy loss in gas) is larger than 500 keV,
  2. its energy loss per centimeter along its path projection on pad plane is larger than 1 keV, and
  3. its θ_{Lab} angle relative to the beam line in the Lab system is larger than 5°.

Simulation:: Efficiency:: Results

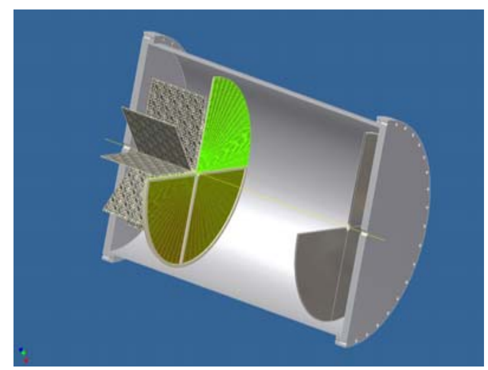
At larger angles, the efficiency only depends on the geometry ($\Rightarrow$ change the geometry?).

Cubic geometry



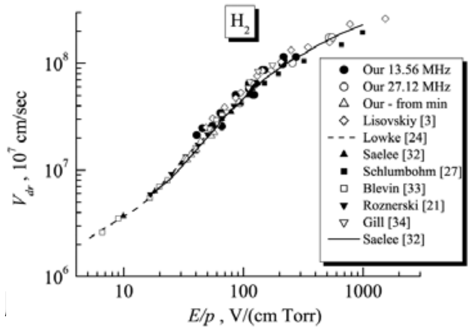


Cylindrical Geometry
➔ higher efficiency



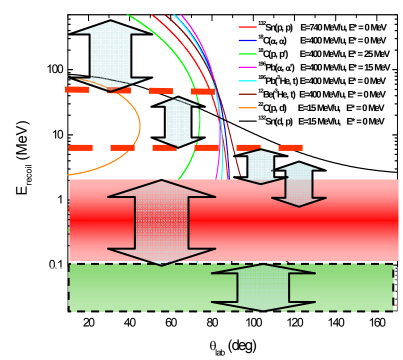
Different Conditions to improve Data & Efficiency

- Gas Choice
  - iC_3H_6, H_2, ^4He, ^3He, D_2 …
  - Contaminants (C or C & O, or C & F)
  - Drift Time (Counting rates)



- $P \propto \rho . T$
  - Temperature, T ↘ – not evaluated v_d↗, σ_x ↘,
  - Pressure, P ↗– not evaluated v_d↘, σ_x ↘, V↗,

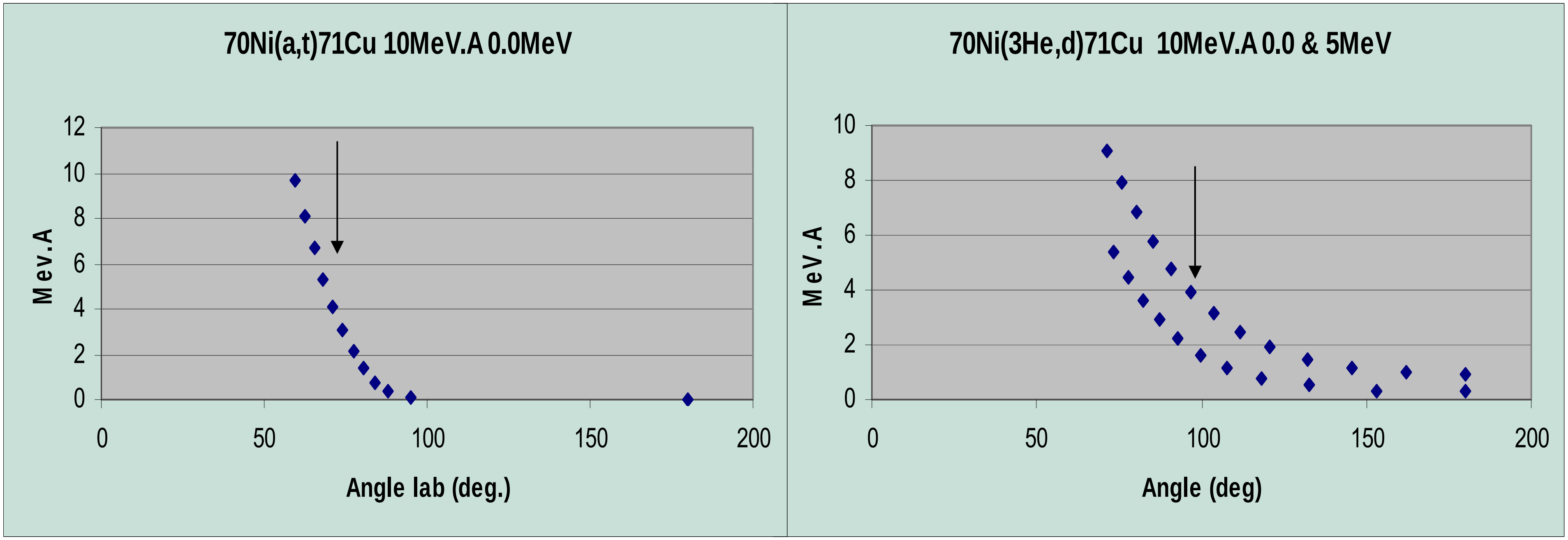
- Reaching high efficiency by employing different set-ups **with or without an active target** for different phase space cover ➔ **Simulations**

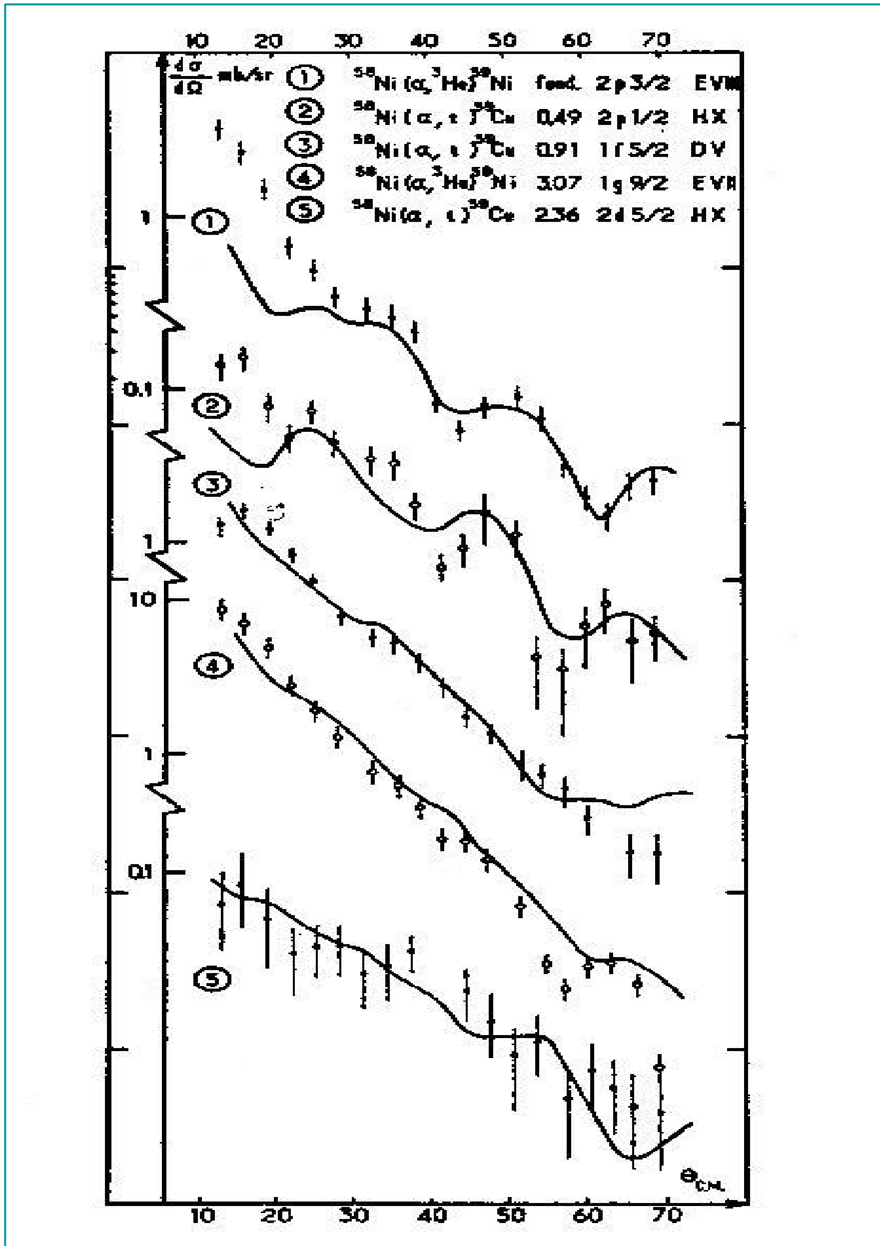


Physics cases for active targets

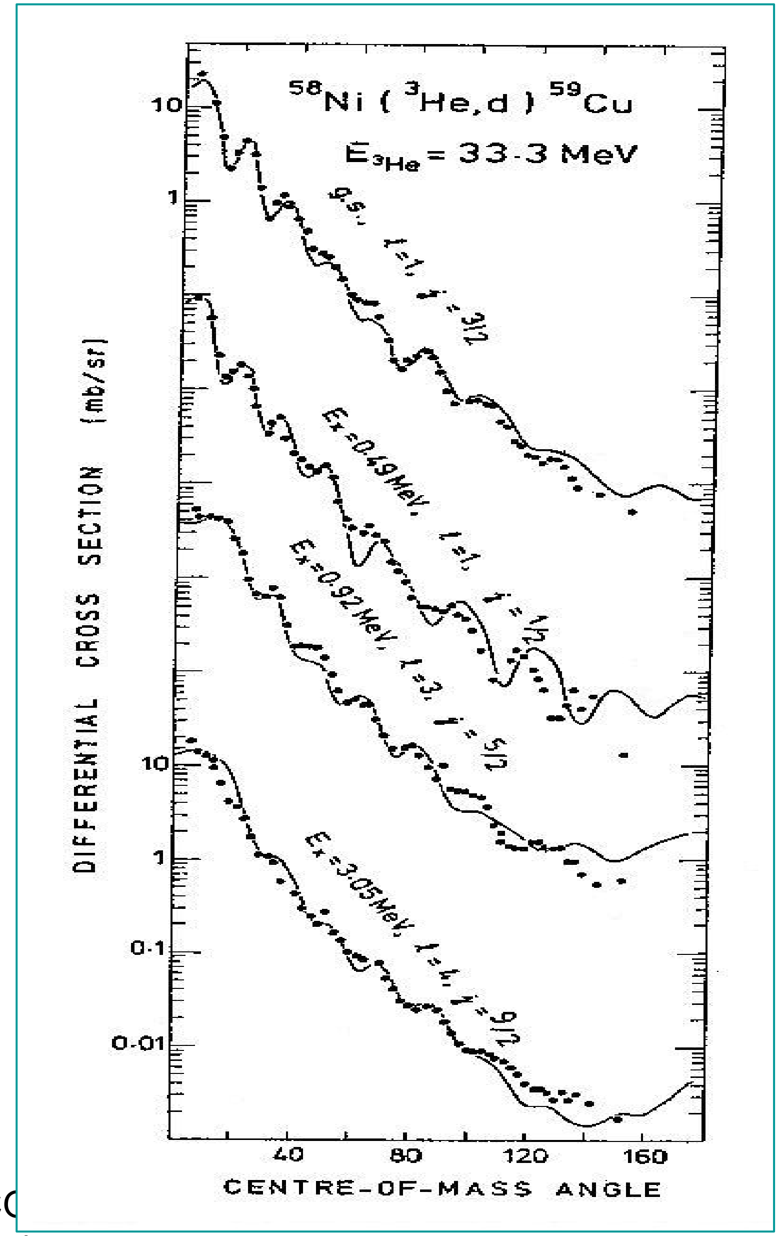
Difficult Reactions – p transfer

- Physics – shifting of the π shells as a fn of ν number
- Example:- ^{70}Ni(^{3}He,t)^{71}Cu or ^{78}Ni(^{3}He,t)^{79}Cu
- X-section can be high (1-10mb/sr)
- For (^{3}He,d)
  - good L-value signature
  - (^{3}He,d) Form-Factor understood I do not think (α,t) is well understood.





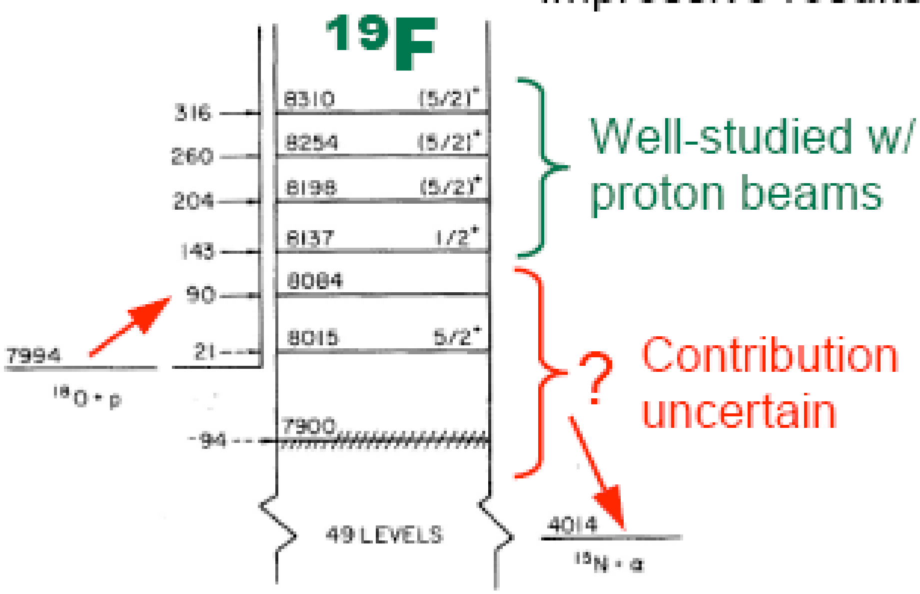
$\frac{d\sigma}{d\Omega}$ mb/sr
① ^{58}Ni(α,^{3}He)^{59}Ni fund. 2p3/2 EVH
② ^{58}Ni(α,t)^{59}Cu 0.49 2p1/2 HX
③ ^{58}Ni(α,t)^{59}Cu 0.91 1f5/2 DV
④ ^{58}Ni(α,^{3}He)^{59}Ni 3.07 1g9/2 EVH
⑤ ^{58}Ni(α,t)^{59}Cu 2.36 2d5/2 HX
θ_{CM}



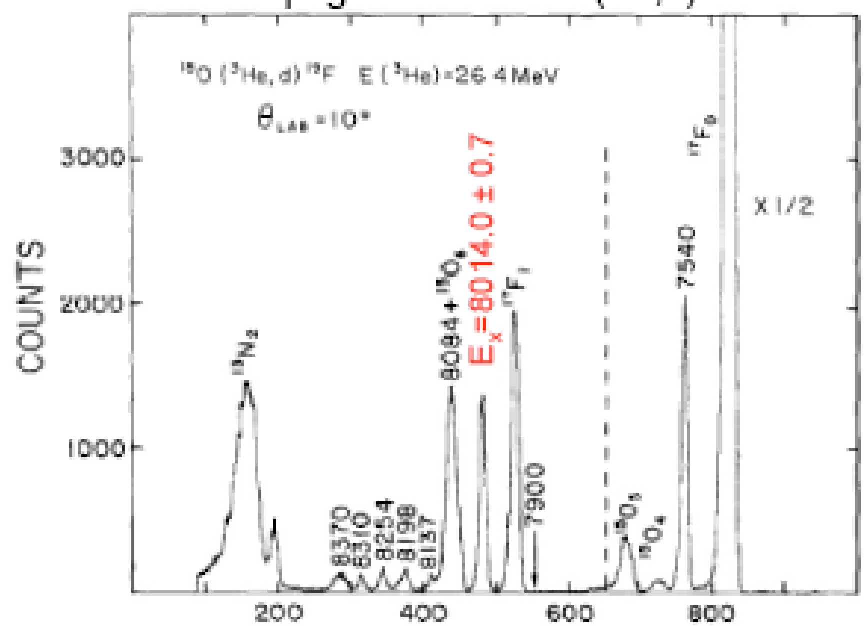
^{58}Ni (^{3}He,d) ^{59}Cu
$E_{^3He}$ = 33.3 MeV
g.s., l=1, j=3/2
Ex=0.49MeV, l=1, j=1/2
Ex=0.92MeV, l=3, j=5/2
Ex=3.05MeV, l=4, j=9/2
DIFFERENTIAL CROSS SECTION (mb/sr)
CENTRE-OF-MASS ANGLE

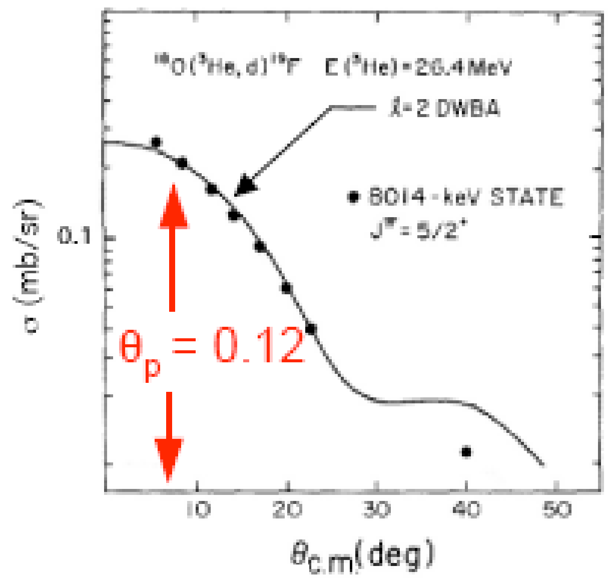
Transfer reactions, e.g. (^{3}He,d) like?

- Impressive results with stable (^{3}He) beams



Champagne and Pitt ^{18}O(He,d) 1986





$$\Gamma_p = 2\left(\frac{\hbar^2}{\lambda \mu R}\right)\left(\frac{\theta_p^2}{F_\ell^2 + G_\ell^2}\right) \Longrightarrow \Gamma_p = 2\times10^{-19}\ \text{eV}$$

1 mA p + ^{18}O → 1 event / 3x10^5 years

- Accurate E_x
- Unambiguous ℓ, J^π inferred
- Γ if broad
- Γ_p via S_p or ANC but model dependent

Jeff Blackmon, LSU

General Electronics for Time projection chambers GET

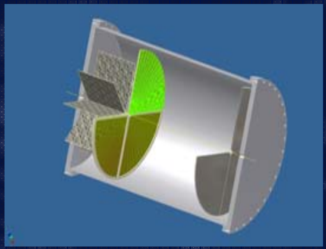
a Multi-Project for

IRFU/SPhN, GANIL, GSI, Compostel, CENBG, NSCL/MSU, Darsebury, York

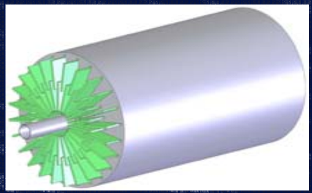
Irfu
cea
saclay

Emanuel Pollacco Liverpool ACTAR Dec 2008

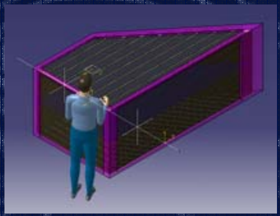
Multi-Project & Multi-Laboratory



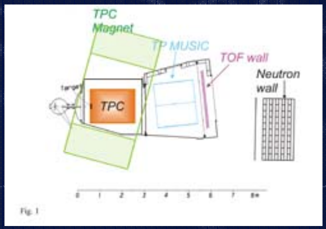
1. ACTAR
   - Active Target
   - Saclay & GANIL & Darsebury, Compostel, GSI, York …
2. 2p - TPC
   - Particle decay
   - CENBG



3. AT-TPC
   - Fragmentation (π^+,π^-) & Active-Target - ***Magnet***
   - MSU



4. R3B-TPC
   - Heavy projectile fragmentation – ***Magnet****
   - Saclay & R3B collaboration
5. SAMURAI-TPC
   - Fragmentation (π^+,π^-) - ***Magnet***
   - Riken, Kyoto University, …



Individually, the labs will not be able to build the instruments to perform the experiments- Costs/engineers

Multi-Project & Multi-Laboratory

FP6 – ACTAR program

- Physics – Yellow Book
- Detector Simulations
- Gases & Gas Amplification tests
- **Electronic system studies**

Nucl. Phys. Based

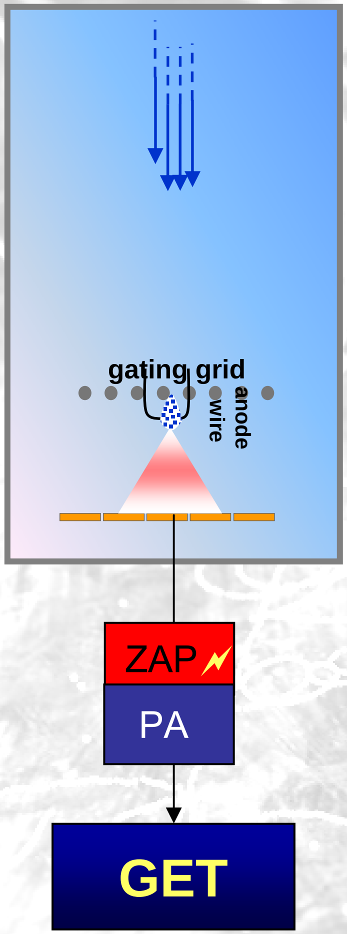
- Medium Sized System
- Multiple Applications
- Modular/Scale-Free
- Very High Dynamic Range
- High through-put for low occupation events

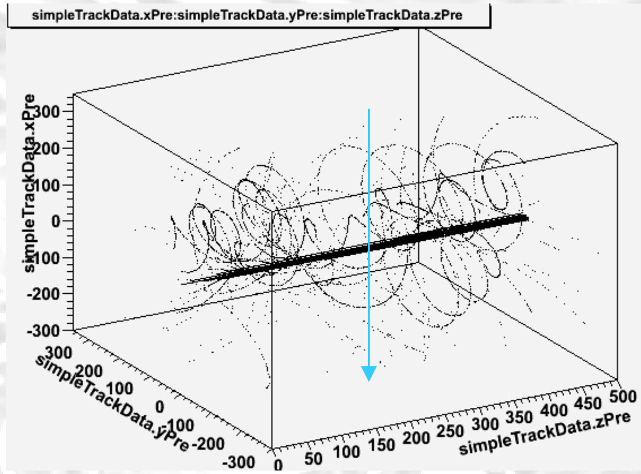
Principle element of the project (phase I)

To draw a detailed Conceptual Design, Build & Test a prototype for general nuclear physics TPCs electronics.

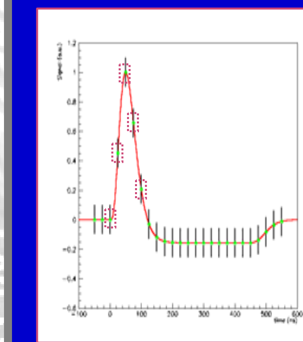
System will be an assessment standard for medium size and high throughput system for Nucl. Phys.

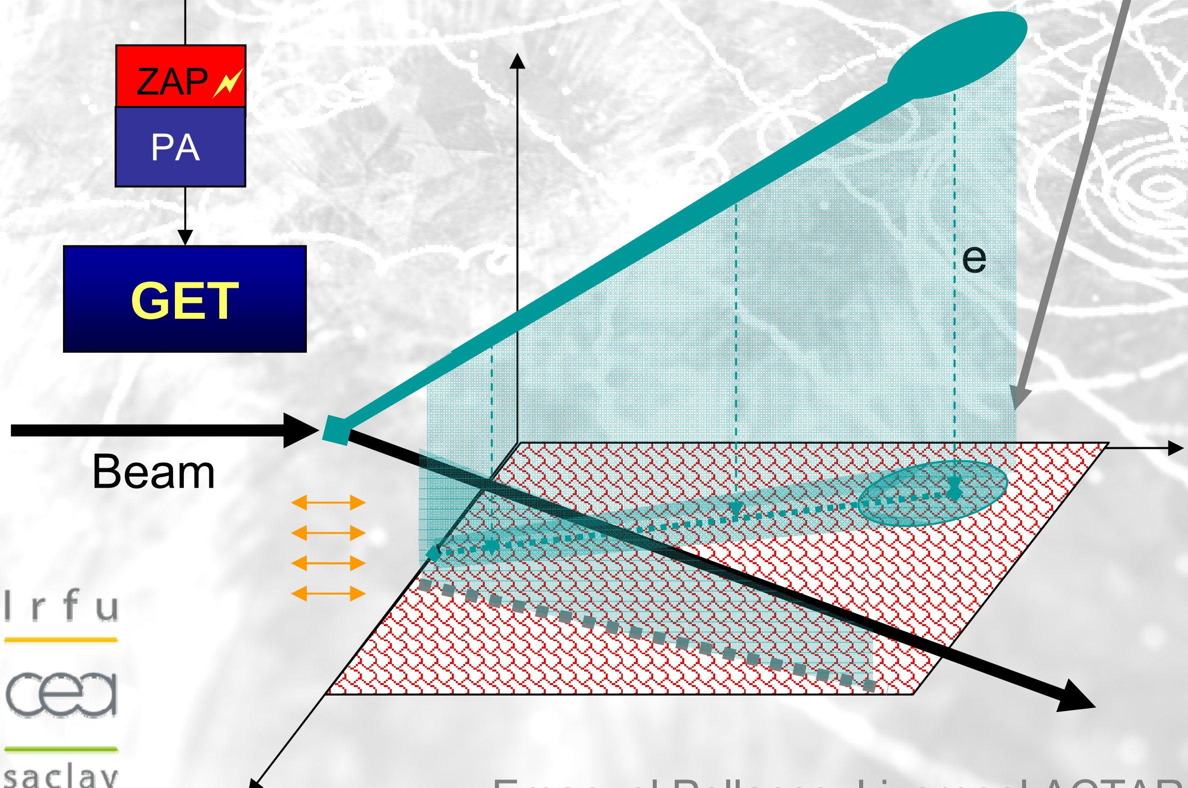
Irfu
cea
saclay





Measure
Q(t), X, Y
per Pad
Sampling ADC



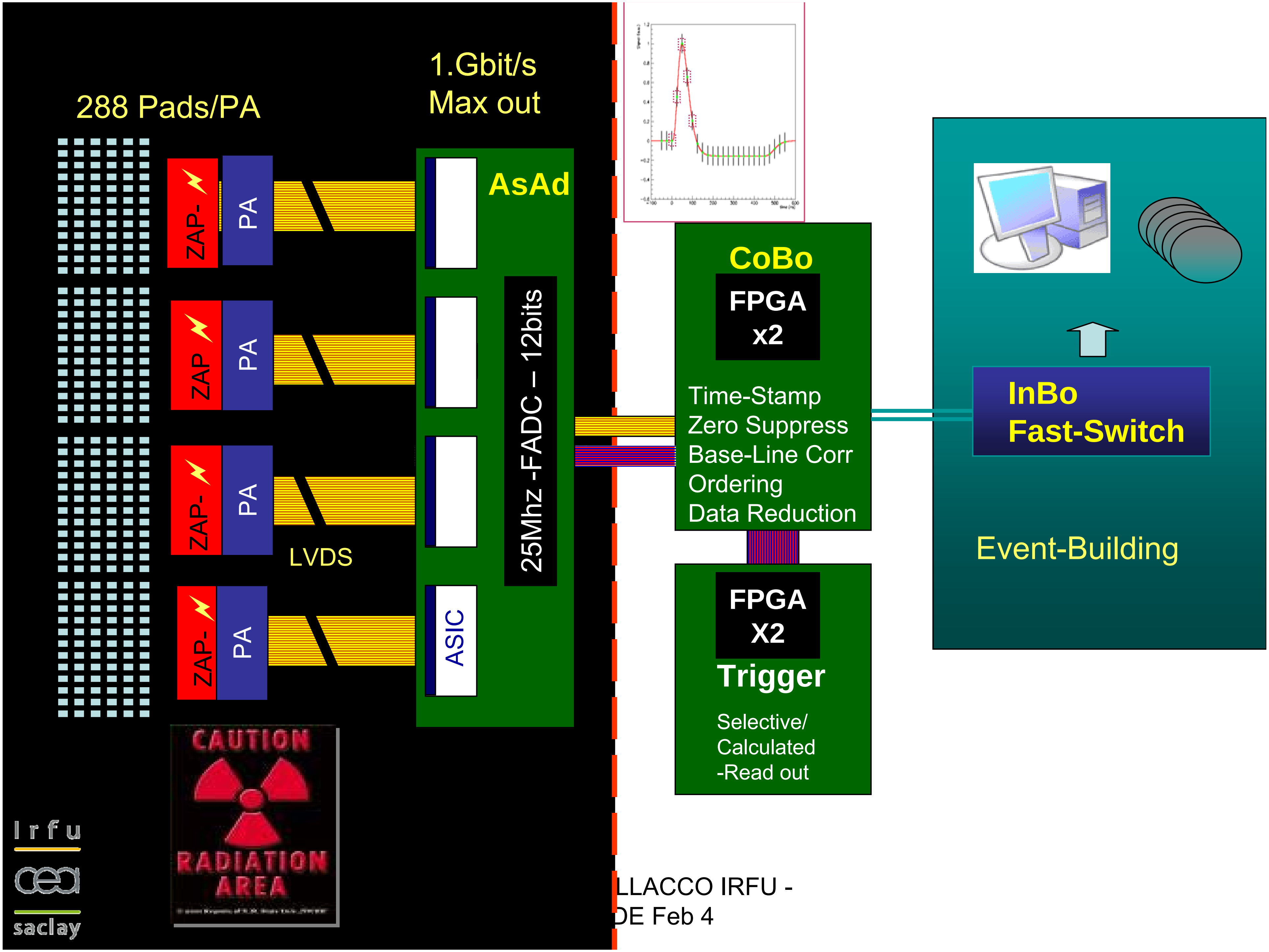


- **High S/N ratio**
  Low Threshold (π)
- **High Dynamic Range** (U)
  Resol^n
  Charge; Time; Position
- **Internal Trigger**
- **Selective Readout**
- **Zero Suppress**
  Base-Line Correction
  Time Stamp
  Automated Calibration

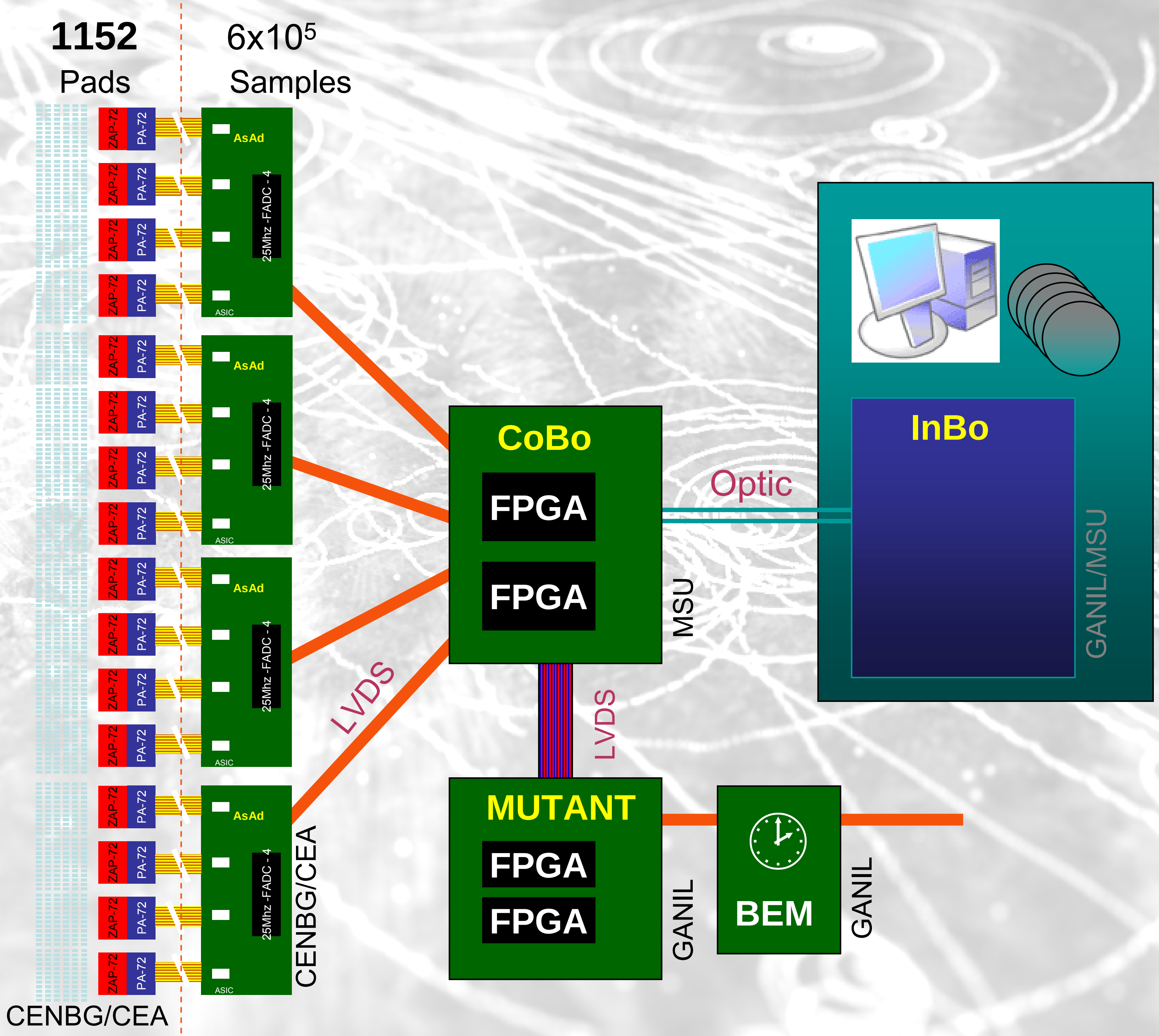
Irfu
cea
saclay

GET
A Simple Architecture To Give

Scale ‘Free’
Modular
Portable - different labs
Automated

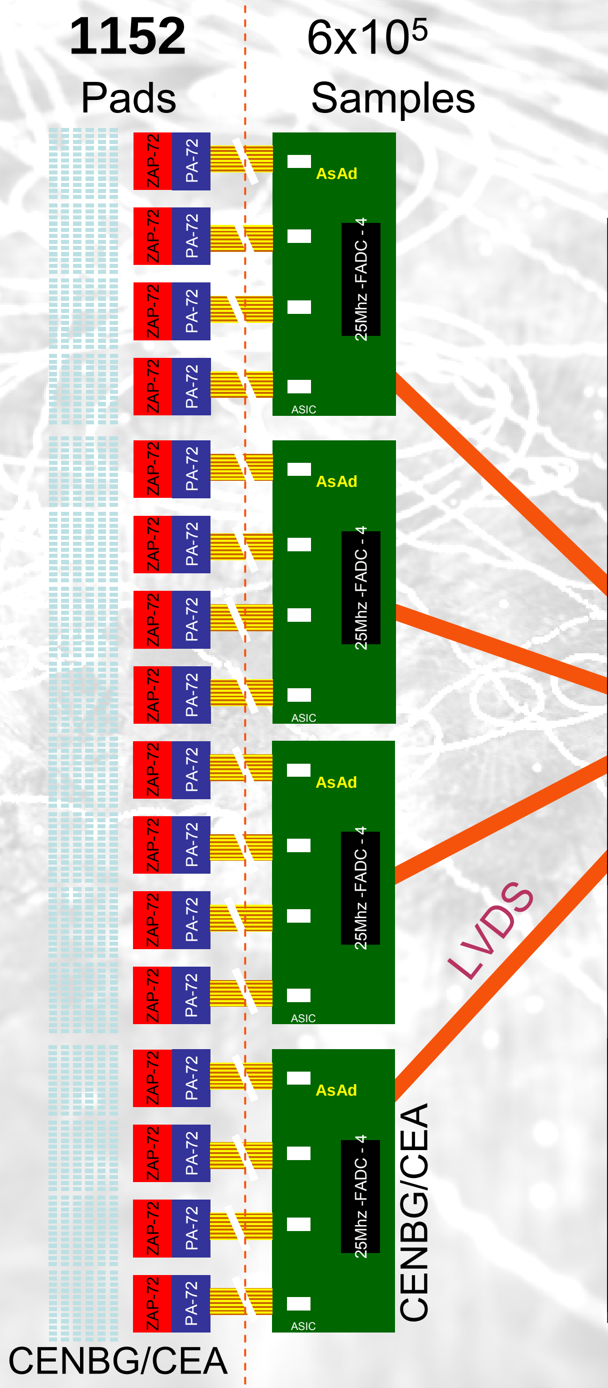

288 Pads/PA
1.Gbit/s
Max out
ZAP-
PA
ZAP-
PA
ZAP-
PA
ZAP-
PA
LVDS
AsAd
25Mhz -FADC – 12bits
ASIC
CoBo
FPGA
x2
Time-Stamp
Zero Suppress
Base-Line Corr
Ordering
Data Reduction
FPGA
X2
Trigger
Selective/
Calculated
-Read out
InBo
Fast-Switch
Event-Building
CAUTION
RADIATION
AREA
Irfu
saclay
LLACCO IRFU -
DE Feb 4

Basic Architecture



Irfu
cea
saclay

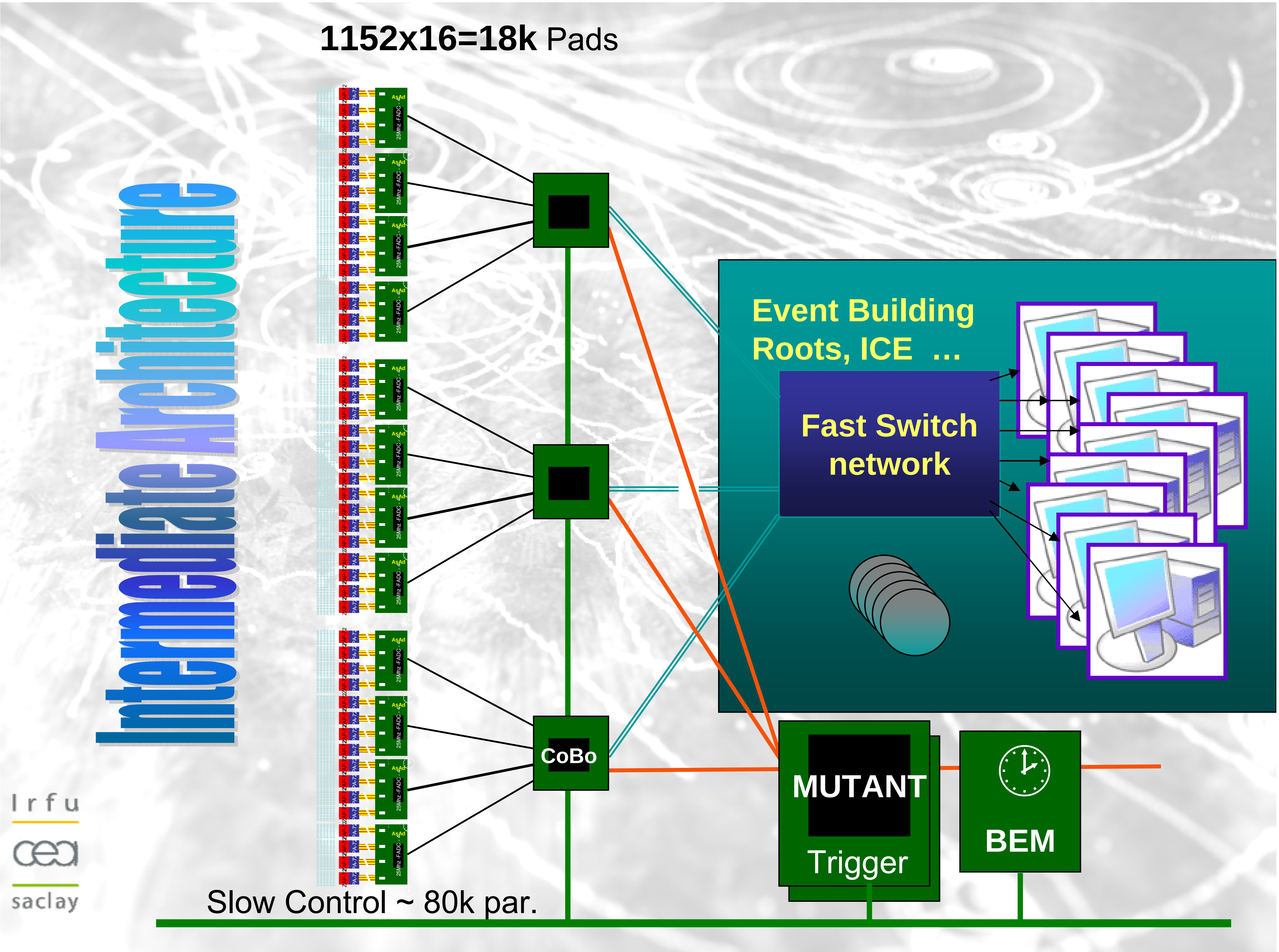
Basic Architecture



TRIGGER

Numeric (LE Disc)
Level 0 - External
Level 1-Pad Multiplicity
Level 2 – Event Topology

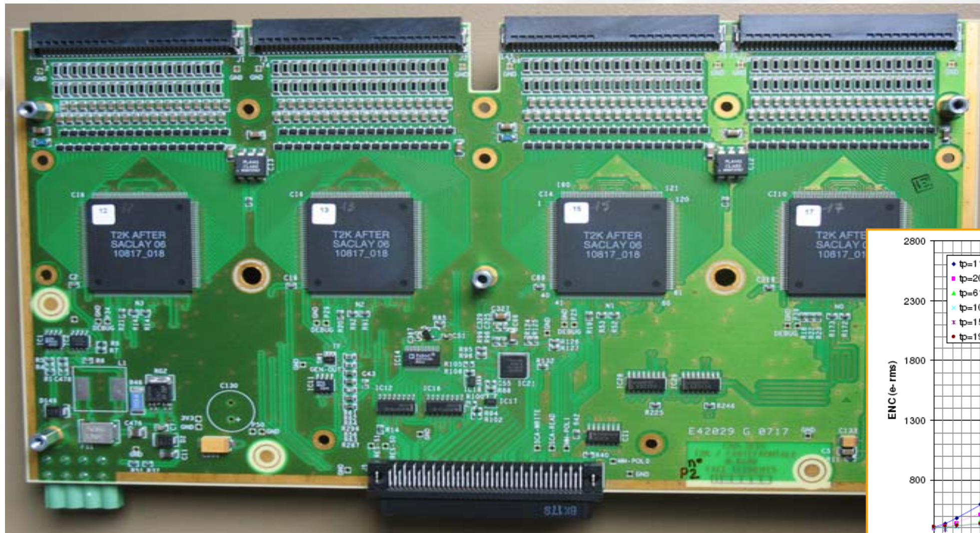
Calculated read pattern
(Selective read-out)

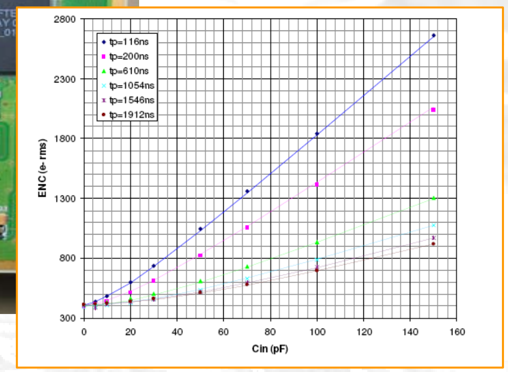


Intermediate Architecture
1152x16=18k Pads
Event Building
Roots, ICE …
Fast Switch
network
CoBo
MUTANT
Trigger
BEM
Slow Control ~ 80k par.
Irfu
cea
saclay

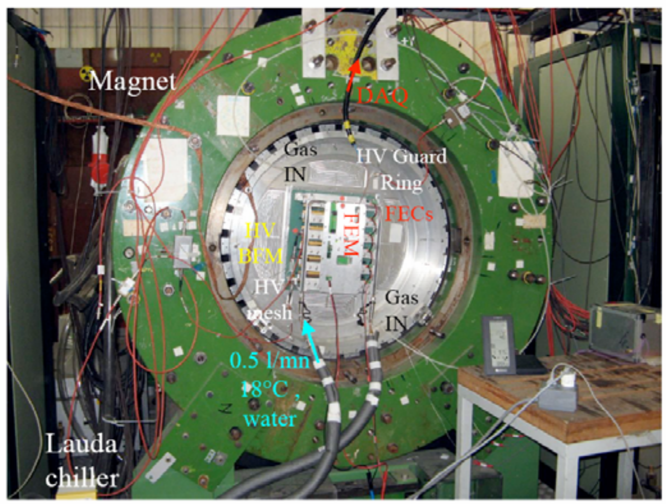

ASIC
for
GET
Based on the T2K
Program

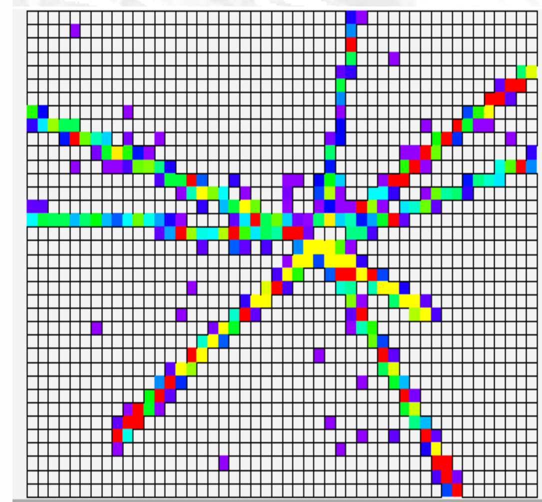
T2K





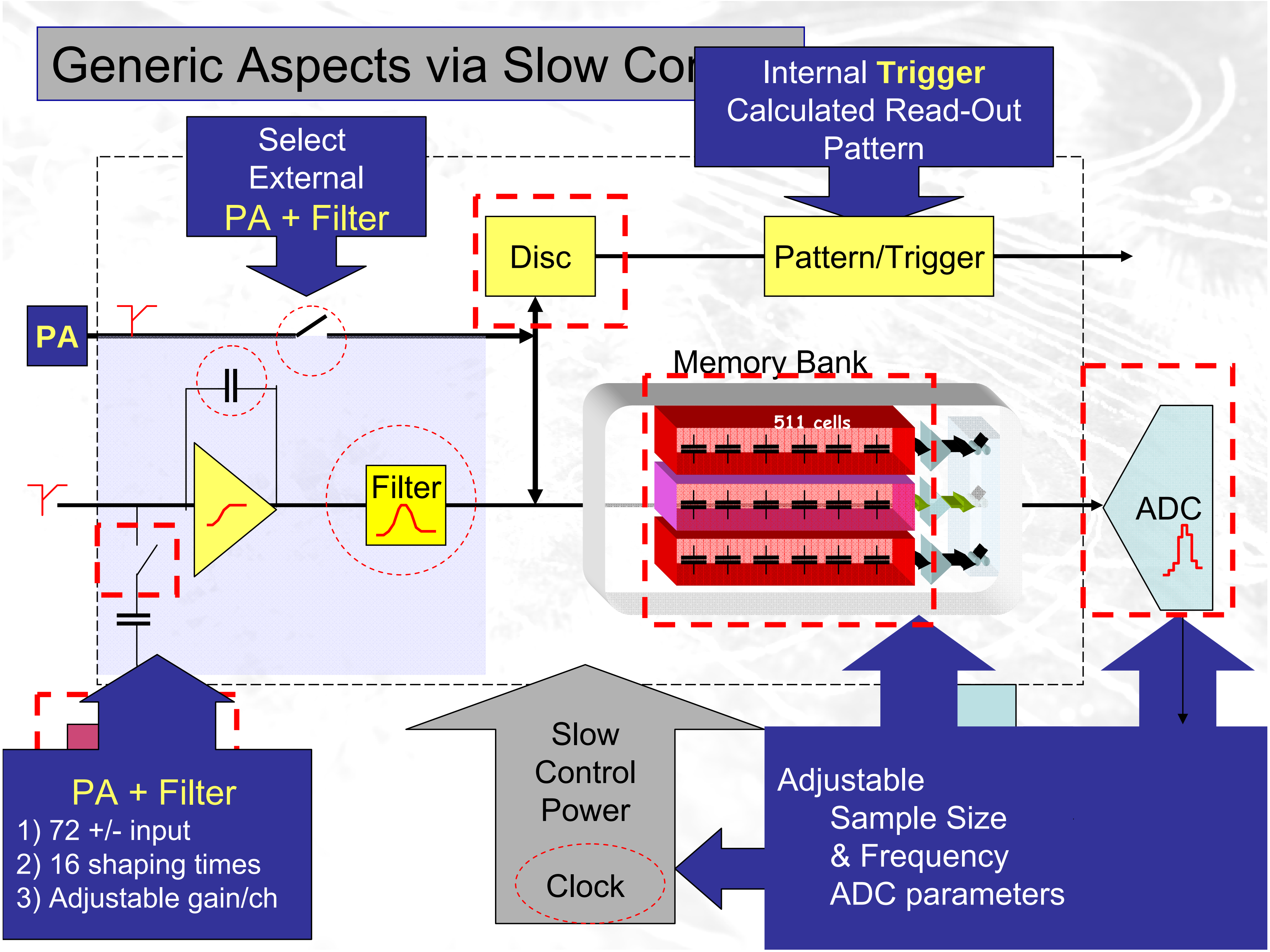
HARP test set-up at CERN (oct 07)



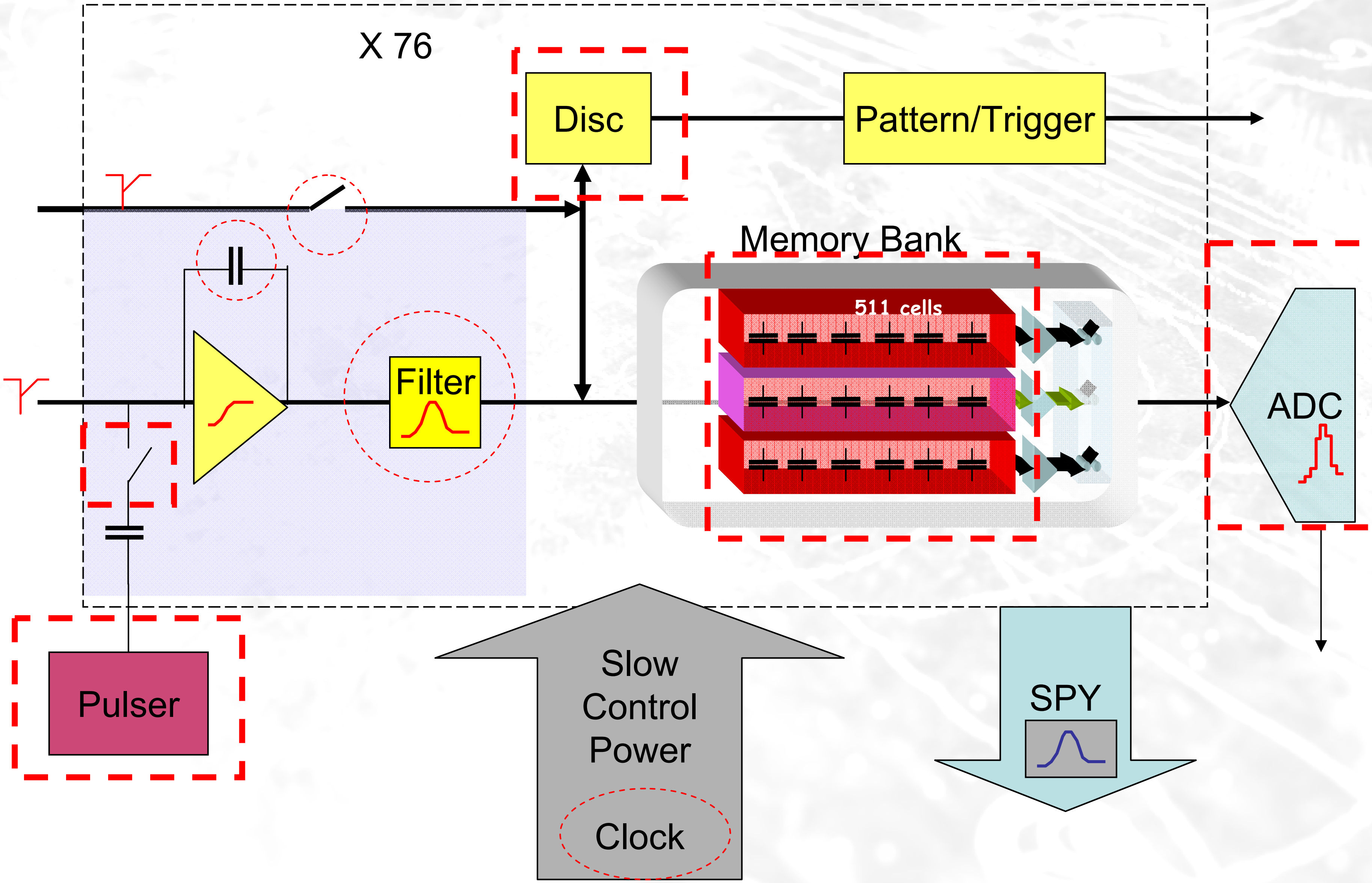


SEDI/IRFU

15 GeV/c p-Pb (# 20K events)
FE electronics
validated on 1728 channels


Generic Aspects via Slow Cor
Internal Trigger
Calculated Read-Out Pattern
Select External
PA + Filter
Disc
Pattern/Trigger
PA
Memory Bank
511 cells
Filter
ADC
PA + Filter
1) 72 +/- input
2) 16 shaping times
3) Adjustable gain/ch
Slow Control Power
Clock
Adjustable
Sample Size
& Frequency
ADC parameters

Generic Aspects via Slow Control



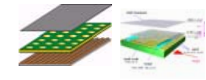
Gains & Losses with an Active Target

- X3 to X10 in luminosity
- Very low PI thresholds to 0.1 MeV
- $E<E_T$ ~ Efficiency 90% for low energy E_T ejectile.
- Energy resol^n < 50keV
- For Z=1 & 2, mass & charge resol^n for $<E_T$.
- Angular resol^n = 0.5°
- **Nouvelle method→ Nouvelle discoveries!**
- Instrument adoptable to a number of techniques

- Limited max. energy 2 MeV.A within the TPC.
- Coupling MUST2
- No Gamma coincidence
- $E>E_T$ ~ Efficiency 30%
- Complex Front End Electronics
- High data capture
- To develop data analysis techniques for Nucl. Phys


END
Sebastian Proost

MWPC, GEM & Micromegas Performances



	MWPC	GEM	Micromegas
Rate capability	10^4Hz/mm^2	>5x10^5Hz/mm^2	10^6Hz/mm^2
Gain	High 10^6	low 10^3 (single) > 10^5 (multi GEM)	High > 10^5
Gain stability	Drops at 10^4Hz/mm^2	Stable over 5*10^5Hz/mm^2	Stable over 10^6Hz/mm^2
2D Readout ?	Not really	Yes and flexible	Yes and flexible
Position resolution	> 200 µm (analog)	50 µm (analog)	Good < 80 µm
Time resolution	~ 100 µs	< 100 ns	< 100 ns
Magnetic Field effect	High	Low	Low
Cost	**Expensive, fragile**	**Cheap, robust**	**Cheap, robust**