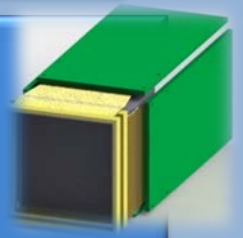
*Enrico De Filippo (INFN Catania) for the **NEWCHIM** collaboration*

GHT-2017 Orsay

GASPARD HYDE TRACE

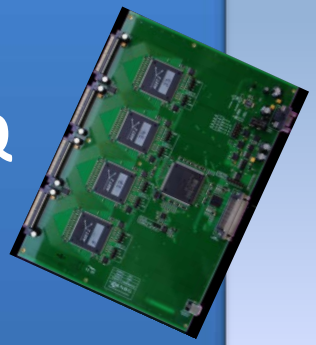
INFN Istituto Nazionale di Fisica Nucleare

# *Farcos: an ancillary device for spectroscopy and correlations*



**Physics cases: Working with Chimera + Farcos array (few examples using the Farcos prototype with stable and exotic beams)**

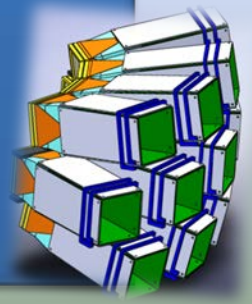
**Present status of FARCOS: electronics, DAQ, mechanics…**



**Motivations for a the new front-end electronic and DAQ**

**GET: generic electronics for TPC: a compact system going from front-end electronic to data readout. Chimera DAQ coupling**

**Recent developments (new charge pre-amplifiers, dual gain modules…). Tests under beam.**



**Perspectives in 2017 and beyond : the ChiFar experiment**

# *Some physical cases studied with CHIMERA detector:*

## What we do with the CHIMERA detector ?

Nuclear Equation of State and Symmetry energy of asymmetric nuclear matter: light particle correlations and space-time characterization of emitting sources. Symmetry energy parametrization.

Dynamics and thermodynamics in heavy ion-reactions: time scale of particles and cluster emission, neck emission: fragment-fragment and particle correlations.

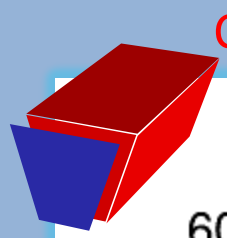
Multi-particle correlations. Alpha particle clustering (*see recent B. Borderie et al. (Chimera collaboration) PLB 755, 475 (2016*).

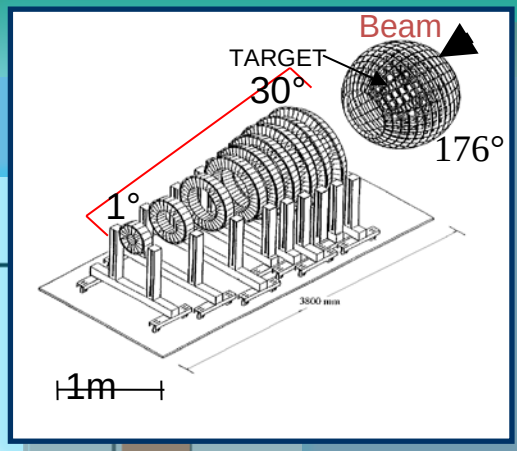
Isospin dependence of compound nucleus formation and decay: study of the isospin influence on the reaction dynamics and on the competition between different decay modes (ISODEC)

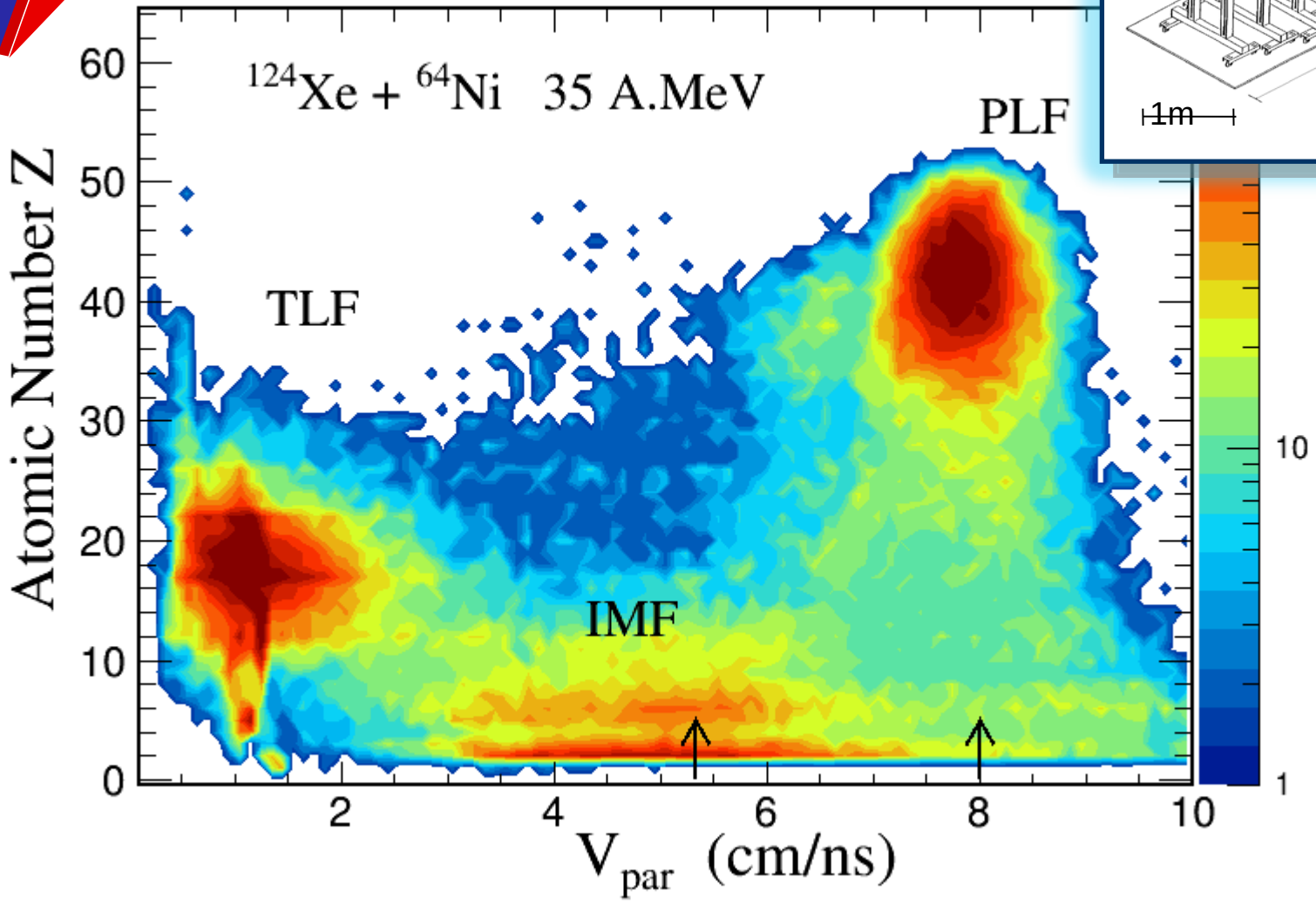
Correlations of light particles from break-up reactions in neutron rich nuclei (UNSTABLE and CLIR experiments with FRIBs beams).

The Asy-Eos experiment at GSI: symmetry energy at high densities (2-3$\rho_0$). (*see recent P. Russotto et al. (AsyEos coll.) PRC 94, 034608 (2016*).

# An example: three body analysis of fragments



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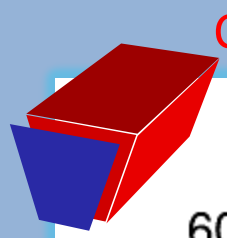


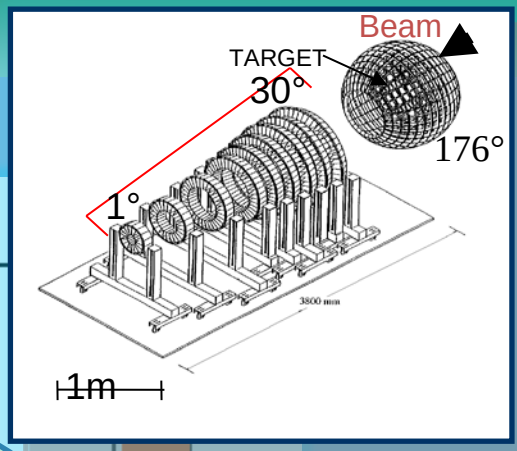


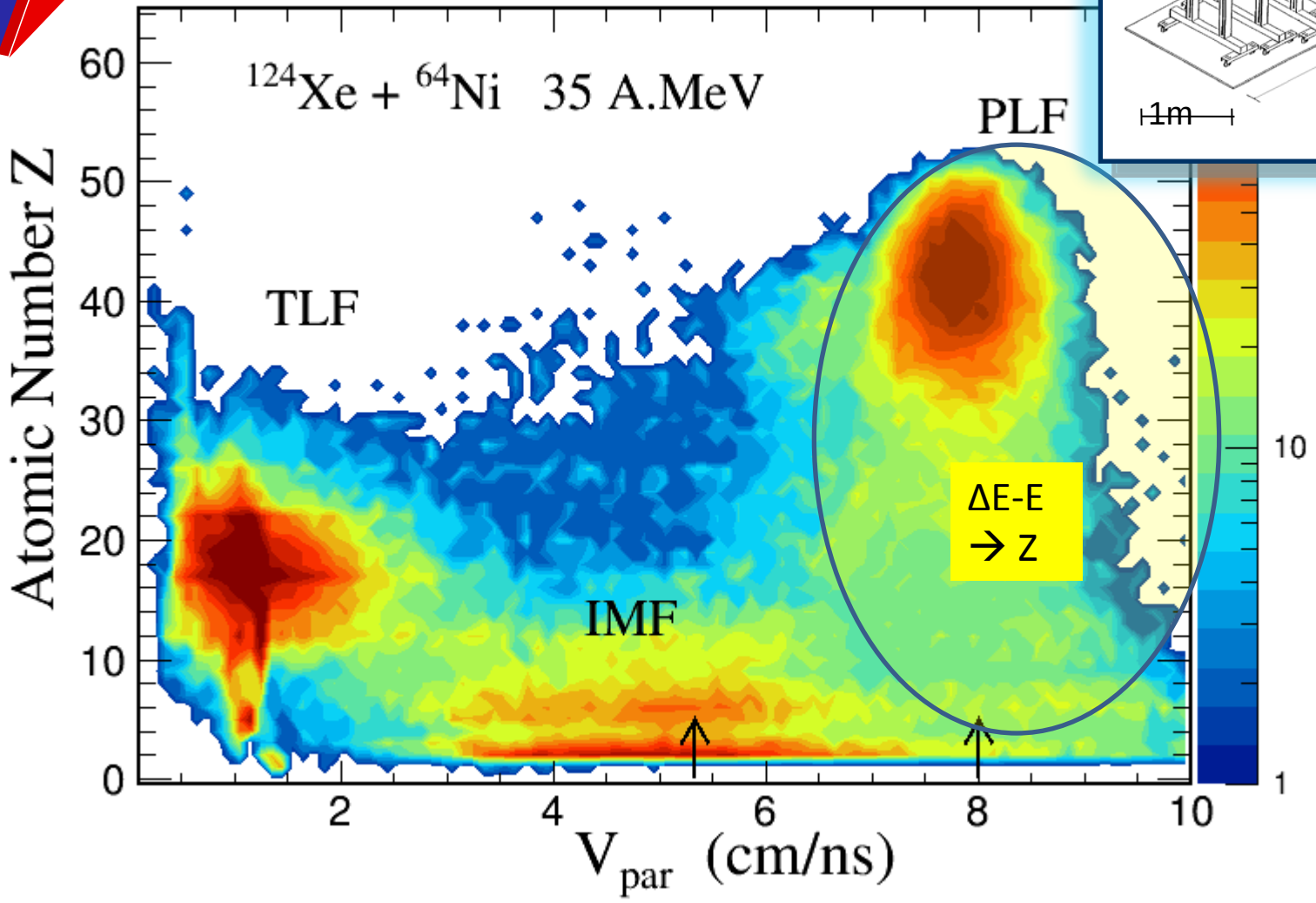

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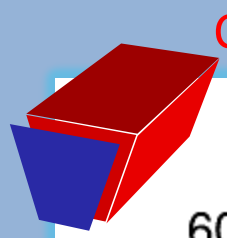


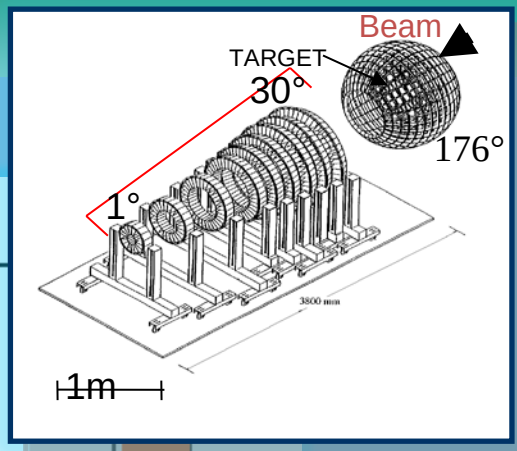


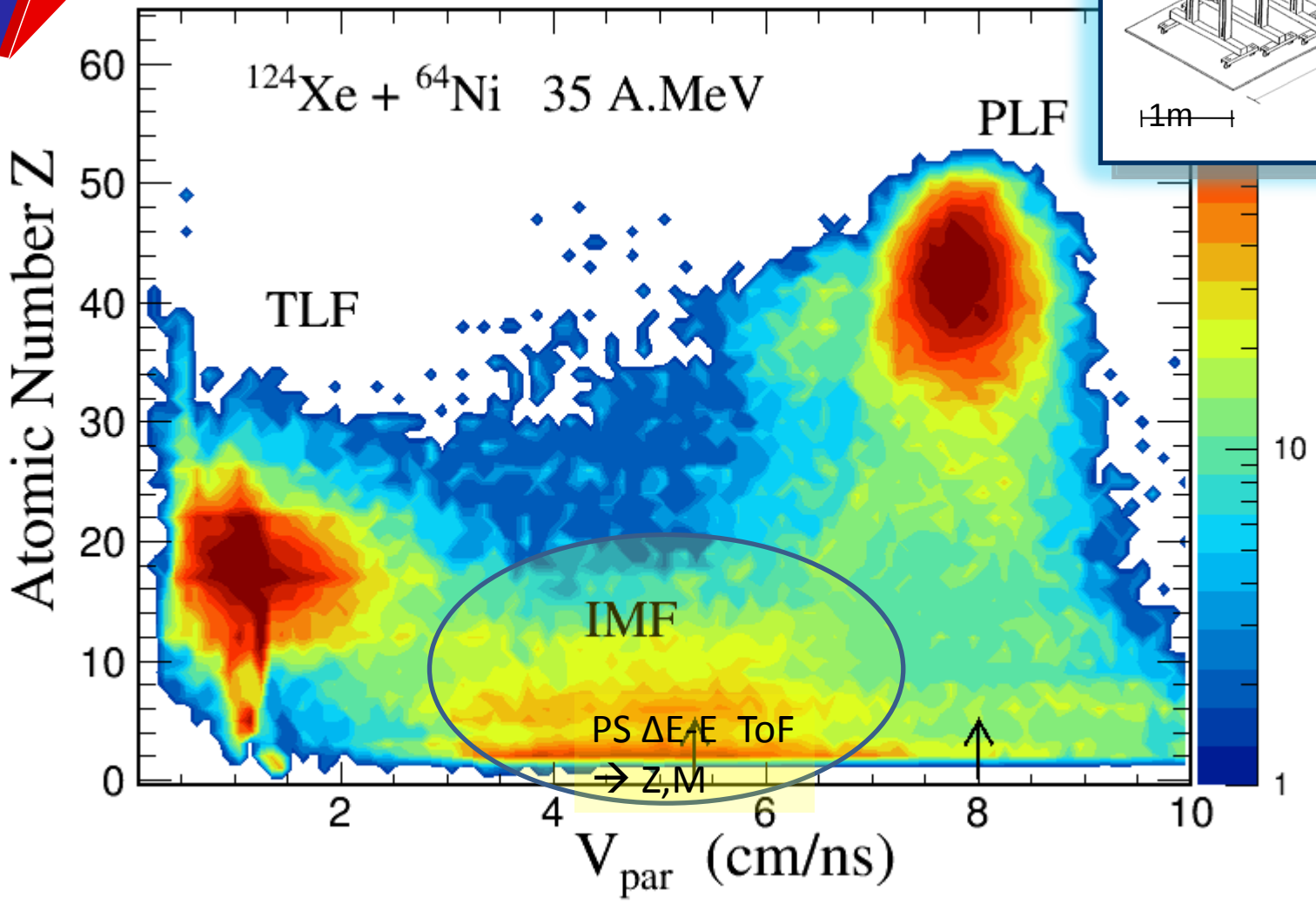

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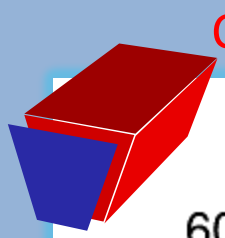


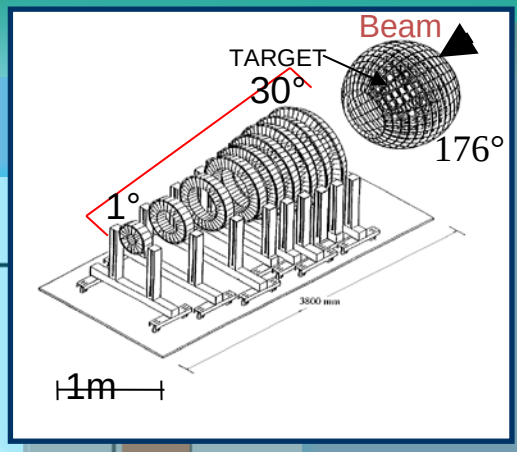


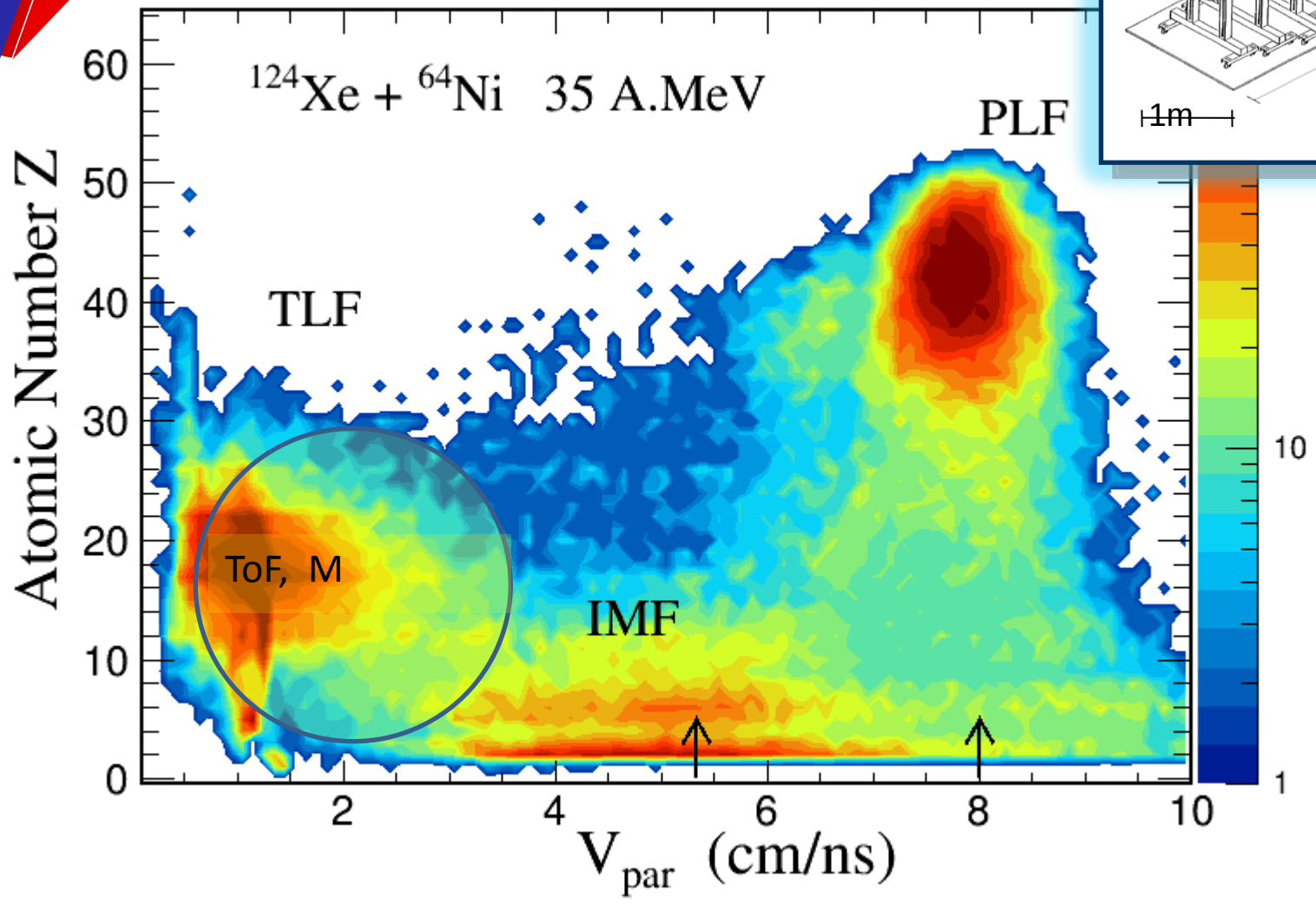

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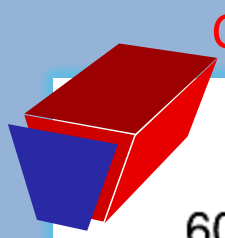
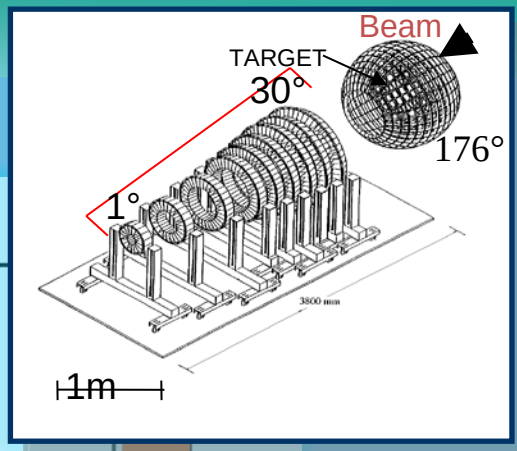
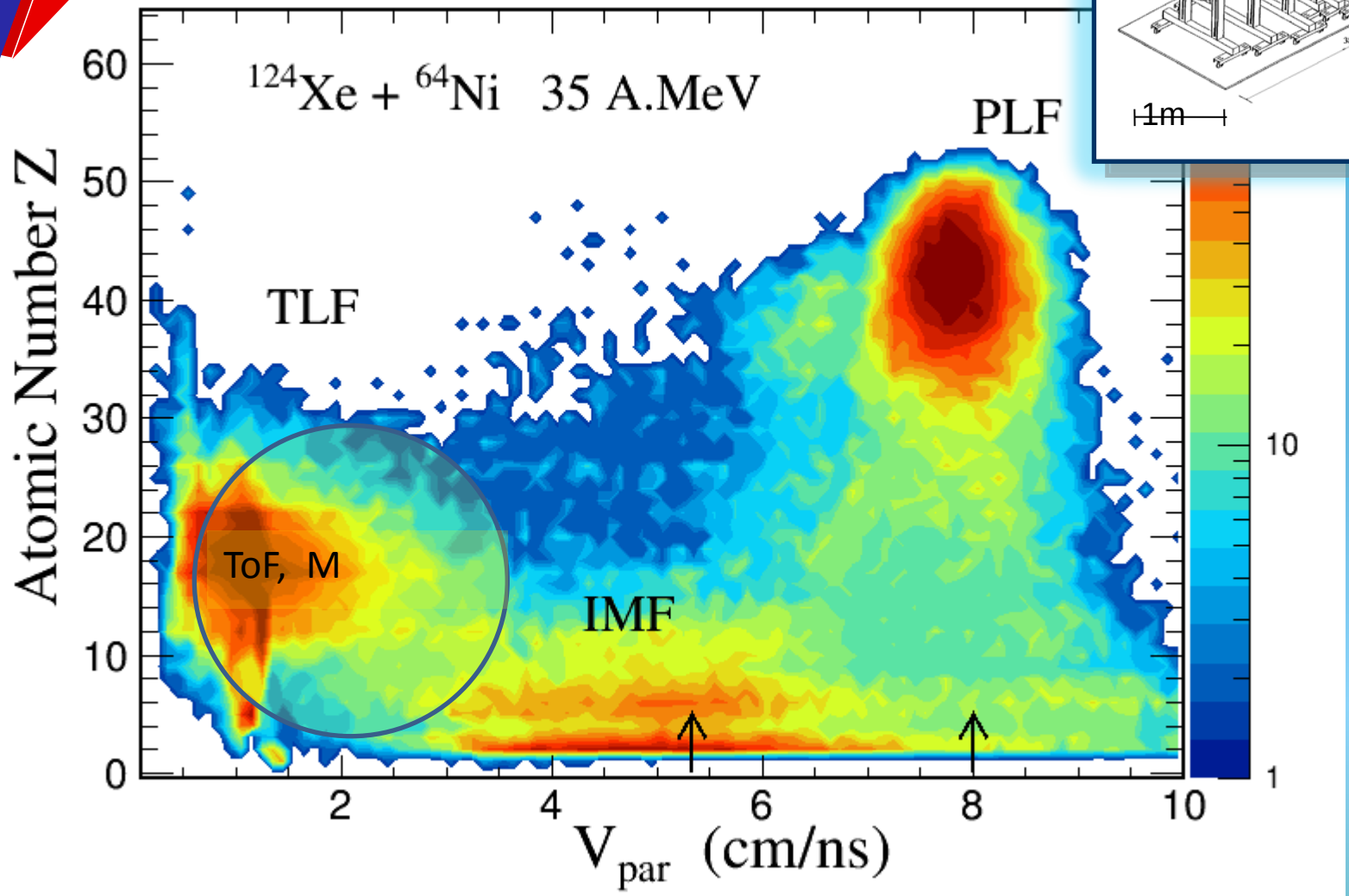


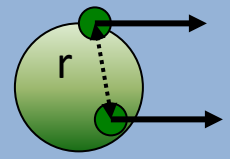



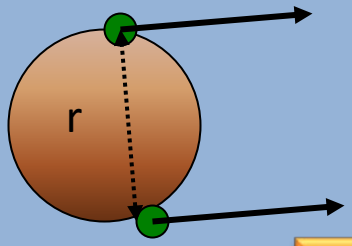

What is FARCOS and **why** we need it ?

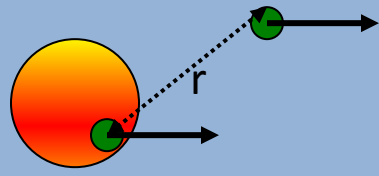
# CORRELATORS: physics case

**HBT interferometry:**
particle correlations at small relative momentum;
nuclear dynamics;
Space-time characterization of the emitting source;
Emission time: from pre-equilibrium emission to secondary decay
Connections with Asy-Eos in asymmetric nuclear matter




**more correlation** if source is smaller in **SPACE**

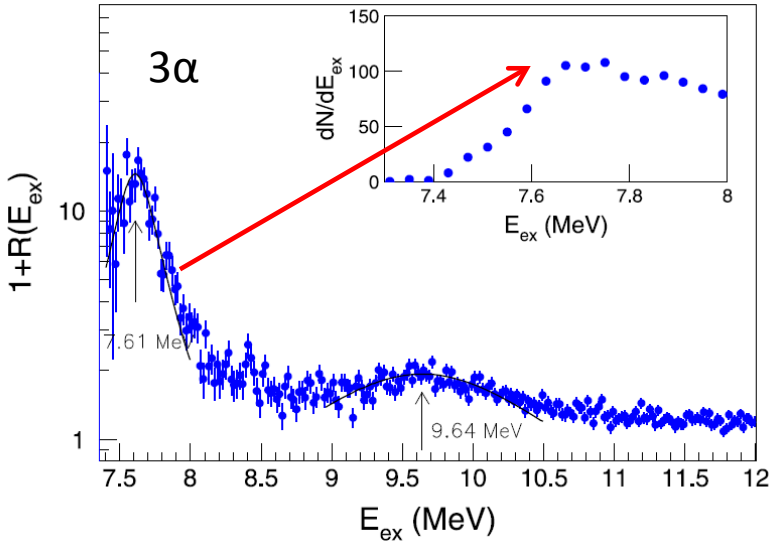



**more correlation** if source is smaller in **TIME**

**Multi particle correlations**:
Spectroscopy of unbound states;
Cluster structures

**Chimera data**




3α correlation function in $^{12}C$ evidencing the Hoyle state at 7.61 MeV

Ad. Raduta et al., PLB 705, 65 (2011)

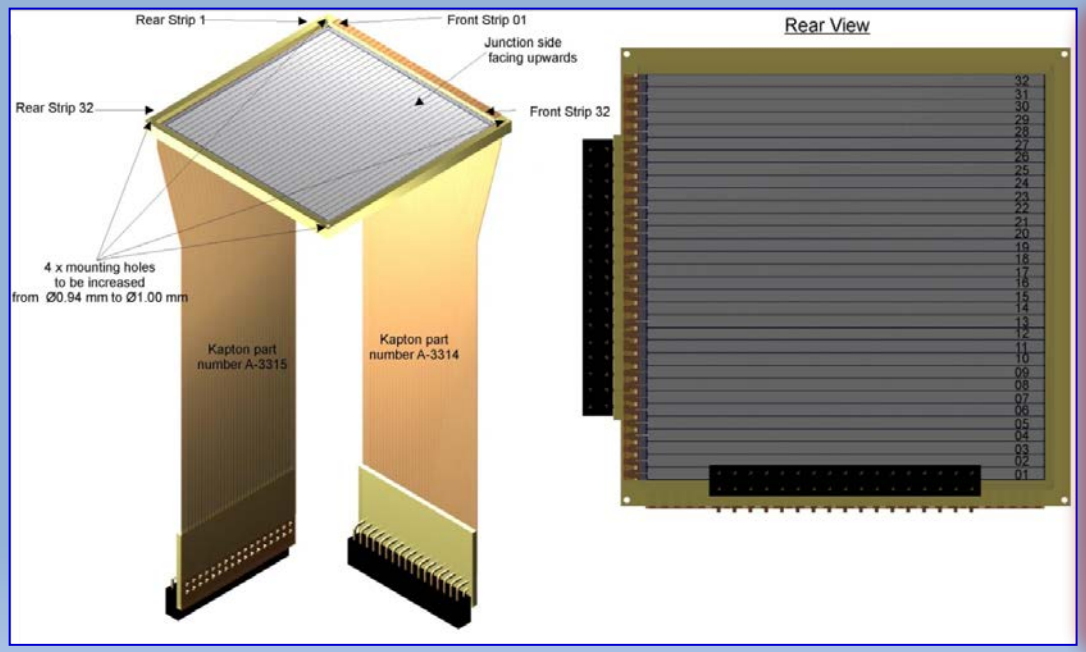
See next talk

# What is FARCOS and **why** we need it ?

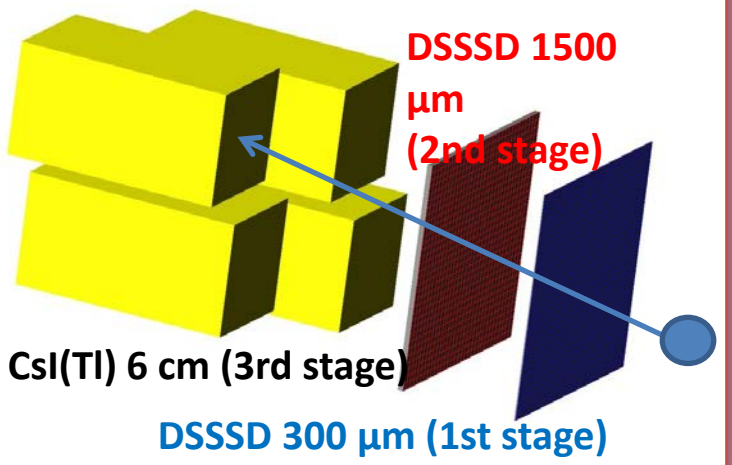
**High energy and angular resolution ($\Delta\vartheta$<1°)**
**Low thresholds ( <1 MeV/A):**
**Pulse-shape on first Si layer for low energy experiments**
**High counting rate (1KHz)**
**Large Dynamic range (20MeV to 2GeV)**
**Flexibility, Modularity, Trasportability**
**Easy coupling to 4$\pi$ detectors or spectrometers**
**Integrated Electronics (GET)**

# FARCOS: Femtoscope Array for COrrelations and Spectroscopy

Technical Design Report (TDR): https://drive.google.com/file/d/0B5CgGWz8LpOOc3pGTWdOcDBoWFE/view




132 channels by each cluster




High angular and energy resolution

**64 mm, 32 strips, Double-Sided Silicon Strip Detectors**
**produced by Micron Semiconductor.**
**(300 and 1500 µm / C= 25pF and 5pF )**
**Capton cable 2x32pin connectors**
**Minimum PCB**
**frame-area thick, 4 mm,**
**frame-thick 6.5 mm**
**ΔE= 20KeV** (α 5.48 MeV) **ΔE/E (elastic)=0.2-0.3%**
**Rise time<20ns**

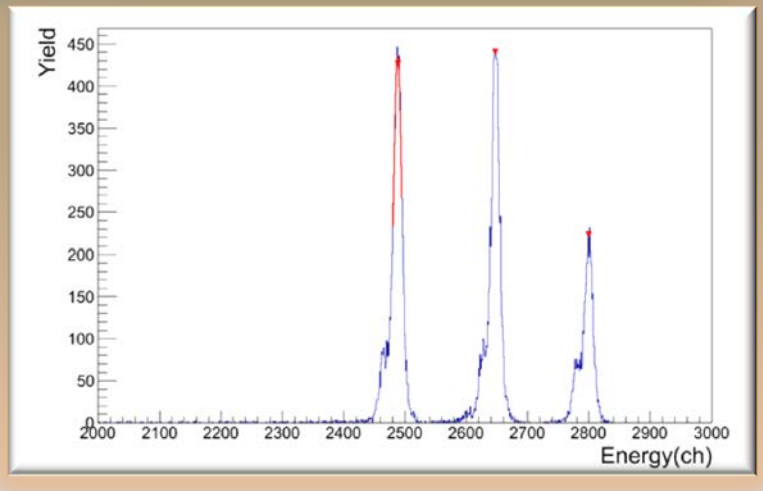
**Highly homogeneous CsI(Tl) crystals**
**produced by SCIONIX.**
**Wrapped with 0.12 mm thick white reflector +50 µm aluminized mylar.**
**Aluminized mylar window 2 µm thick (0.29 gr/cm$^2$). Read by Photodiode Hamamatsu 300 µm**
**ΔE/E=2-3%** (α 5.48 MeV)

# **The** FARCOS prototype (4 telescopes, used in all experiments and test up to 2016)

## Pre-Amplifier stage



**1500 µm DSSSD with Mesytec resolution ≈26 keV with 3 alpha source and standard DAQ**




Front-end electronics in experiments for the FARCOS prototype:

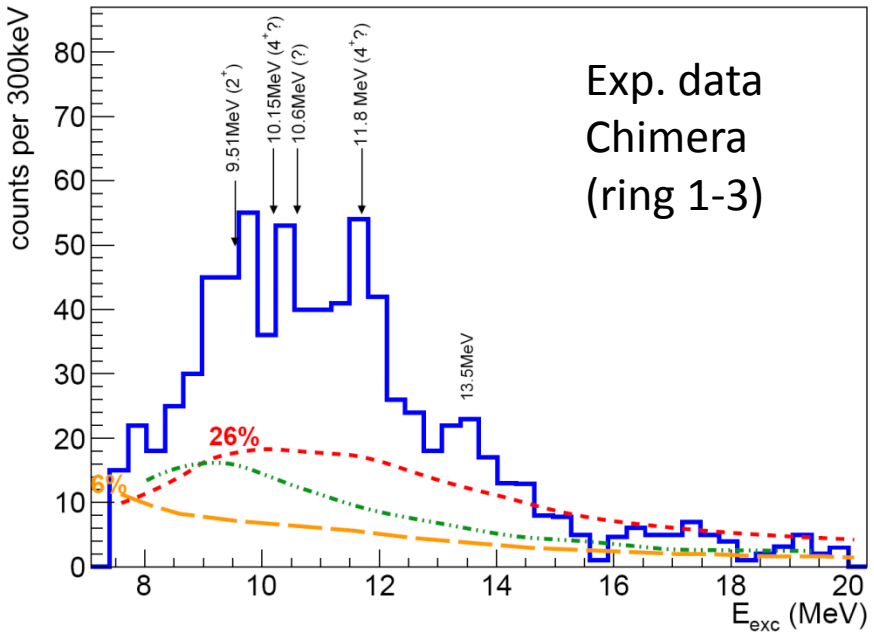
**Standard CHIMERA NIM (16 channels) pulse shape amplifiers + analog (VME) CHIMERA DAQ**

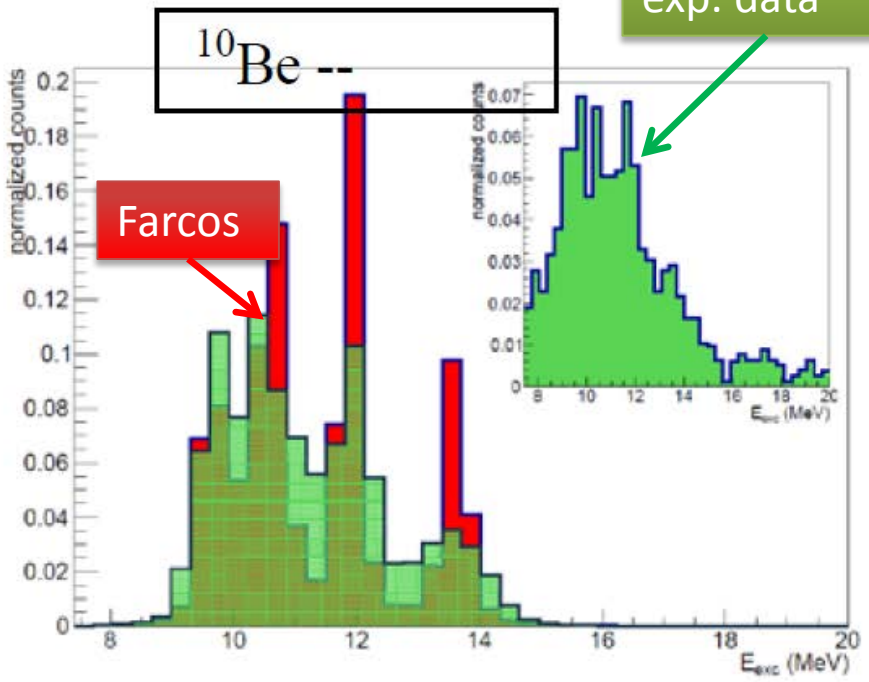
or (few test channels)

**Digital acquisition of PAC signals with GET electronics**

# Relevance of energy and angular resolution with FARCOS: an example

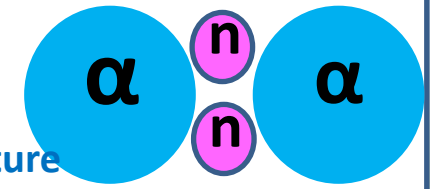
MonteCarlo simulations for the $^{10}$Be* decay (α+$^{6}$He channel) in Chimera and Farcos setup (as in the CLIR experimental setup: 4 telescopes placed symmetrically around the beam axis).




see: D. Dell' Aquila et al.,
Phys. Rev. C93, 024611 (2016)

**$^{10}$Be**:
**Signals of molecular structure**



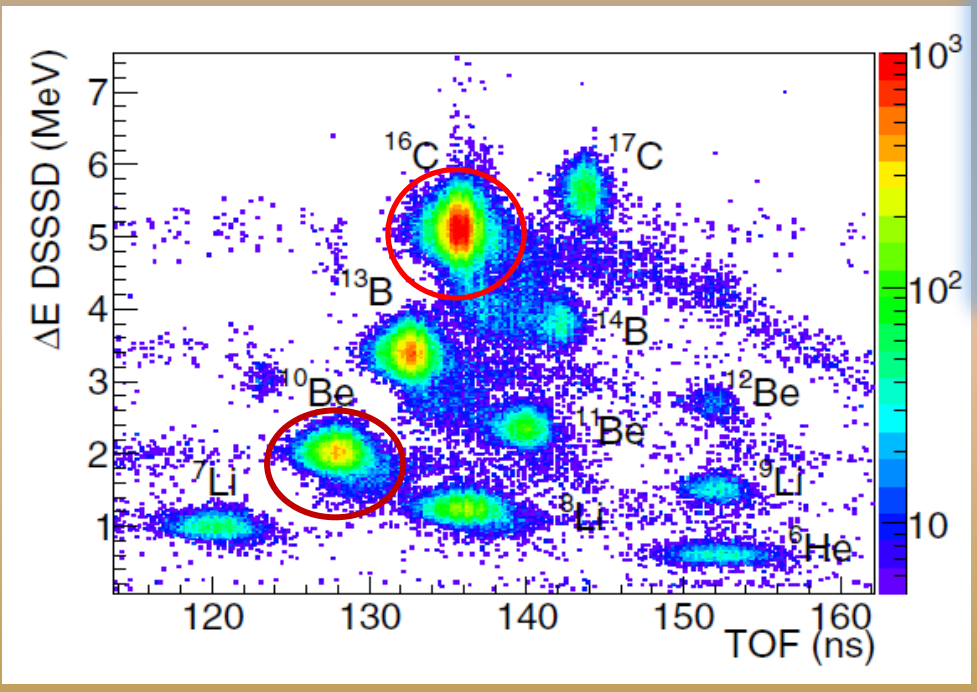

M. Freer et al. PRL 96, 042501 (2006)

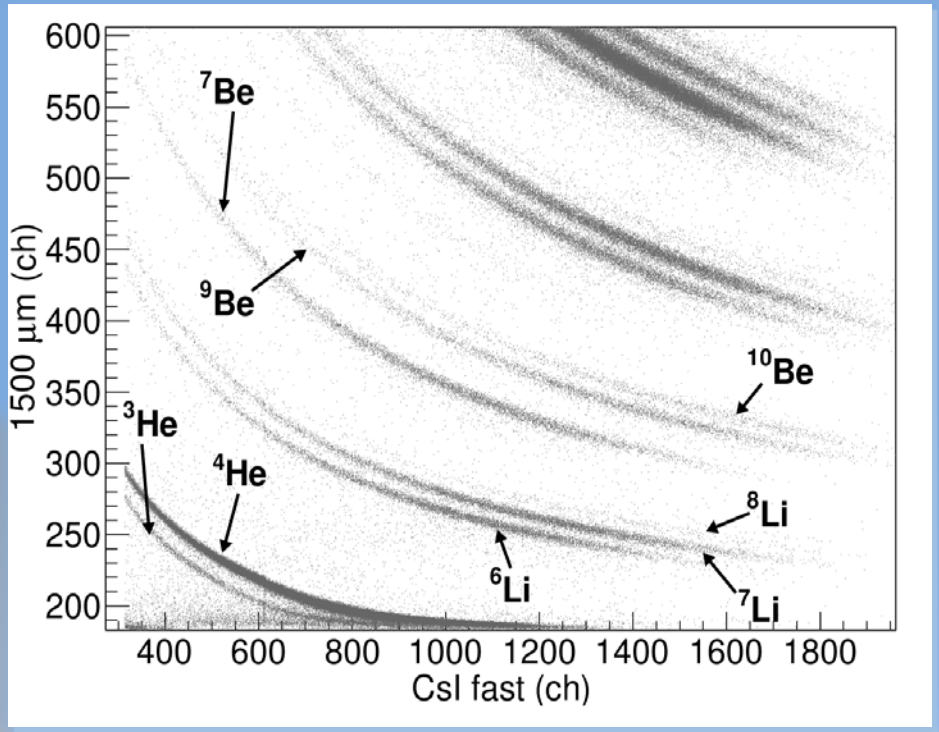
# The CLIR experiment (clustering phenomena in exotic nuclei)

Study of the structure of $^{10}$Be and $^{16}$C by means of sequential break-up at intermediate energy

*FRIBs cocktail beams from $^{18}$O + 1.5 mm Be target, 55 A.MeV primary beam, as seen by the Chimera tagging system*

$^{16}$C $(49{,}5\ MeV/u)\ 10^5\ pps$;
$^{13}$B $(49{,}5\ MeV/u)\ 5 \cdot 10^4\ pps$;
$^{10}$Be $(56{,}0\ MeV/u)\ 4 \cdot 10^4\ pps$;




D. Dell'Aquila et al., Phys. Rev. C93, 024611 (2016) and IWM-EC 2016 (proceedings in press).

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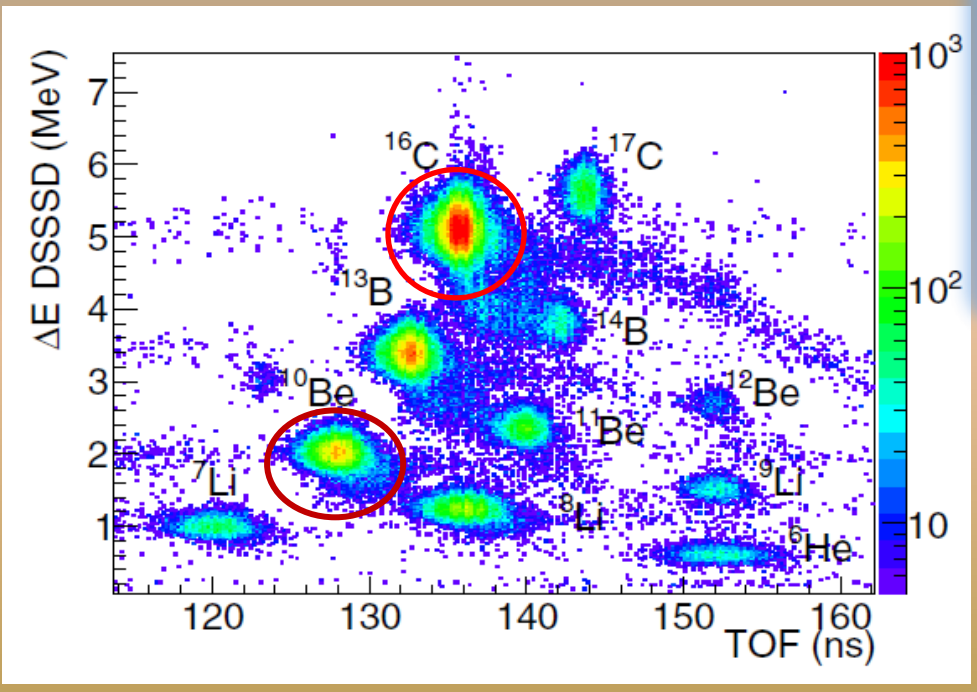
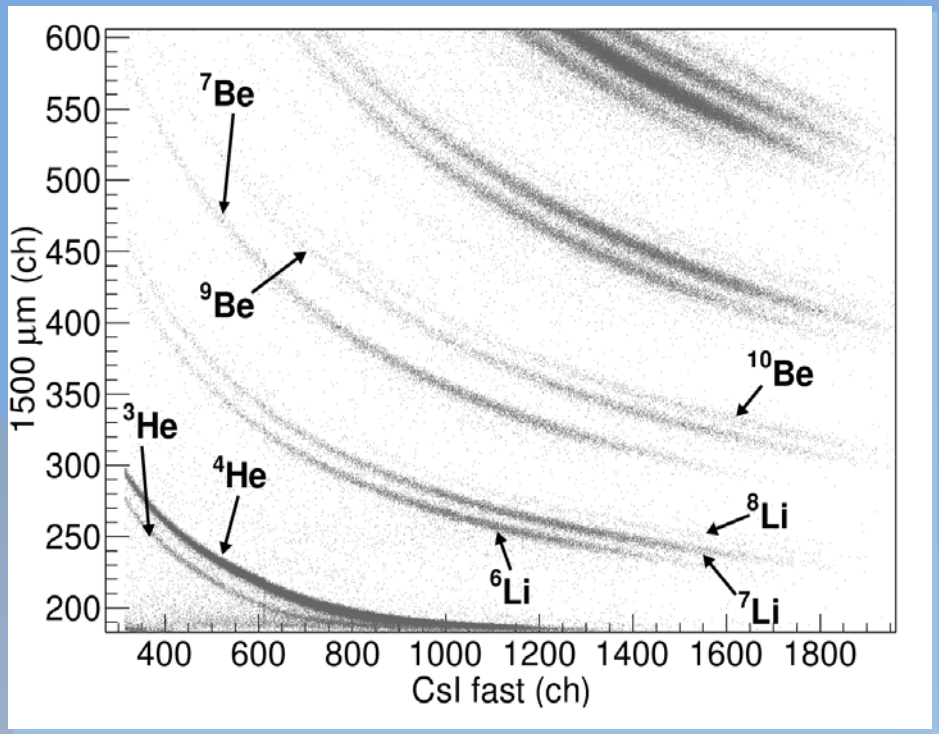


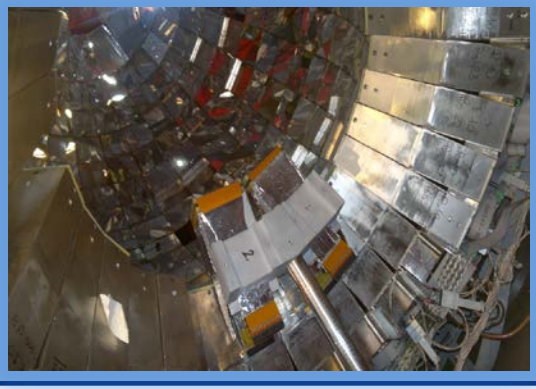



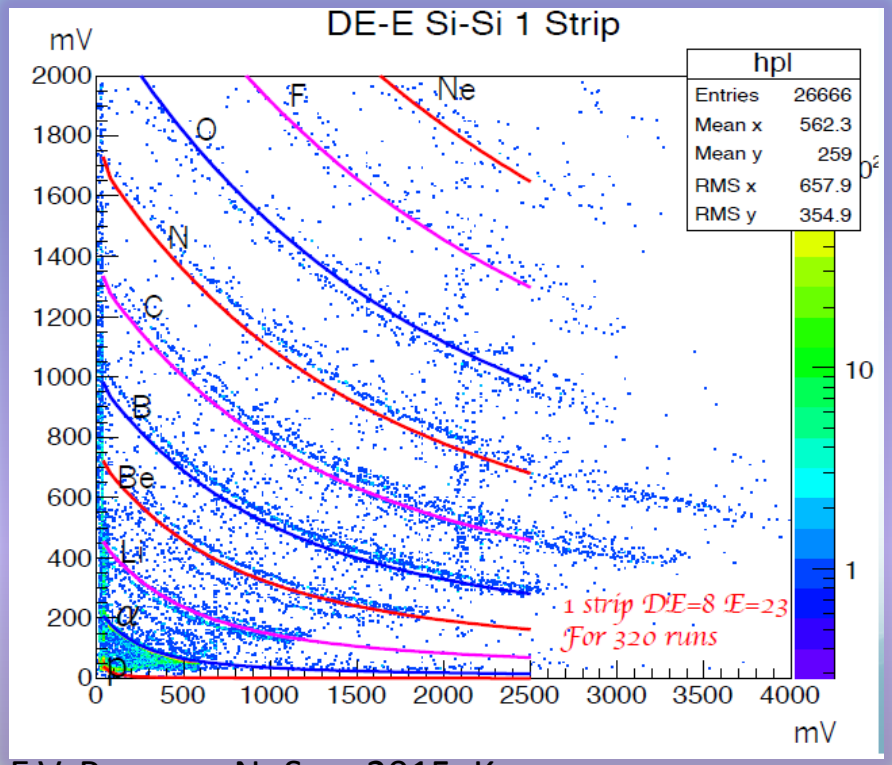

**exp CLIR in JUNE 2015:**
**CHIMERA + FARCOS prototype**

D. Dell'Aquila et al., Phys. Rev. C93, 024611 (2016) and IWM-EC 2016 (proceedings in press).

# **Setup:** The 4π CHIMERA + a module of FARCOS prototype in the InKiIsSy (Inverse Kinematics Isobaric Systems) experiment: $^{124}$Xe + $^{64}$Zn,$^{64}$Ni@35 A.MeV

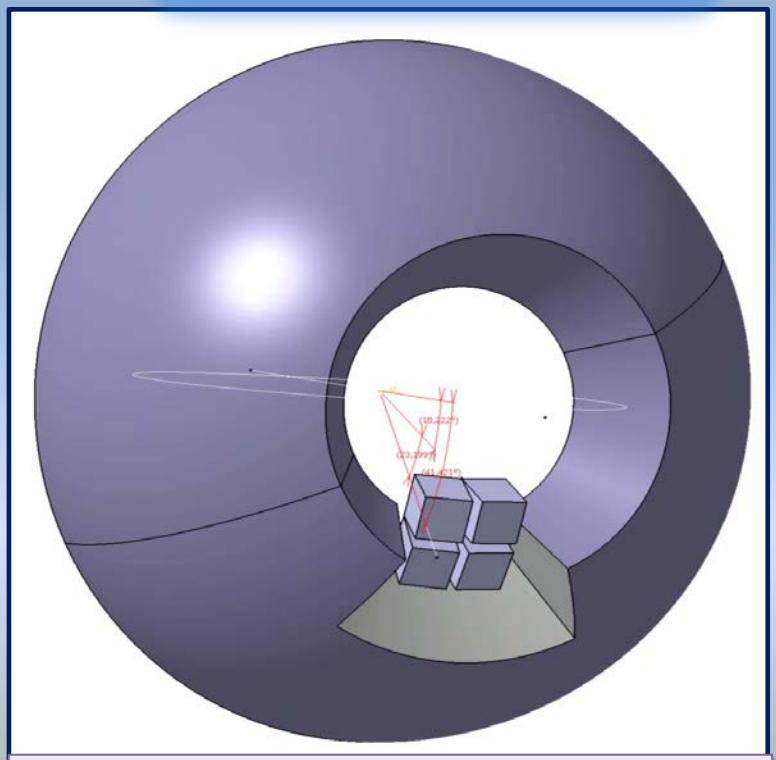
Physical case: competition between dynamical and statistica IMF emission.
Influence of the N/Z ratio of the entrance channel in the dynamical fission of th quasi-projectile






E.V. Pagano, NuSym 2015, Kracow

See P. Russotto et al., Phys. Rev C91, 014610 (2015) and E.d.F. et al.



4 telescopes 25 cm from the target
$\theta_{lab}$ ~ 15-45 deg, $\Delta\phi$ ~ 75 deg

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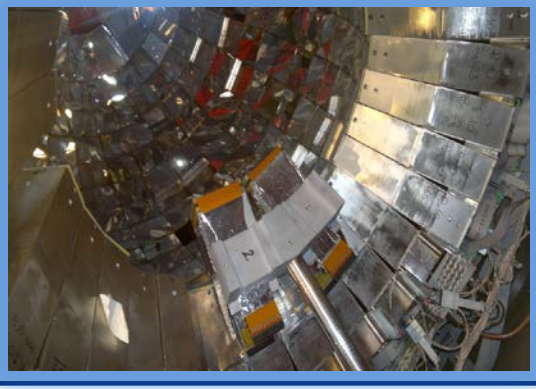
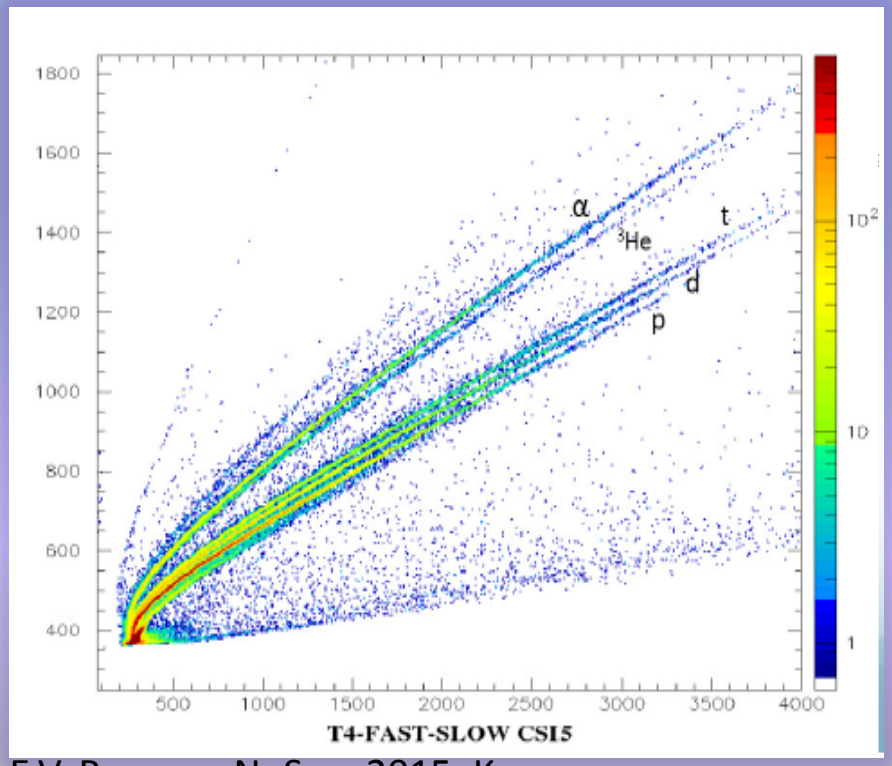
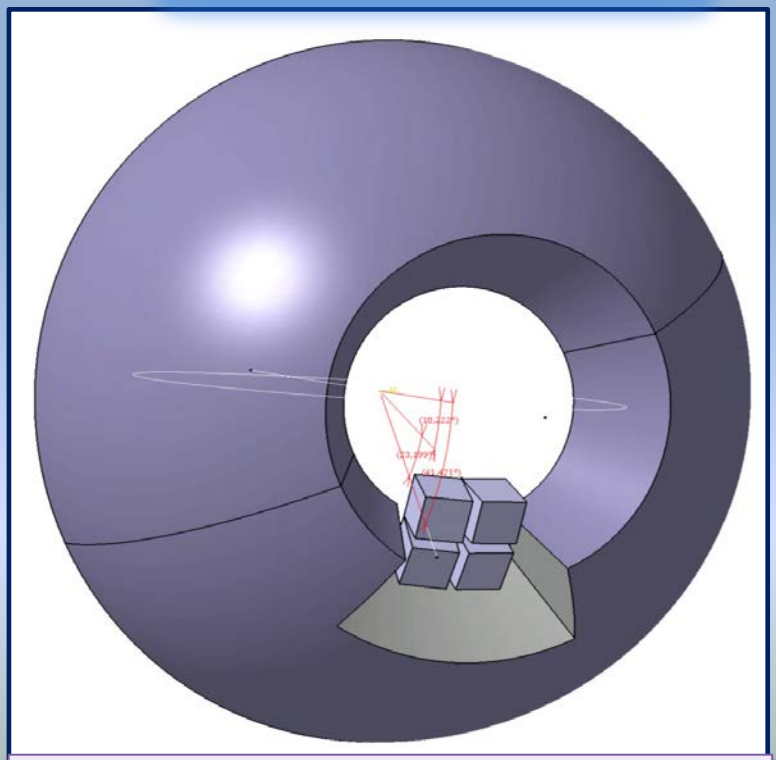





E.V. Pagano, NuSym 2015, Kracow



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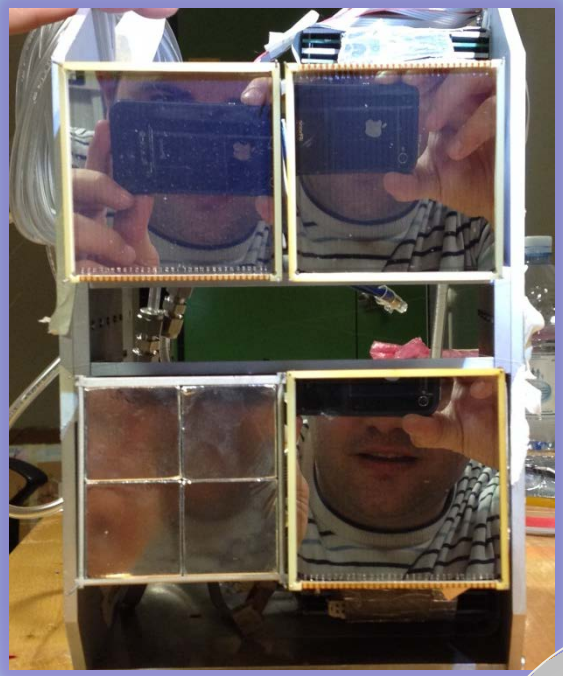
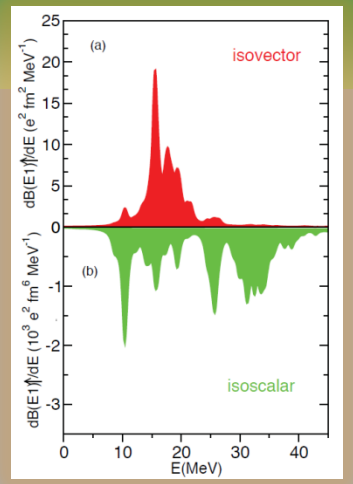
$\theta_{lab}$ ~ 15-45 deg, $\Delta\phi$ ~ 75 deg

See P. Russotto et al., Phys. Rev C91, 014610 (2015) and E.d.F. et al.

# Setup: Detection system for the Pygmy experiment

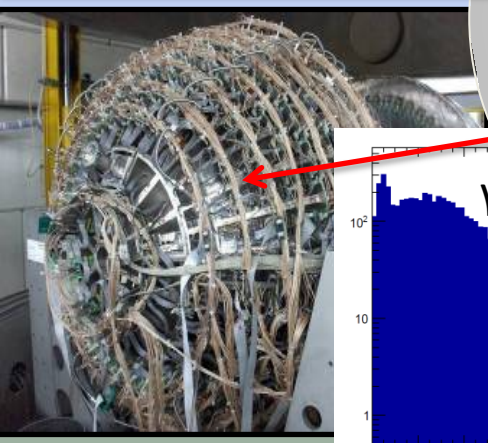


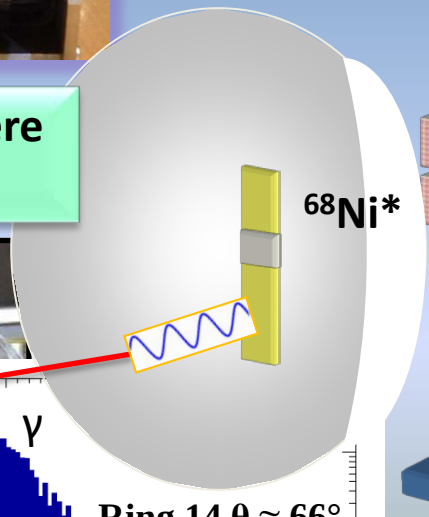
Search of the isoscalar excitation of the PYGMY resonance in $^{68}$Ni using the LNS FRIB facility from a 40 A.MeV $^{70}$Zn primary beam

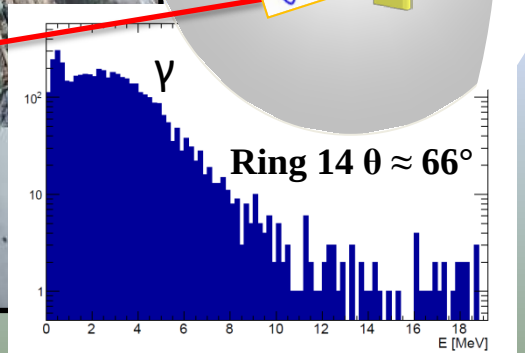


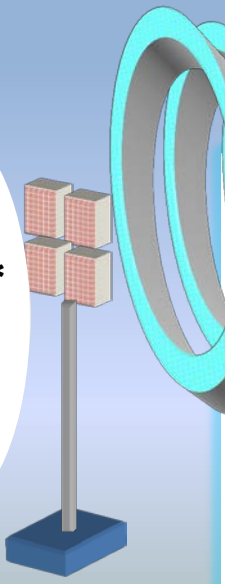

**FARCOS detects and identifies the $^{68}$Ni (stopped in the two silicon stages of the telescopes)**

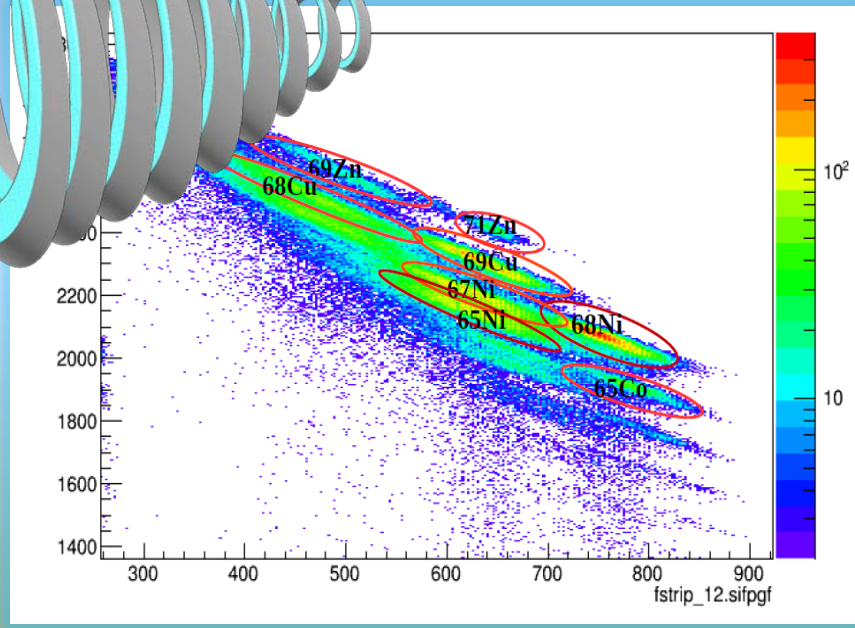
**The CsI(Tl) in the Sphere provide γ detection**





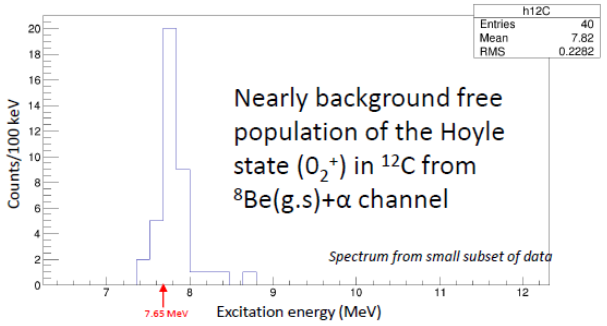





# FARCOS in Siko experiment

**SiKo experiment**

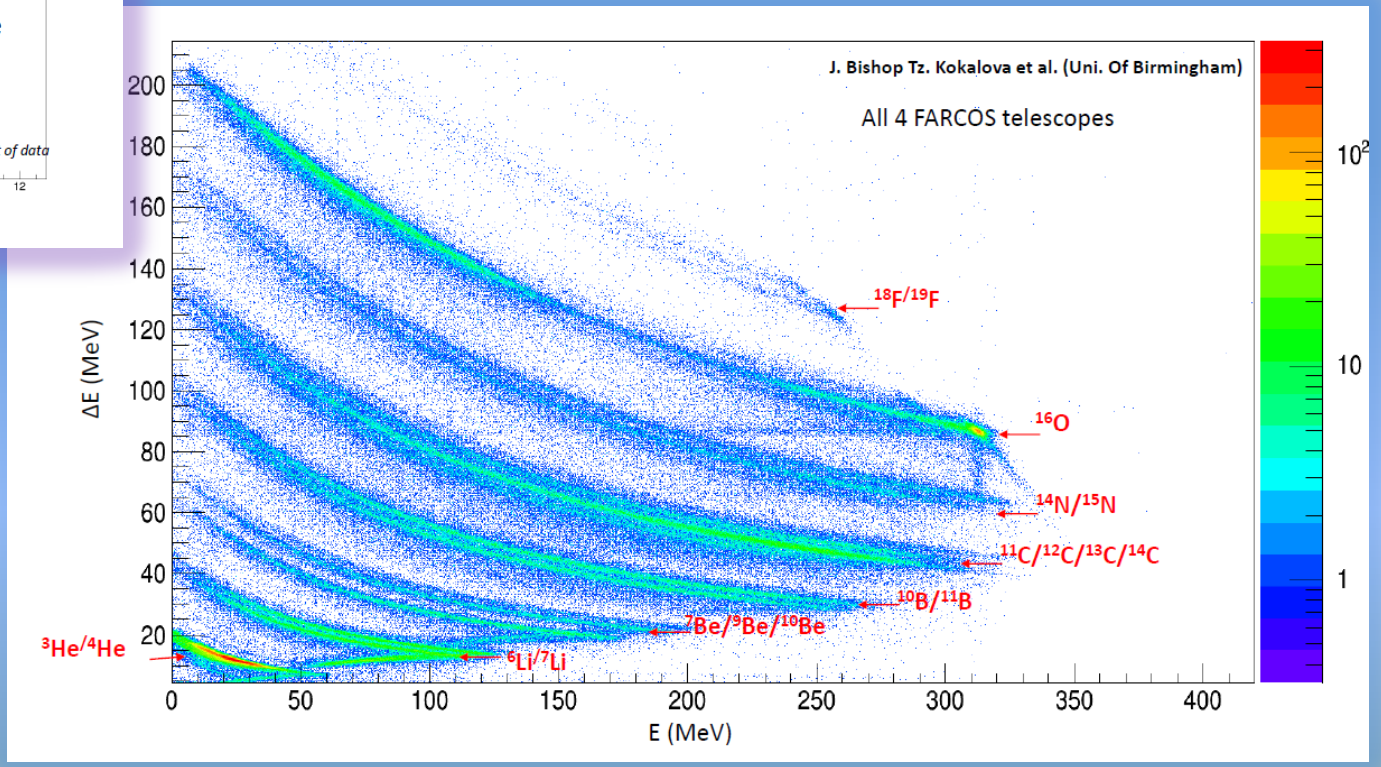
- University of Birmingham (UK) & INFN-LNS (Italy)
- Performed at LNS-Catania with K800 cyclotron
- $^{16}O$ beam on $^{12}C$ (nat.) target @ 160, 280, 400 MeV
- Combination of FARCOS+CHIMERA:
  - CHIMERA allows for high solid-angle coverage
  - FARCOS provides high resolution excitation spectra




University of Birmingnam & CHIMERA collaboration

J. Bishop, Tzani Kokalova et al. (University of Birmingham)

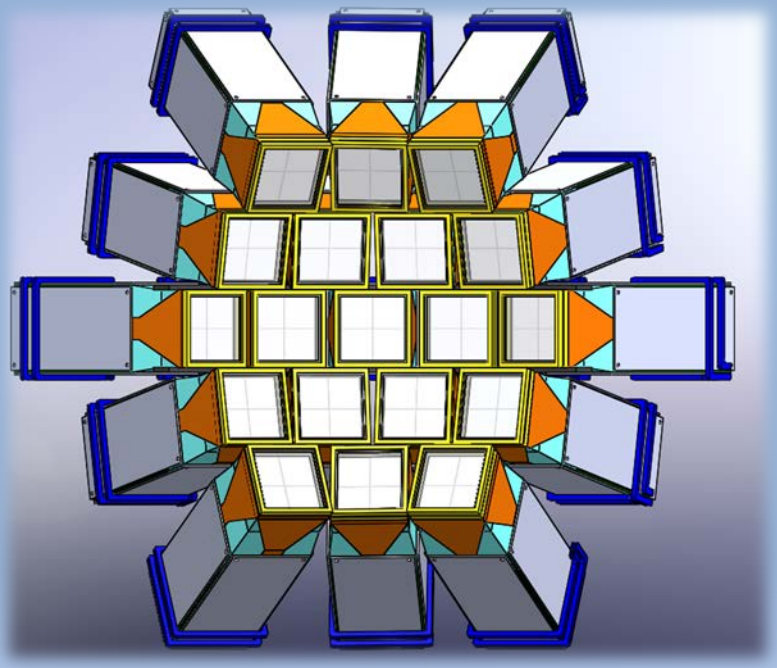
Main goal: to find evidence of α-gas like states in $^{28}Si$

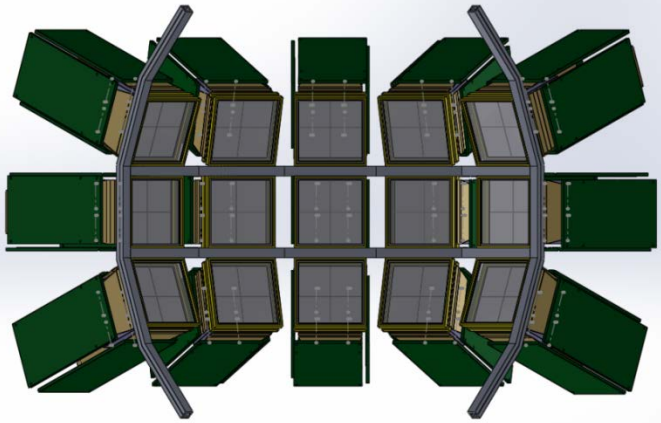


# Assembling of the «real» FARCOS: high modularity

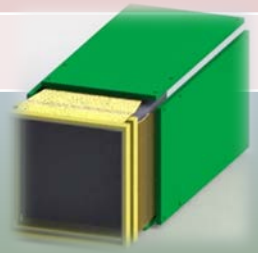
Starting prototype: 4 telescopes : NEWCHIM (2015-2019 final planning 20 telescopes)

| Year | Tel. | Operation |
|---|---|---|
| 2015 | 6 | test acq. GET for FARCOS<br>construction of 2 telescopes<br>purchase of final GET electronics |
| 2016 | 10 | test dual gain module<br>test GET electronic +DAQ<br>Study of alignment system |
| 2017 | 14(10) | test new asic pre-amplifiars<br>final design modular support<br>implementation asic pre-amplifier<br>new DAQ VME+ GET running<br>First experiments with new Chimera+Farcos front-end |
| 2018 | 18(?) | Construction of new telescopes |
| 2019 | 20+2 | 20 telescopes ready |
| . . . . . | | |



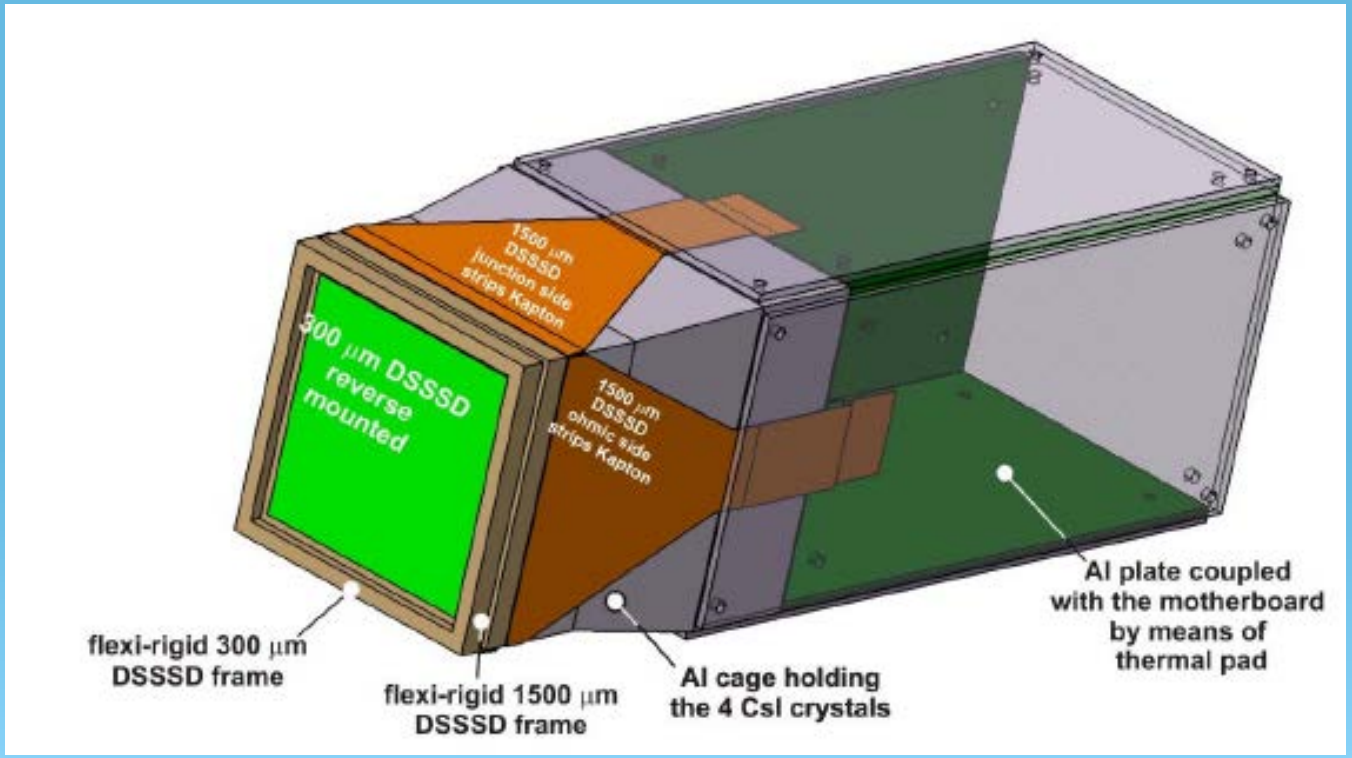


Design simulation: Luis Acosta



Final cost prediction: ≈< 1 M€

# Assembling of the «real» FARCOS: high modularity




A Kapton cable connects each face of each DSSSC to a custom PCB motherboard housing the front-end ASIC (2x(16+1) channels.

# *Why a new front-end electronic ?*

The final FARCOS array constituted by 5 modules (20 telescopes, in the final project) needs the readout of about **4k** channels.

CHIMERA CsI(Tl) front-end (1192 detectors) is now obsolete, in particular the amplifiers and the **VME** QDCs for CsI fast-slow component integration (more than 15 years old technology).

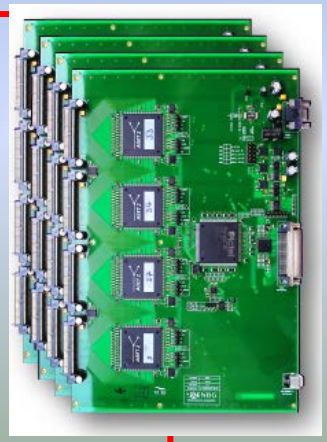
**Our choice was to develop a first stage front-end circuit for FARCOS (including new ASIC pre-amplifiers) and new dual-gain modules coupled to a compact hardware architecture covering digitalization and signal readout, syncronization and trigger functions . All these last aspects are covered by the GET project.**

**Consequences → digital DAQ for Farcos and CHIMERA (CsI) + Analog DAQ (Silicons)**
**Upgrade of the CHIMERA front-end for CsI(Tl) (in progress….)**

R&D Financed 75% (France)
25% (USA)

## GET Project

Project supervisor: E. Pollacco



# More advantages

## Standard CHIMERA

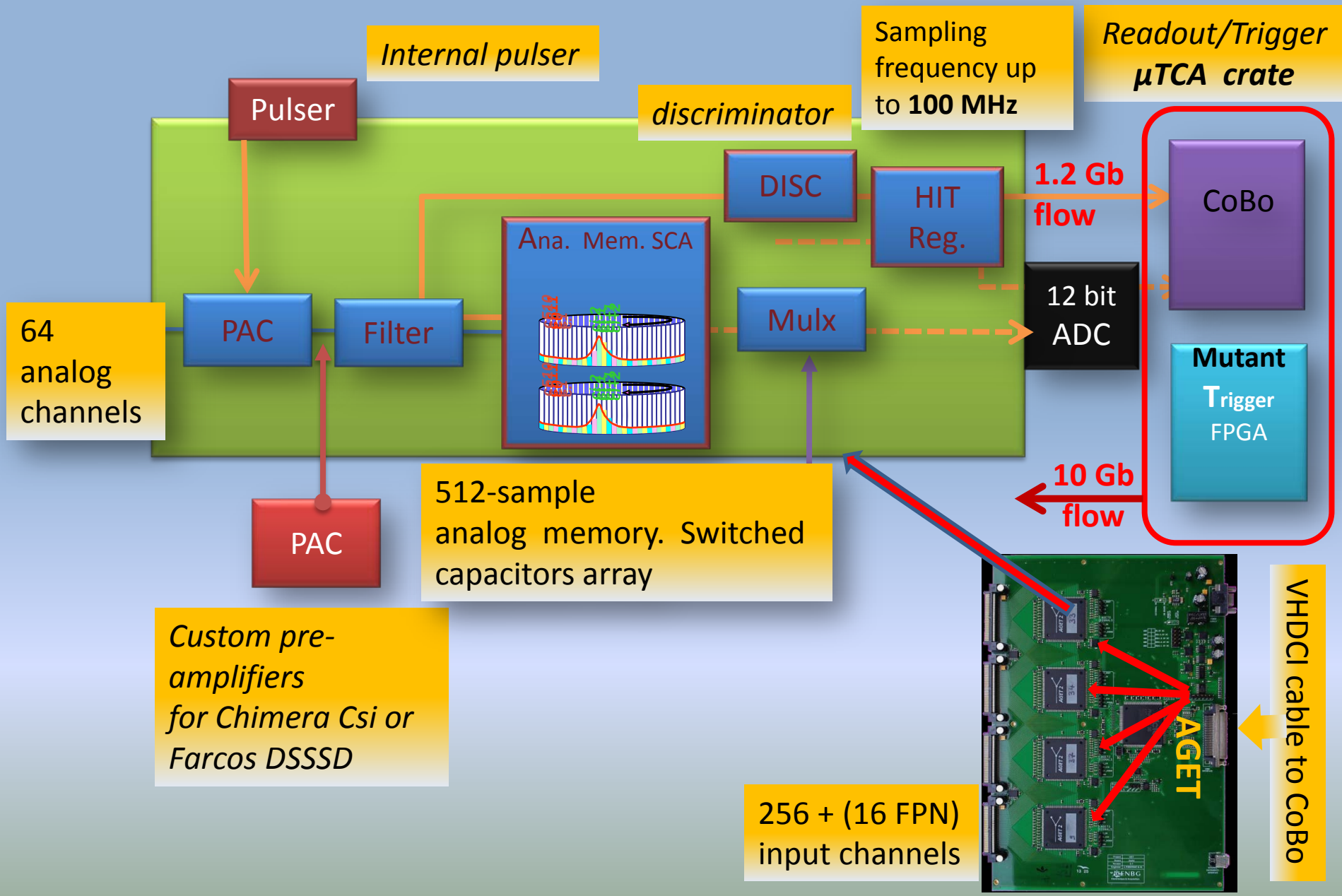
## GET

COMPACT
1+1/2 crate all chimera+ farcos electronics

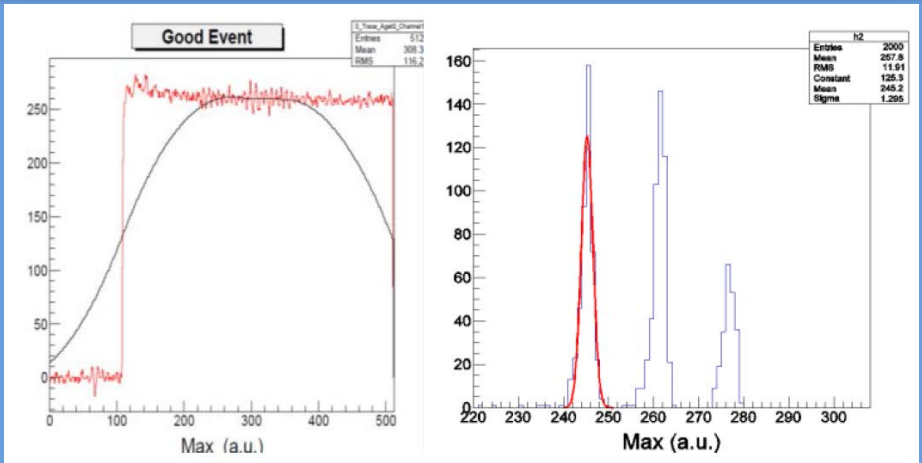
5W for 256 channels

With CHIMERA we need now about 60 kW power on 10 Racks

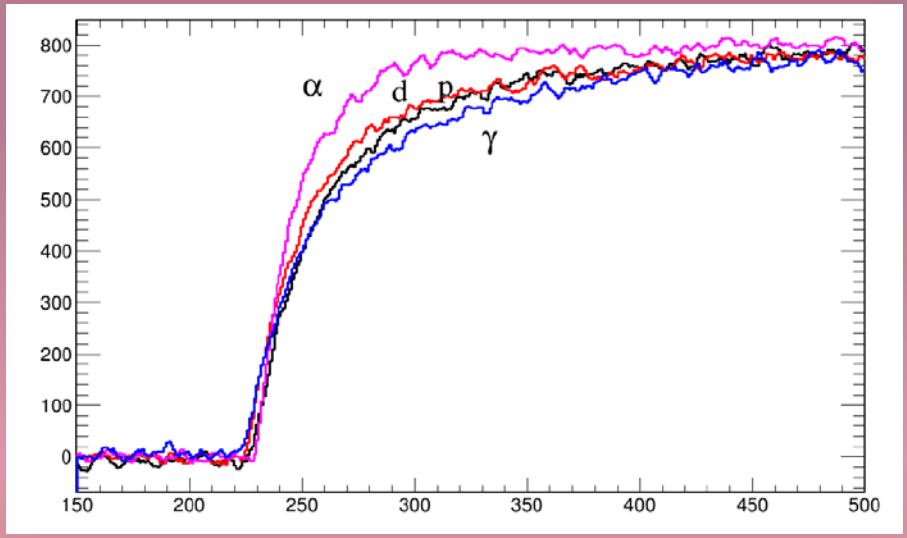
# THE AGET ASIC in the ASAD board



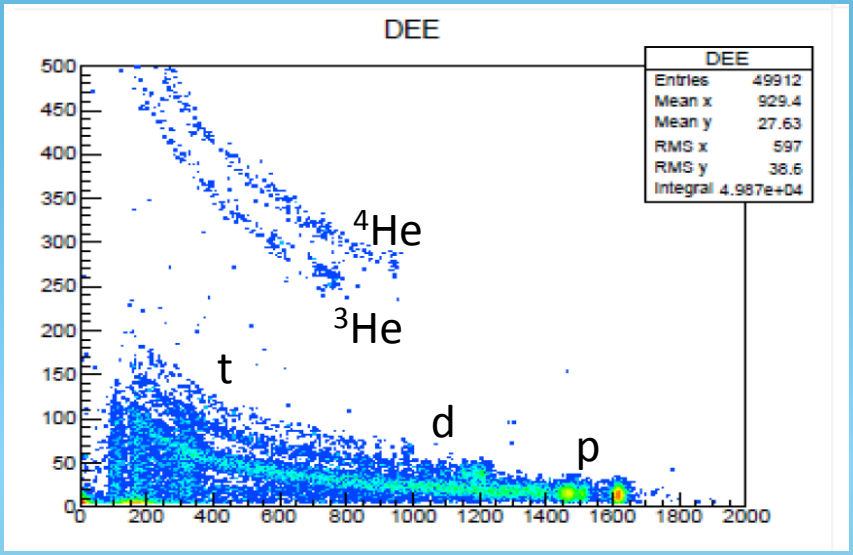
# Tests performed on Farcos and CHIMERA




Digitized pre-amplifier (10 mV/MeV, 100 MeV dynamical range) signal after baseline restore and triangular filter and resulting three peaks alpha source (data obtained with R-Cobo readout ) on a FARCOS strip




Collection of signals in CsI(Tl) for different particles releasing the same light and digitized at 25 MSamples (test with 62 MeV proton beam)

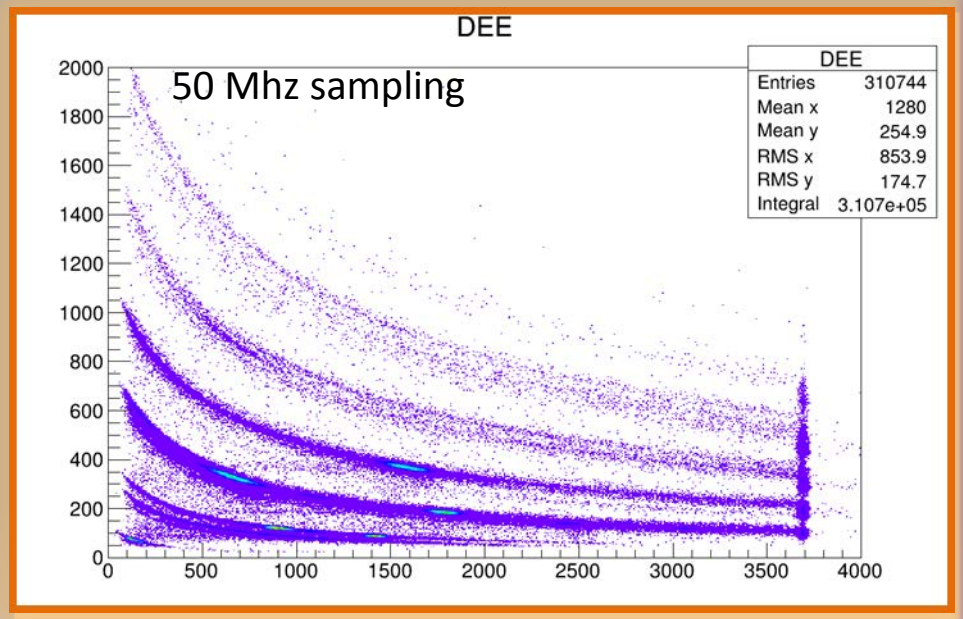


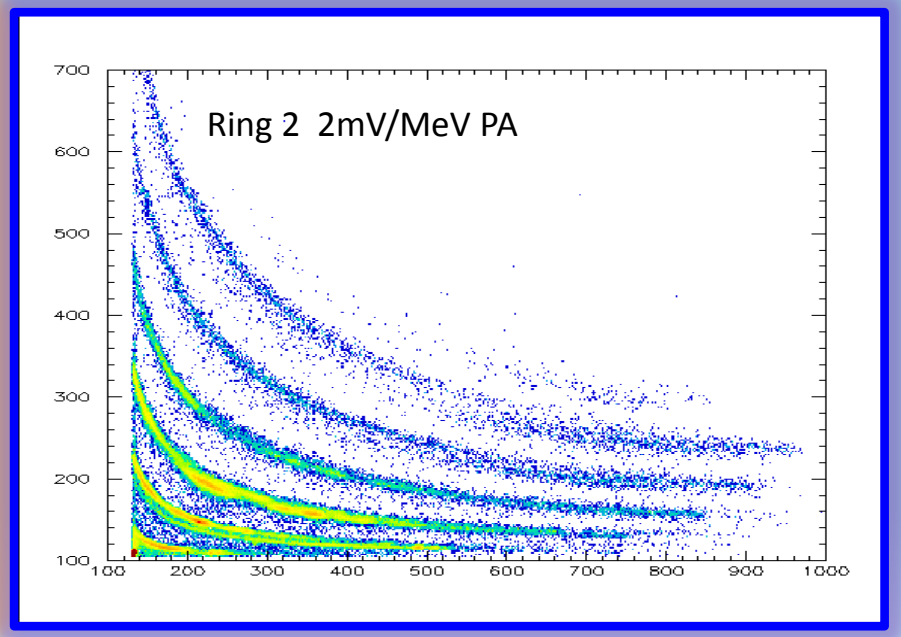

ΔE-E scatter plot in the same experiment p+deuterated plastic target at 62 MeV (Chimera).

# Tests with fragmentation beams (≈ 50 A.MeV) on plastic target

**Data from CLIR@LNS experiment**

Fast component (CsI) vs. ΔE (Silicon

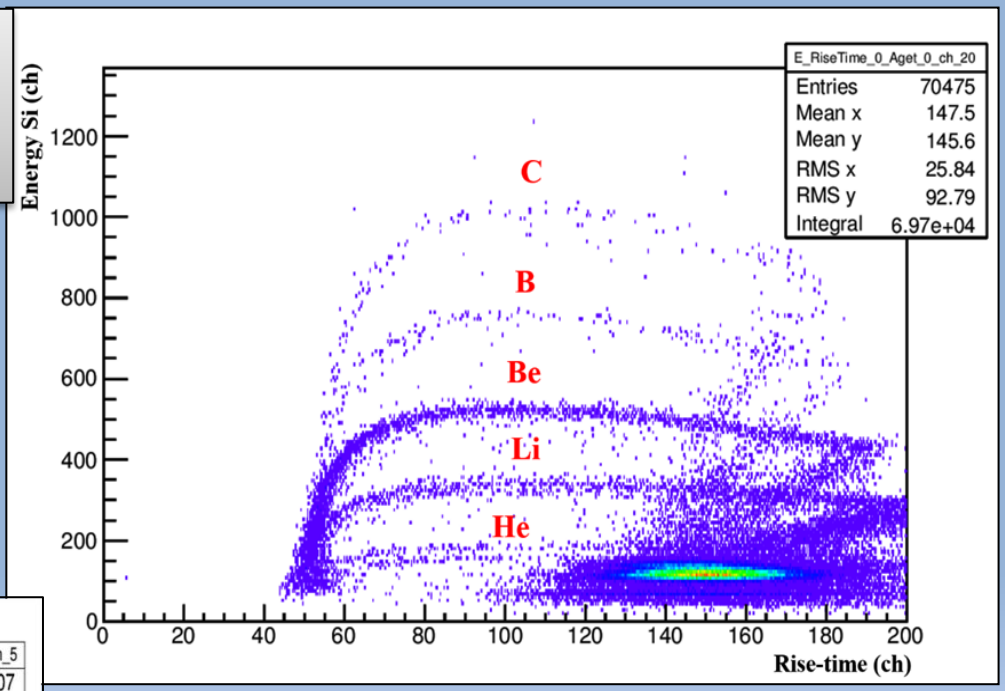


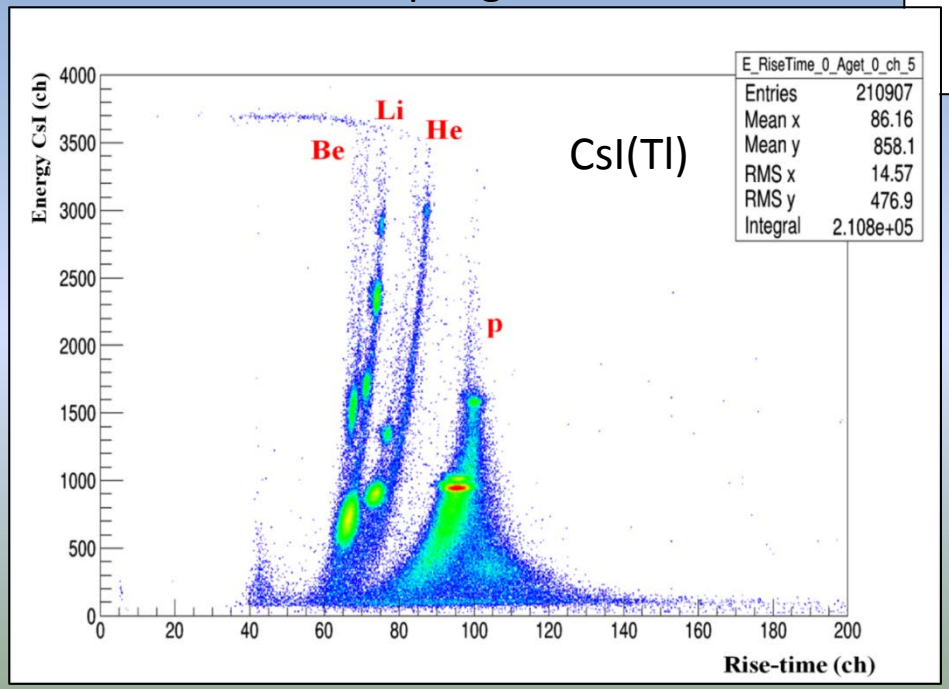

- Standard CHIMERA preamplifier used in the silicon stage (2 mV/MeV) [Chimera, ring 2E]
- The signals are digitized at a frequency of 50MHz
- Both signals Si/CsI are shaped with a 1µs shaping time in the SKF filter stage of AGET chips.
- Better isotopic resolution obtained with GET.
- ⟹ Note the CHIMERA CsI fast component signal saturation → dual gain (DG) module needed (as well for FARCOS silicon strips)

# Tests with fragmentation beams (≈ 50 A.MeV) on plastic target

Si, pulse shape test without HV power supply in Si

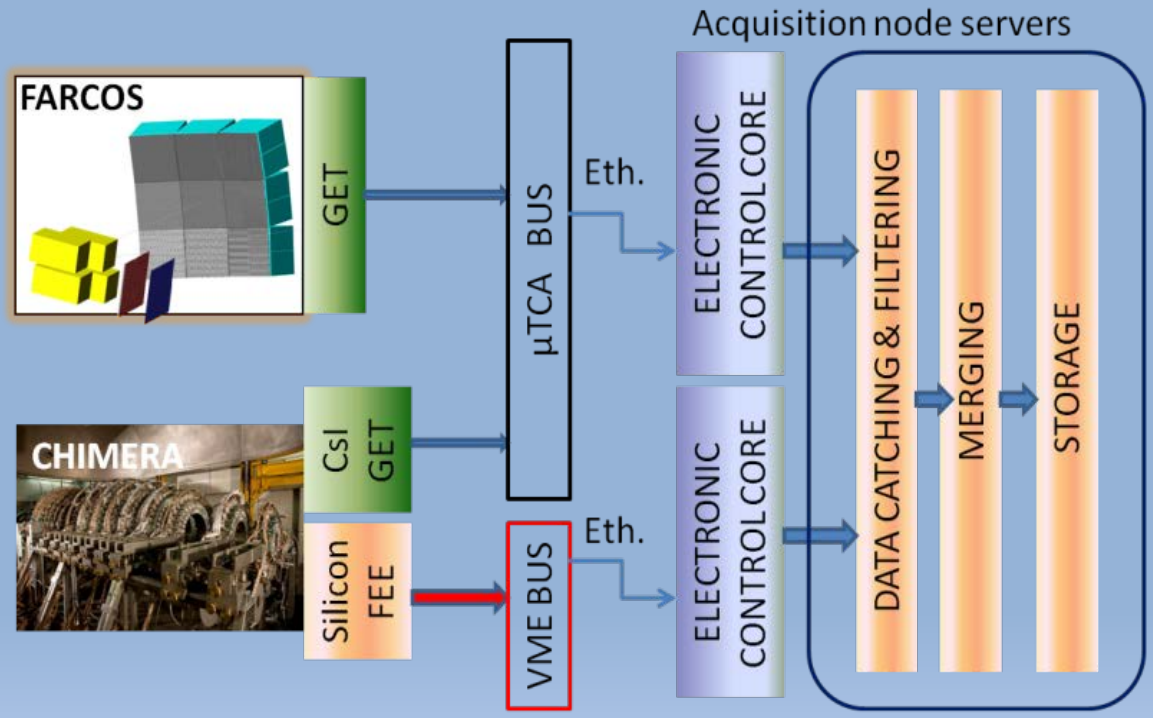



Test at 25 MHz sampling




S. De Luca, PhD thesis

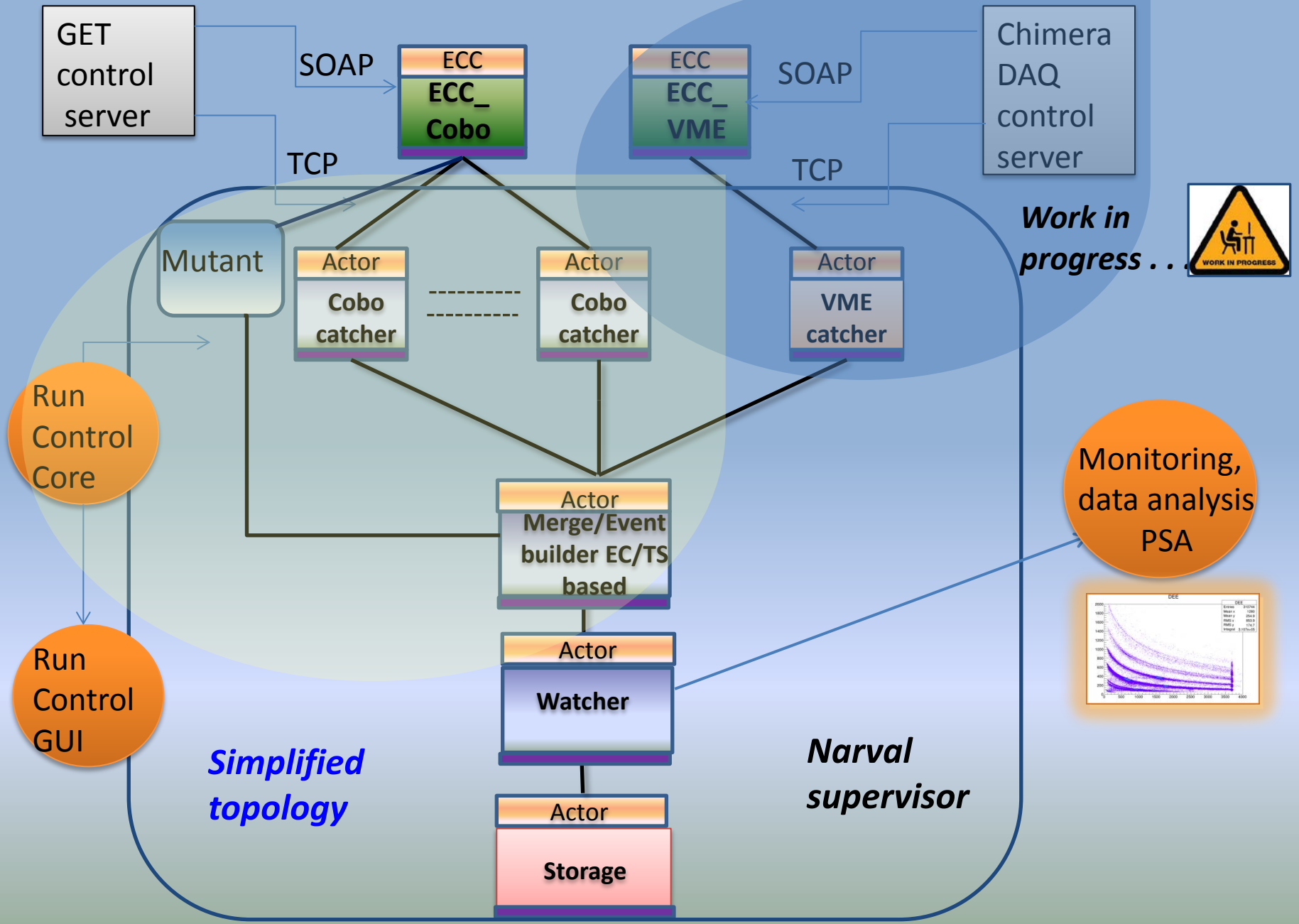
# GET + CHIMERA DAQ COUPLING (a brief overview)




We use «**NARVAL**» as supervisor for both CHIMERA and GET data acquisitions

- developed at IPN-Orsay by X. Grave
- based on the concept of generic **Actors**
- written in OO language ADA with C++ interface
- Data flow: TCP/IP
- Run Control Core and GUI interface based on Java (GANIL)

# GET + CHIMERA DAQ COUPLING (a brief overview)



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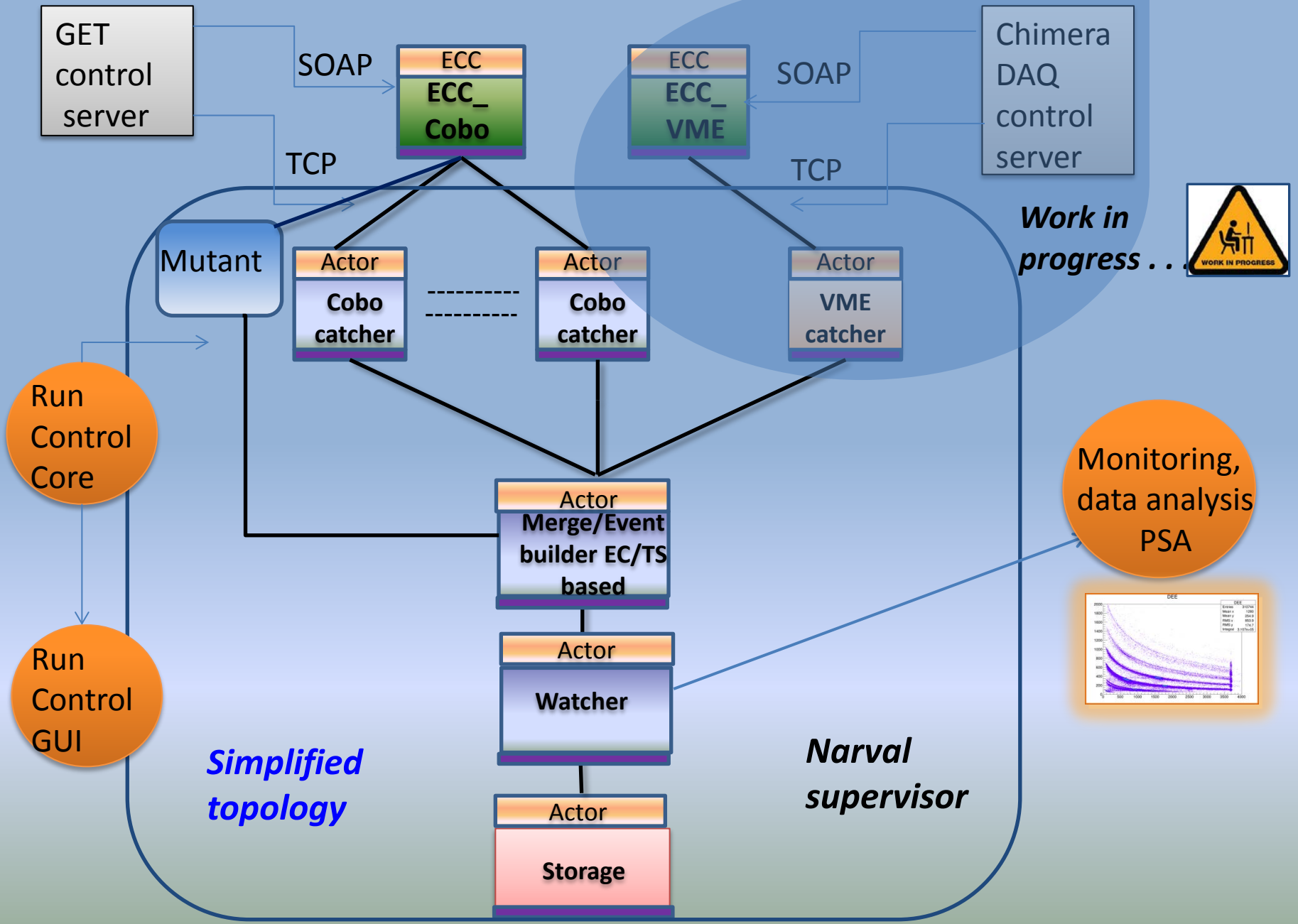


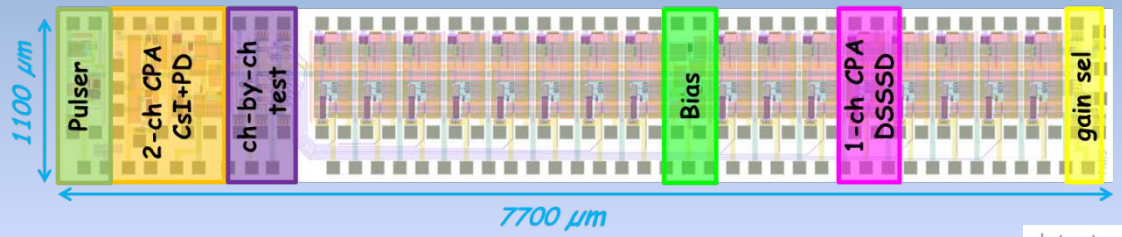
# Selectable-Gain CMOS Charge Preamplifier for Pulse Shape Analysis in Double Sided Silicon Microstrip Detectors for FARCOS

## Specs

- ✓ **single design for both thicknesses and of both polarities**
- ✓ **strip capacitance about 65 pF (300 µm) and 35 pF (1500 µm)**
- ✓ **strip leakage current ~5 nA (300 µm) and ~25 nA (1500 µm)**
- ✓ **target dynamic ranges: 90 MeV, 200 MeV, 350 MeV and 500 MeV.**
- ✓ **static power consumption ~10 mW/channel**
- ✓ **Selectable gain**

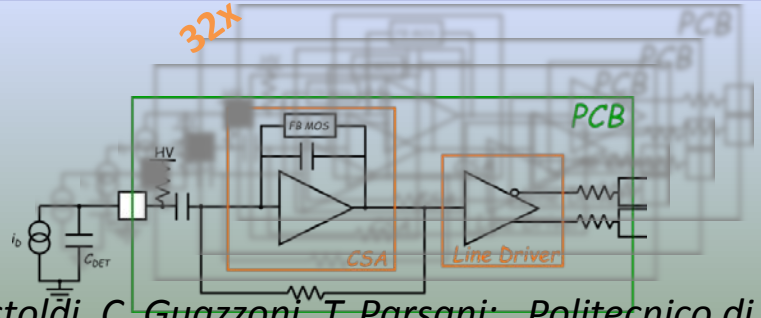
## 16-ch ASIC layout

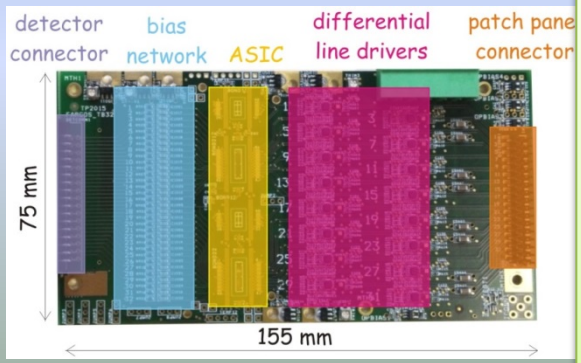
**0.35 µm C35B4C3 AMS tech**




- ✓ 16-ch CPA for DSSSD
- ✓ 2-ch CPA for CsI(Tl) + PD readout
- ✓ on-chip pulser
- ✓ channel-by-channel test signal injection
- ✓ temperature monitor

## 32-ch motherboard differential line drivers




- ✓ **custom designed 8-layer PCB housing ASICs & differential line drivers.**
- ✓ **hi-density right-angle open-pin-field interconnection between motherboard and patch-panel.**

*A. Castoldi, C. Guazzoni, T. Parsani: Politecnico di Milano and INFN sezione di Milano*

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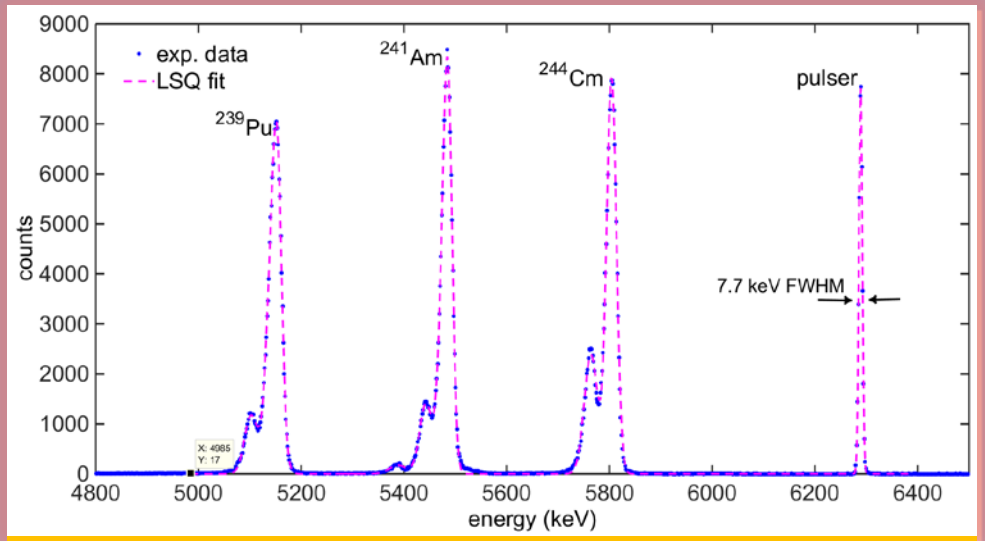
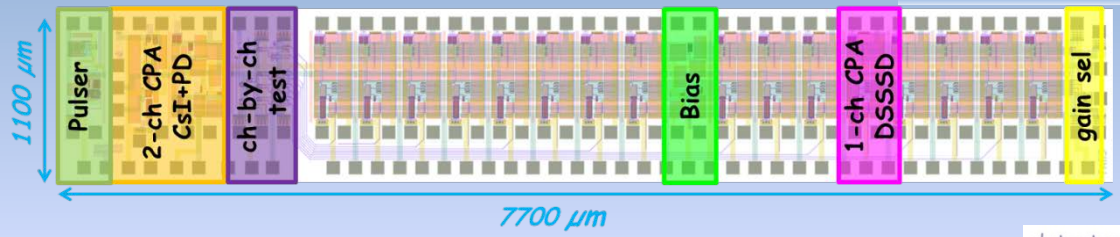



Alpha source with FARCOS DSSSD, 300 mm thick

## 16-ch ASIC layout

**0.35 µm C35B4C3 AMS tech**

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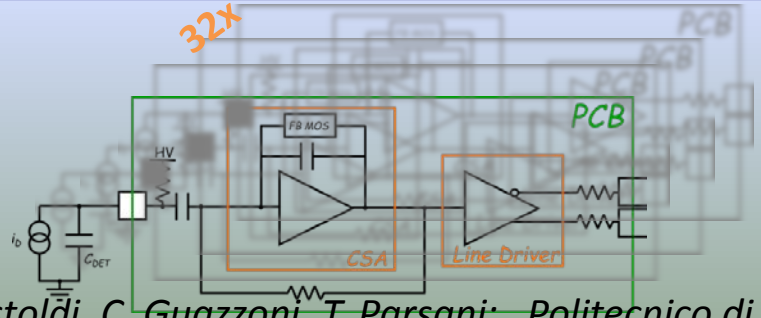


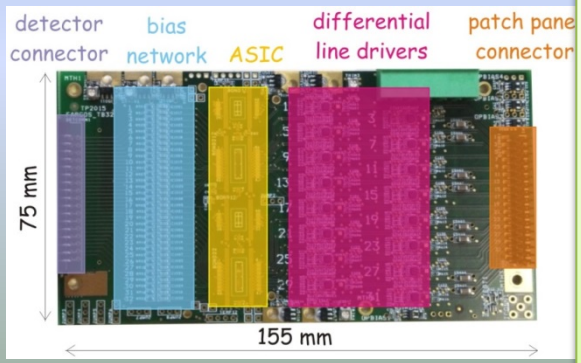


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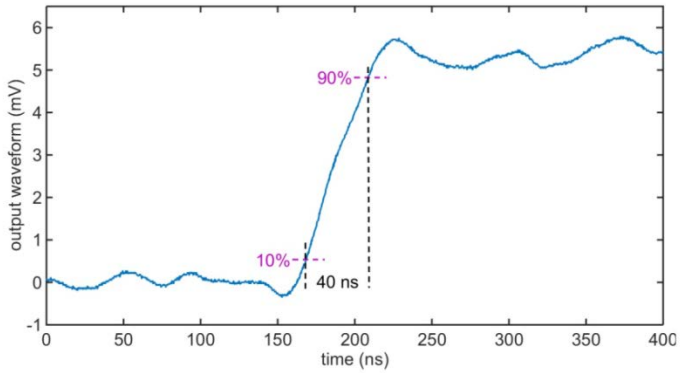
*A. Castoldi, C. Guazzoni, T. Parsani: Politecnico di Milano and INFN sezione di Milano*

# Selectable-Gain CMOS Charge Preamplifier for Pulse Shape Analysis FARCOS telescopes

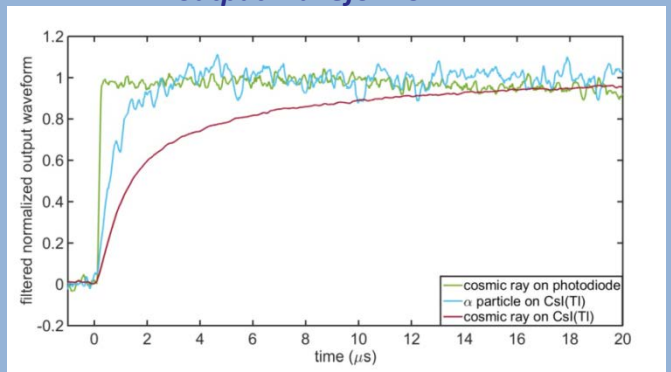
## ❑ CsI(Tl) + PD (dynamic range 90 MeV Si-equivalent)

***pulse rise time***



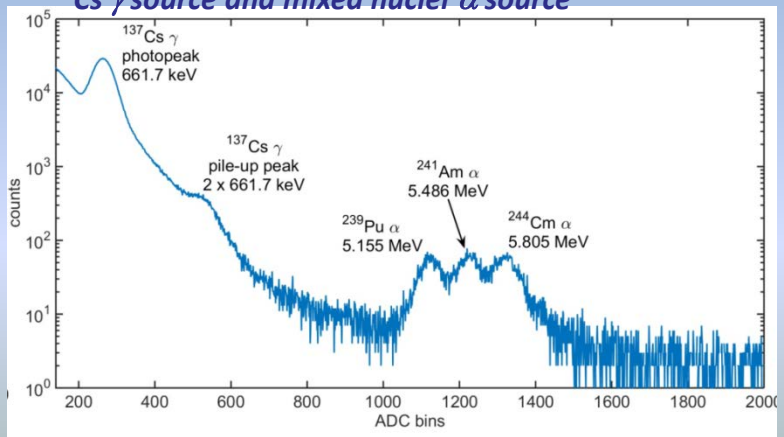

Output waveform (raw data) in the case of the detection of a cosmic ray directly in the Silicon photodiode. The measured rise time (10% - 90%) is 40 ns.

***output waveforms***



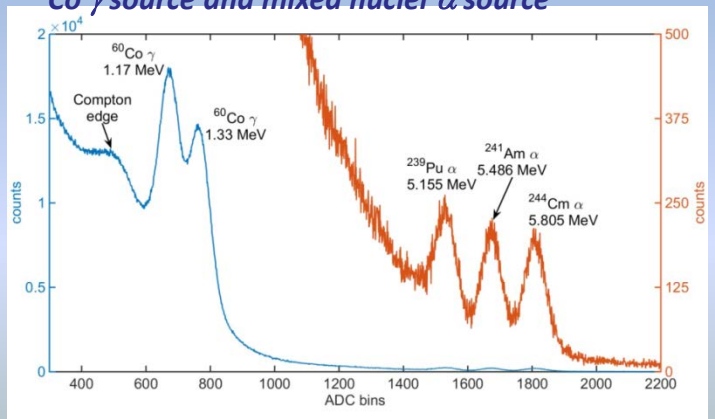

Normalized output waveforms (filtered with a moving average filter with a 700 point span) in the case of the detection of an a particle and of a cosmic ray in the scintillator crystal and of a cosmic ray in the photodiode.

***$^{137}$Cs γ source and mixed nuclei α source***




Energy spectrum of the $^{137}$Cs γ source and of the mixed nuclei α source measured with the VLSI charge preamplifier coupled with scintillator B.

***$^{60}$Co γ source and mixed nuclei α source***



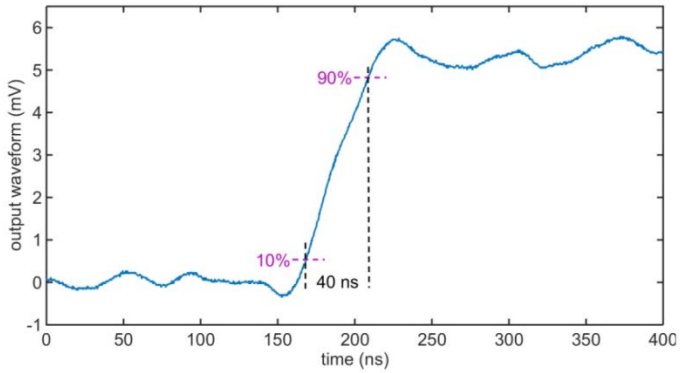

Energy spectrum of the $^{60}$Co γ source and of the mixed nuclei α source measured with the VLSI charge preamplifier coupled with scintillator A. The right axis (orange curve) shows the zoom of the same data.

by C. Guazzoni & collaborators

# Selectable-Gain CMOS Charge Preamplifier for Pulse Shape Analysis FARCOS telescopes

- **CsI(Tl) + PD (dynamic range 90 MeV Si-equivalent)**

***pulse rise time***

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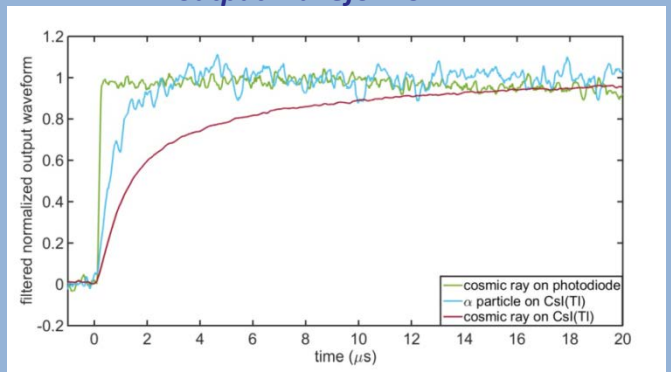


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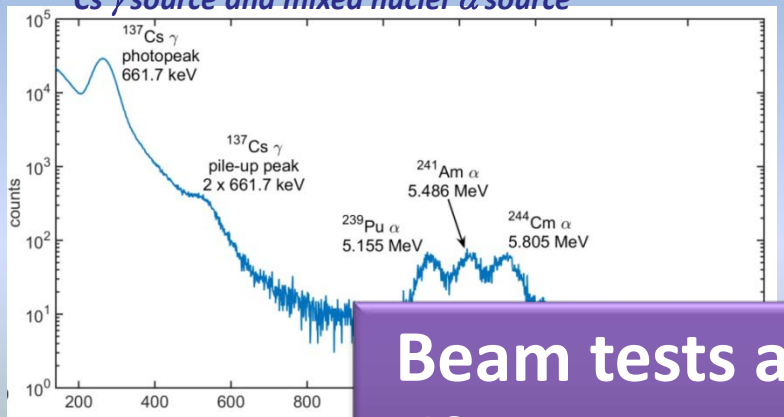
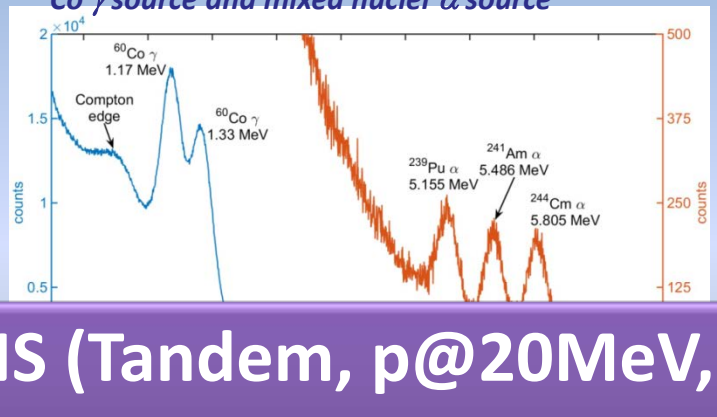



Energy spectrum of the $^{137}$C source measured with the with scintillator B.

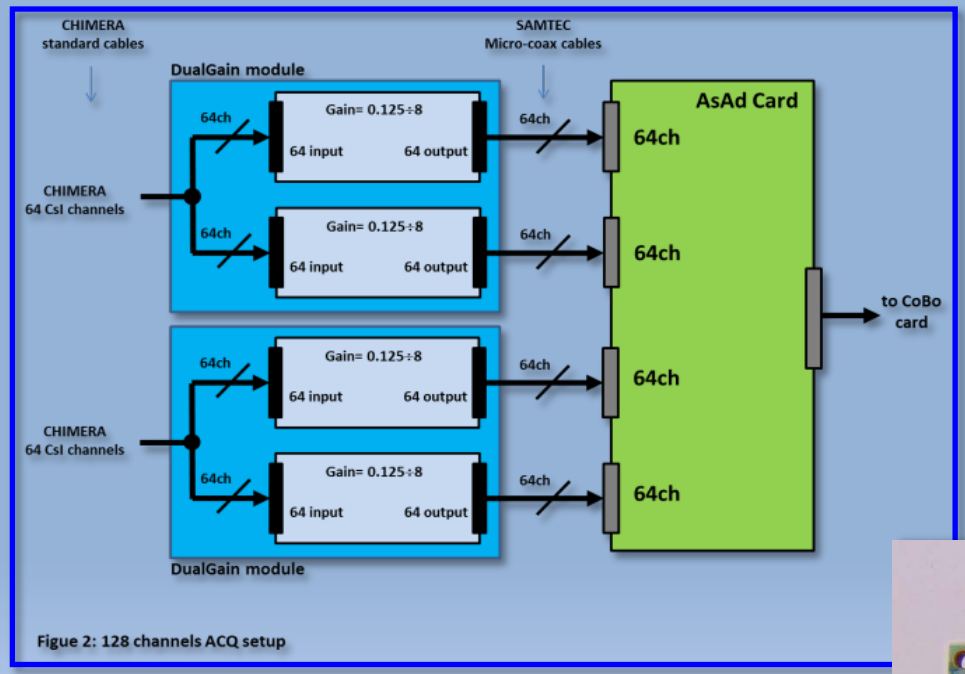
***$^{60}$Co γ source and mixed nuclei α source***




**Beam tests at LNS (Tandem, p@20MeV, $^{16}$O@100MeV) scheduled for February 7-16, 2017**

by C. Guazzoni & collabor

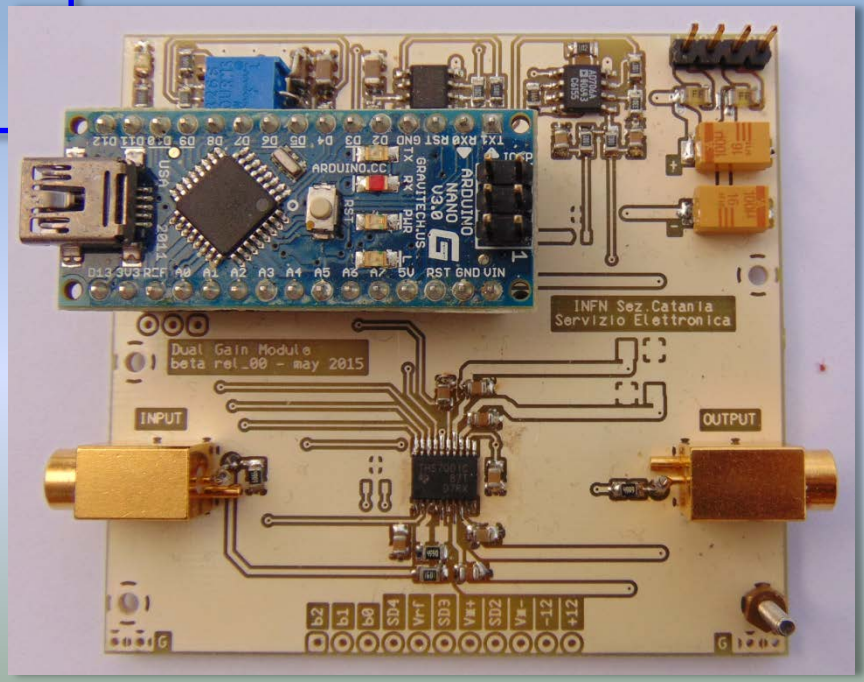
# The FARCOS dual gain module (DG) project (INFN - Catania)



Figue 2: 128 channels ACQ setup

Te FARCOS dual-gain module splits each FARCOS channel and adapts the signals level to the ASAD requirements.

The user can set the gain in the range from 0.032 $V/V_{in}$ to 4 $V/V_{in}$




Development beta card at INFN sez. Catania. The microcontroller allows the data setup, firmware development and user communications.

Test with CS beam: May 2016, LNS

# Dynamical processes in projectile break-up and IMF production at 20 A.MeV studied with the CHIMERA and FARCOS devices. CHIFAR: CHImera-FARcos (approved LNS-PAC proposal)

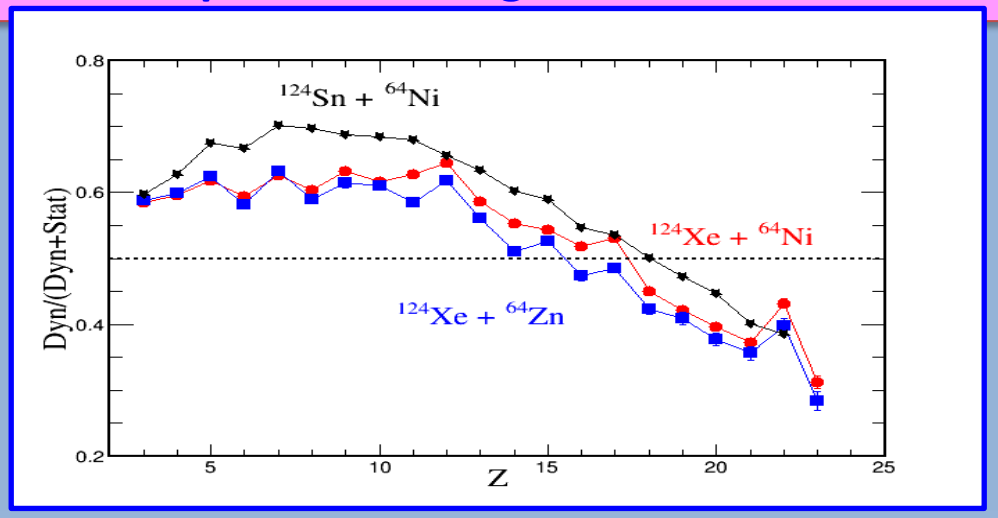
spokes: E.V. Pagano, E.d.F., P. Russotto)

Dynamical processes in projectile break-up and Intermediate Mass Fragments production at 20 A.MeV beam incident energy studied with the CHIMERA and FARCOS devices

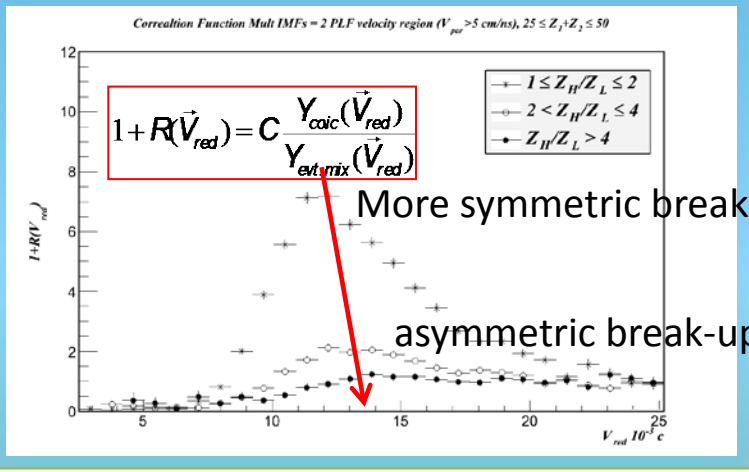
**CHIMERA + 8 FARCOS telescopes**

**$^{124}$Xe, $^{124}$Sn + $^{64}$Ni, $^{64}$Zn**

**$^{112}$Sn+$^{58}$Ni @ 20A.MeV**



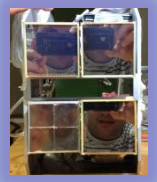

IMF-IMF correlations function (CHIMERA only)



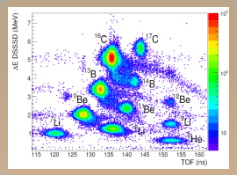

E. V. Pagano et al., proceedings of the IWM-EC 2016 (Ganil) to be published in Nuovo Cimento C

**E.V. Pagano, PhD thesis**

# Summary

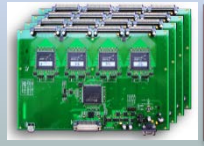


Following the building of a first Farcos module demonstrator and the approval for the construction of 5 Farcos modules (20 telescopes) we have adopted a compact electronic front end based on the design of new ASIC preamplifiers for silicon strips and the GET electronics for digitalization and data readout.



This ancillary detector, with its high and angular resolution, enhances the physics that can be studied with the CHIMERA array (including two and multi-particles correlations) both with stable and radiactive beams, in the field of dynamics of heavy ion collisions and spectroscopy of light nuclei at border of drip lines.

Indeed it wiil be coupled with other devices in national and international laboratories (SPES,GANIL,GSI) following the physics cases



Chimera front-end for CsI(Tl) detector s will be upgraded by using GET electronic as well.

# *Collaboration for Farcos project and Chimera upgrade*


L.Acosta[1,8], L.Auditore[4], C.Boiano[5], G.Cardella[1], A.Castoldi[5], M.D'Andrea[1],
E. De Filippo[1],D.Dell'Aquila[6], S. De Luca[4], F.Fichera[1], N.Giudice[1], B.Gnoffo[1],
A.Grimaldi[1], C.Guazzoni[5], G.Lanzalone[2,7], F.Librizzi[1], P. Litrico[2], I.Lombardo[6],
C.Maiolino[2], S.Maffesanti[5], N.Martorana[2], S.Norella[4], A.Pagano[1], E.V.Pagano[2,3],
M.Papa[1], T.Parsani[5], G.Passaro[2], S.Pirrone[1], G.Politi[1,3], F.Previdi[5], L.Quattrocchi[4],
F.Rizzo[2,3], P.Russotto[1], G.Saccà[1], G.Salemi[1], D.Sciliberto[1],
A.Trifirò[4], M.Trimarchì[4], M.Vigilante[6]

1-INFN Sezione di Catania
2-INFN LNS
3-Dipartimento di Fisica e Astronomia Università di Catania
4-INFN_gr. Coll. Messina and Dipartimento di Fisica Università Messina
5-INFN- Sezione di Milano and Politecnico di Milano
6-INFN-Sez. di Napoli and Dipartimento di Fisica Università di Napoli Federico II
7-Università Kore Enna
8-Instituto de Física Universidad Nacional Autónoma de México, México D. F. 01000