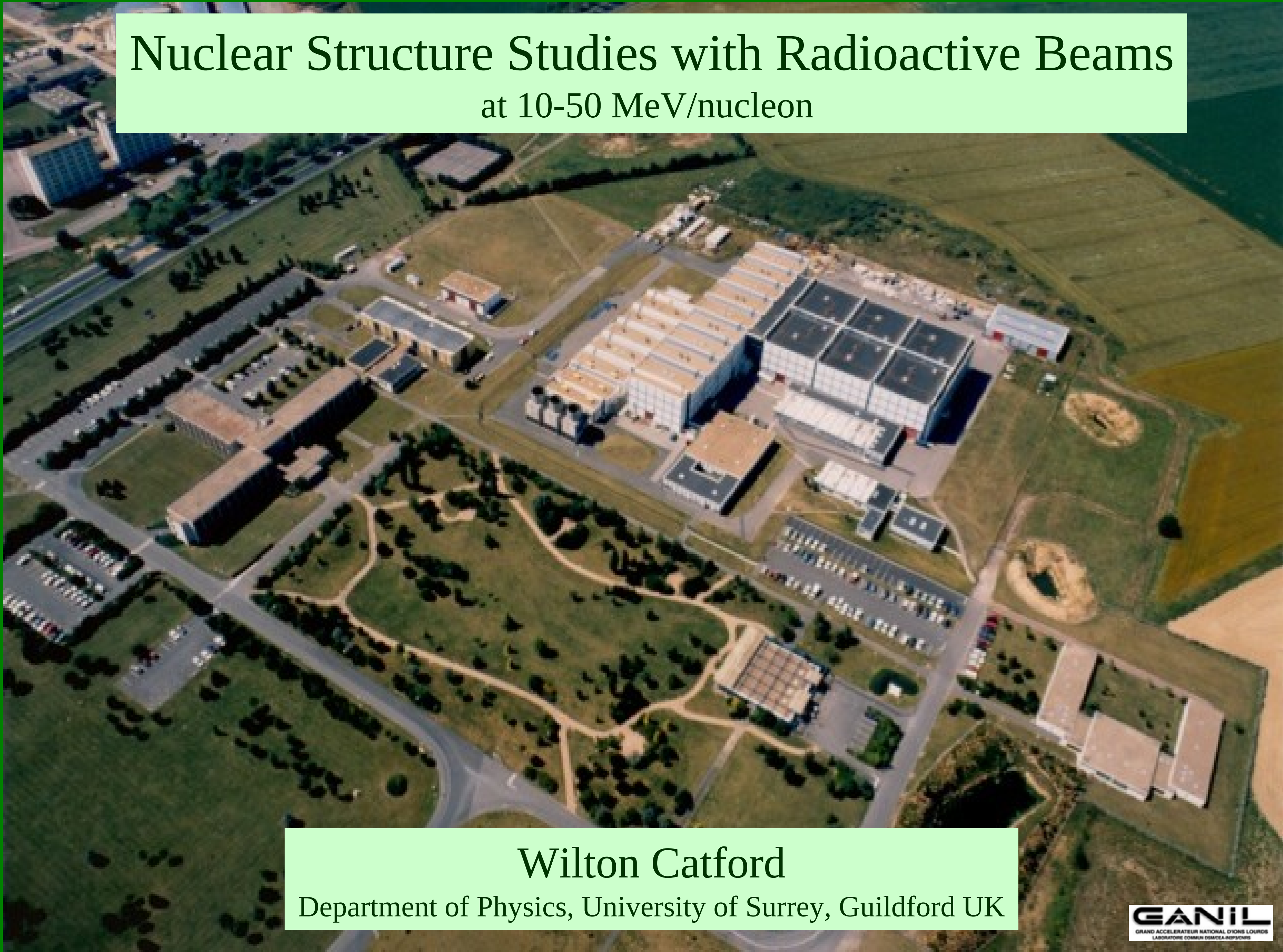
Nuclear Structure Studies with Radioactive Beams
at 10-50 MeV/nucleon



Wilton Catford
Department of Physics, University of Surrey, Guildford UK

Nuclear Structure Studies with Radioactive Beams

at 10-50 MeV/nucleon

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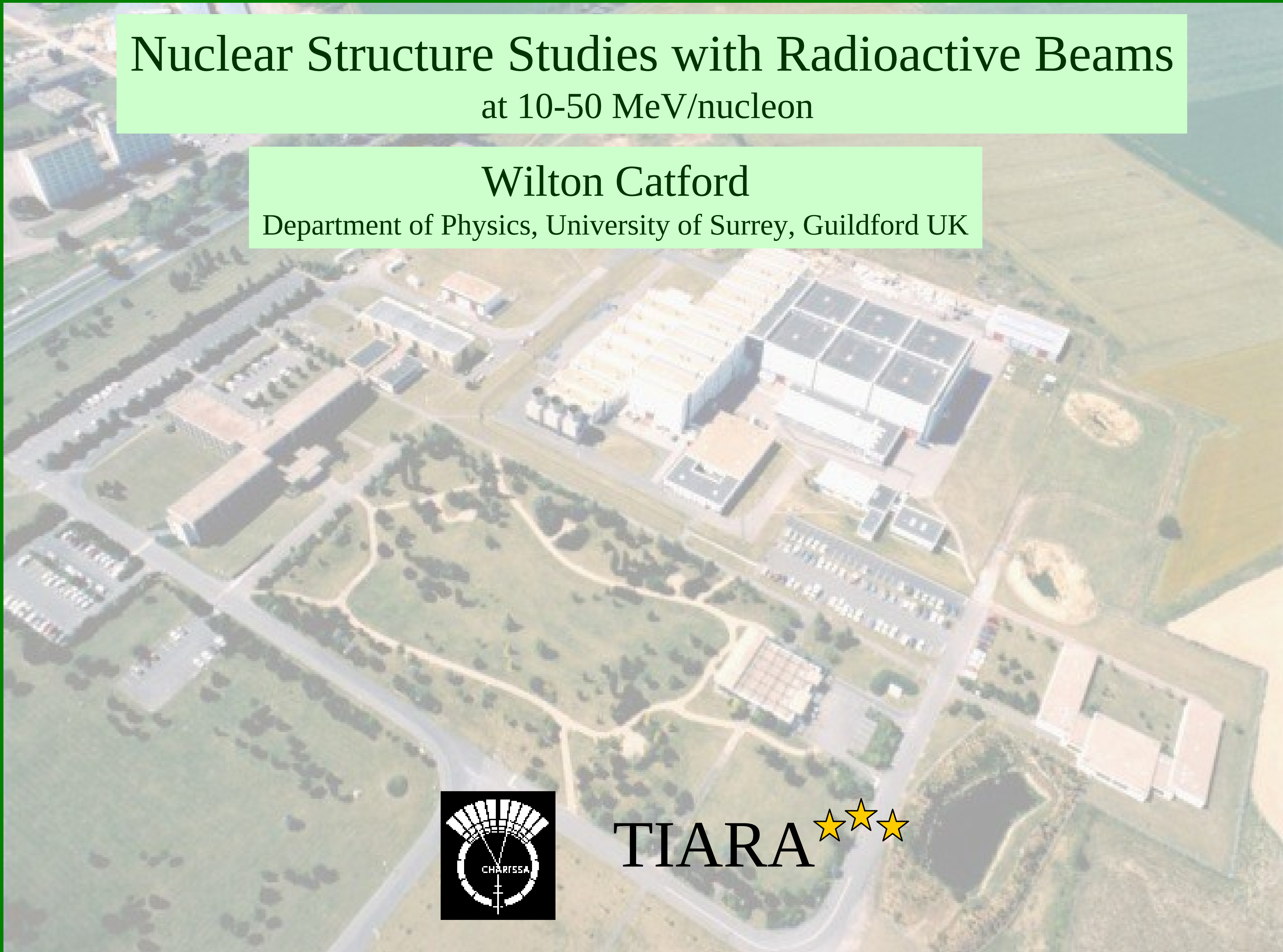


CHARISSA

TIARA

Nuclear Structure Studies with Radioactive Beams
at 10-50 MeV/nucleon

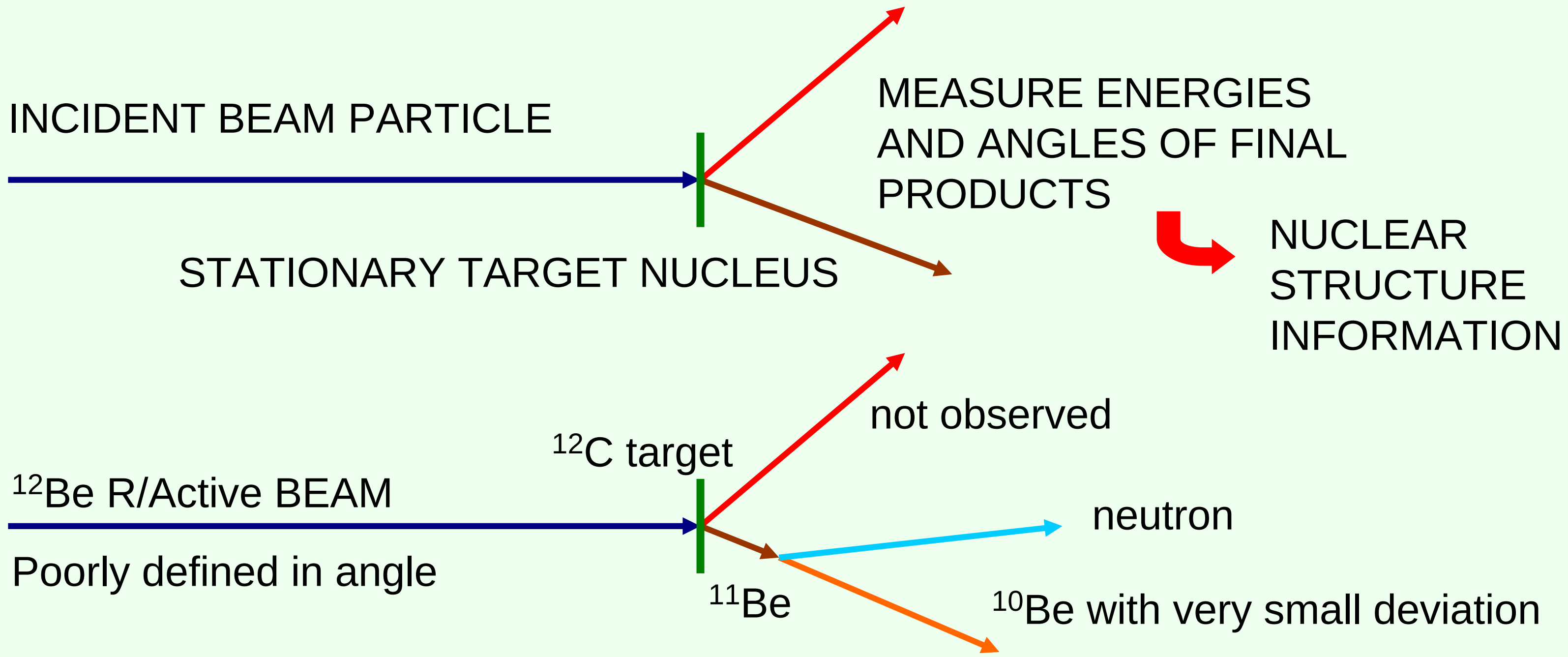
Wilton Catford
Department of Physics, University of Surrey, Guildford UK

- **What we need to detect**
- **Charged particle telescopes developed by Charissa**
- **New charged particle array for nucleon transfer reactions**
- **Prospects and requirements for future developments**

TIARA

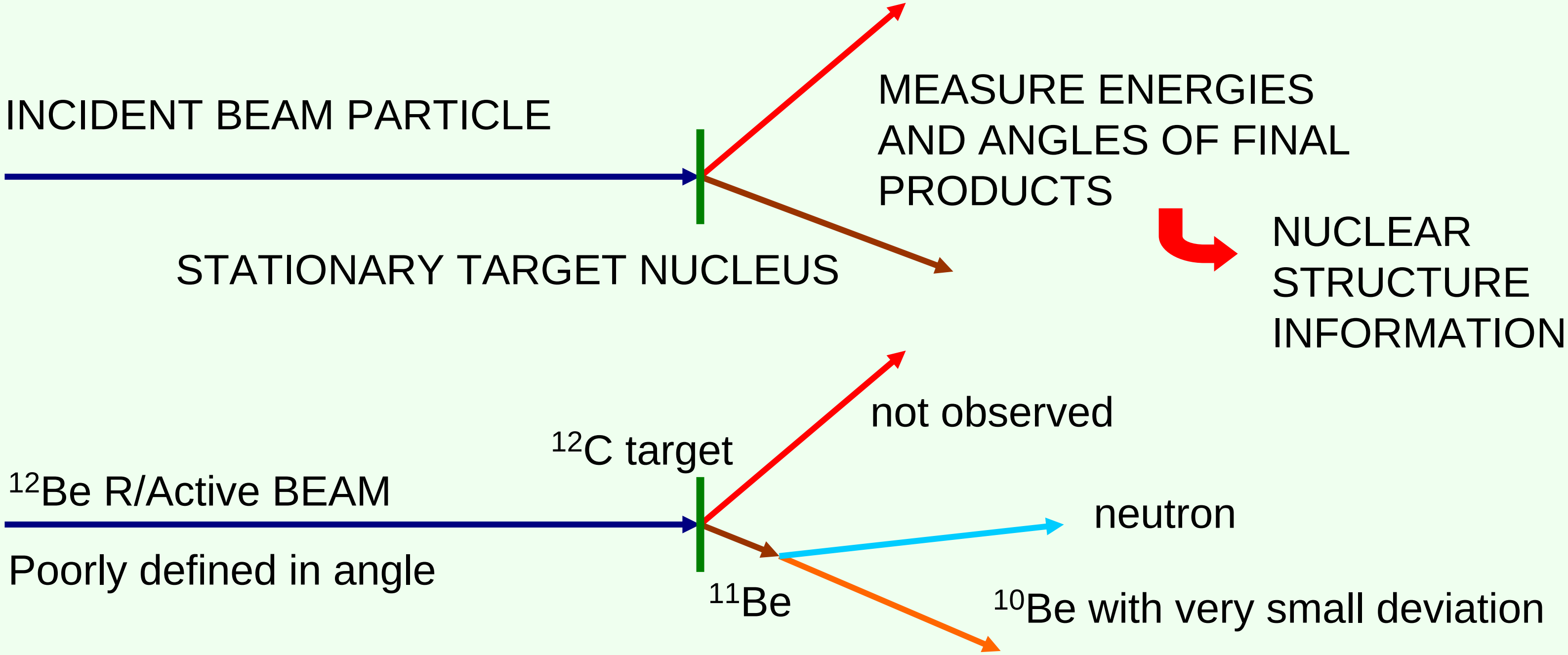
Nuclear Structure Studies with Radioactive Beams

at 10-50 MeV/nucleon

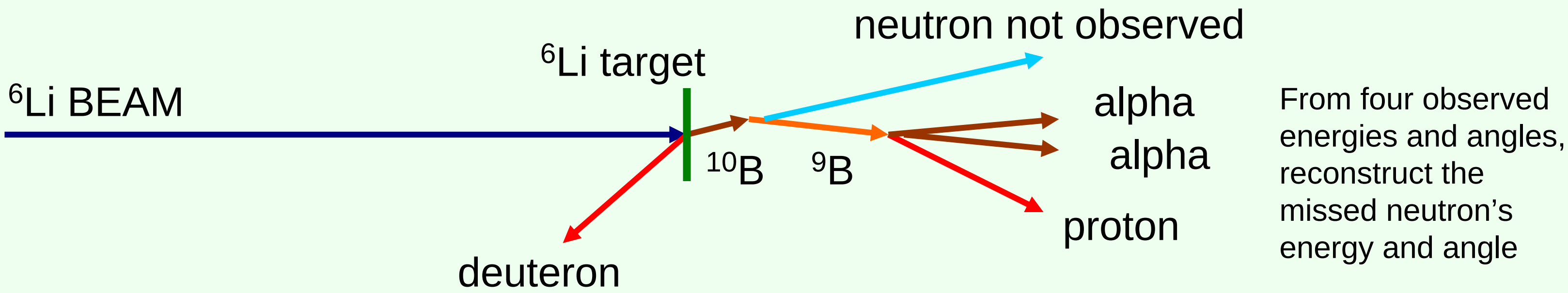


Nuclear Structure Studies with Radioactive Beams

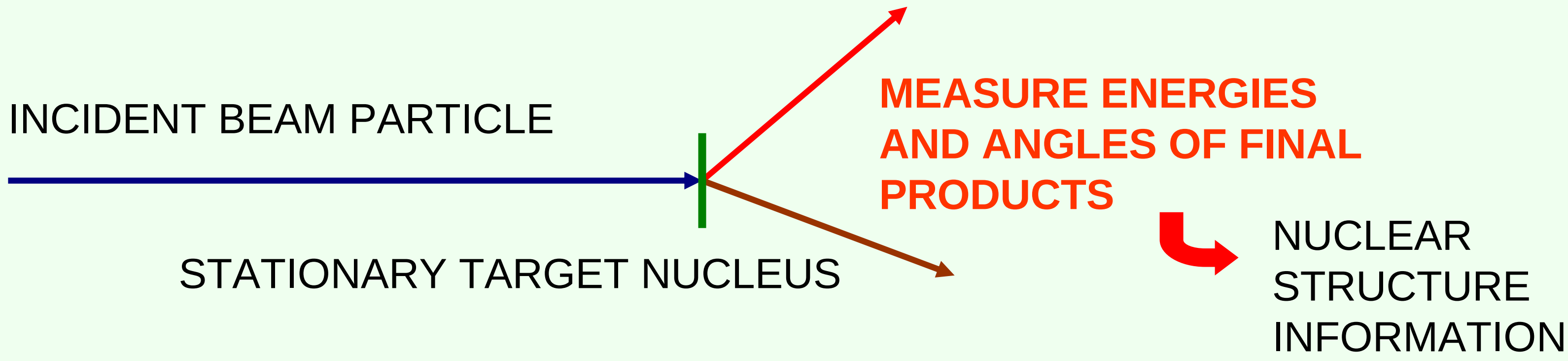
at 10-50 MeV/nucleon



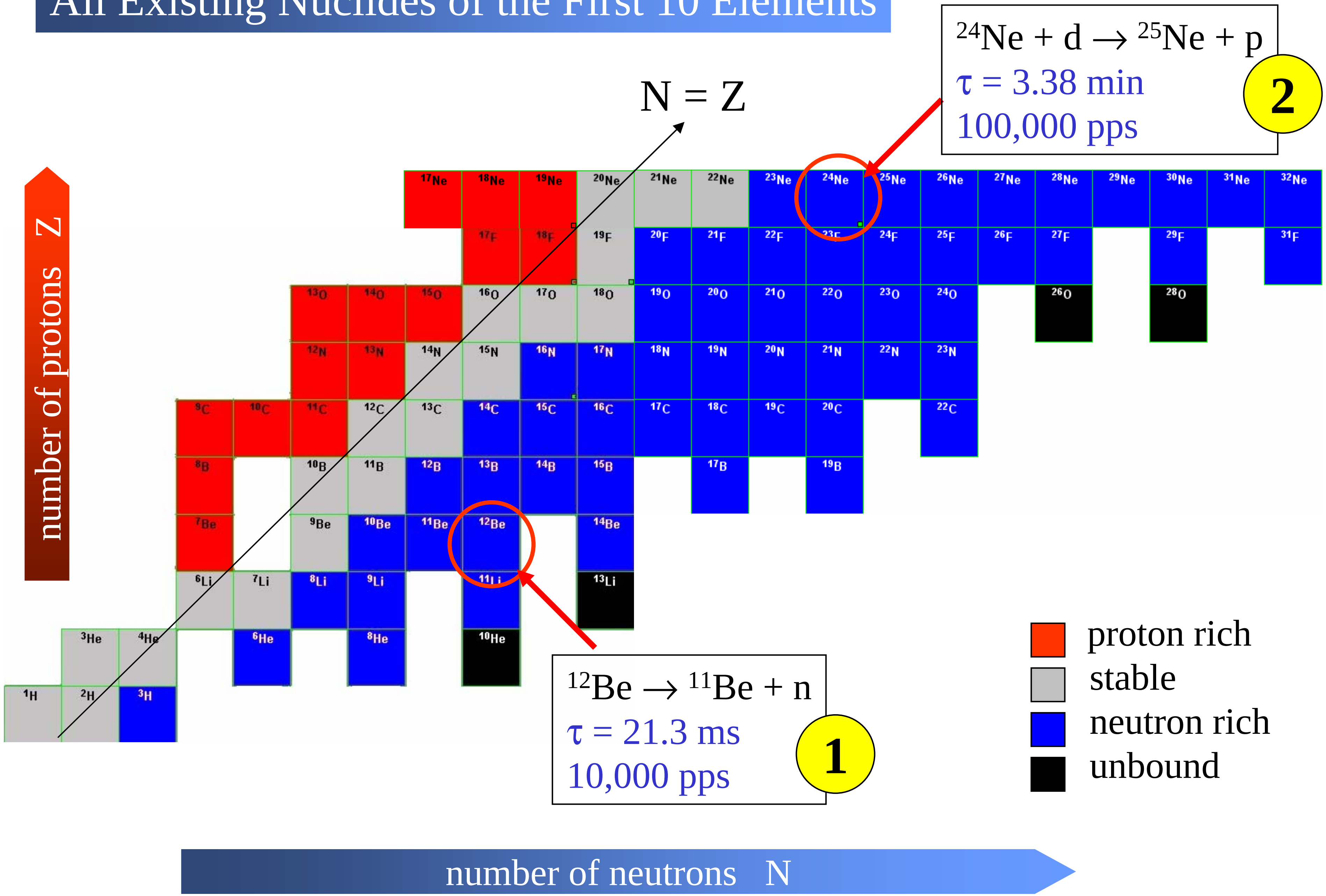
OR another example:



Nuclear Structure Studies with Radioactive Beams
at 10-50 MeV/nucleon



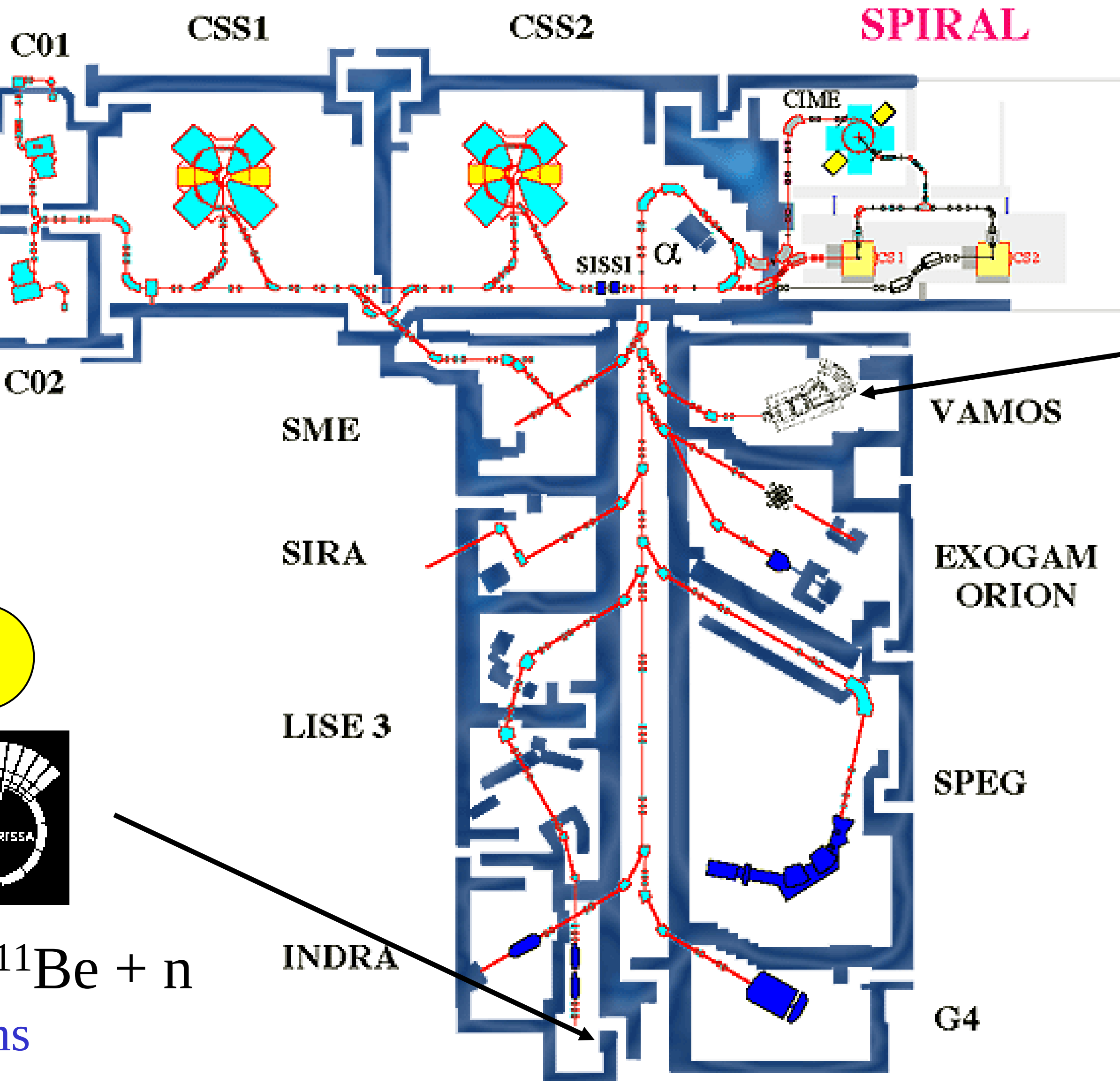
All Existing Nuclides of the First 10 Elements



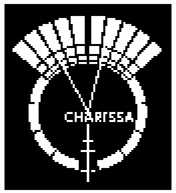
GANIL

GRAND ACCELERATEUR NATIONAL D'IONS LOURDS

LABORATOIRE COMMUN DSM/CEA-IN2P3/CNRS



1



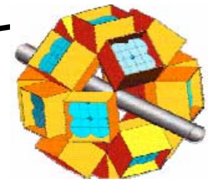
$^{12}Be \rightarrow {}^{11}Be + n$

τ = 21.3 ms

10,000 pps

2

TIARA ★★★

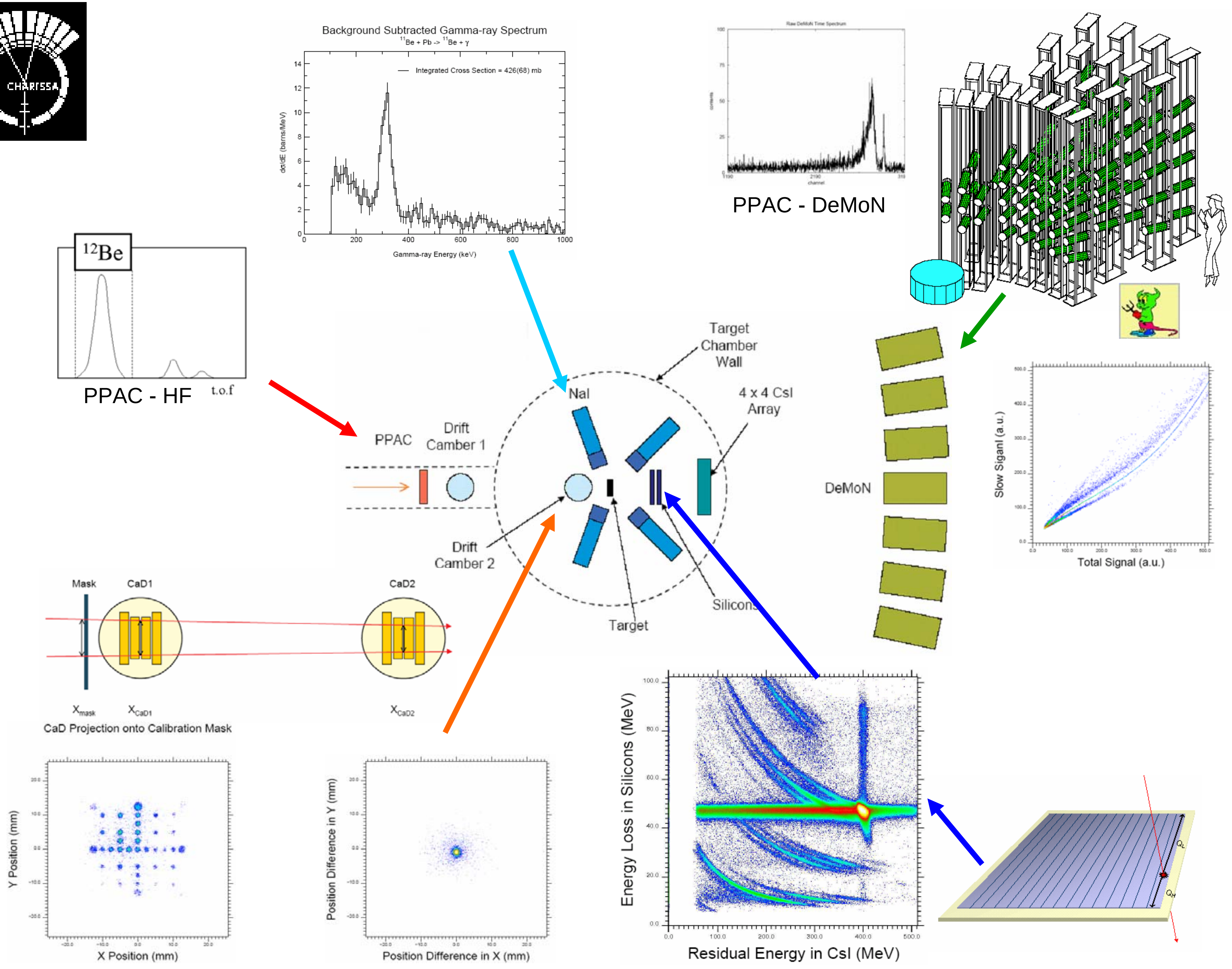


$^{24}Ne + d$

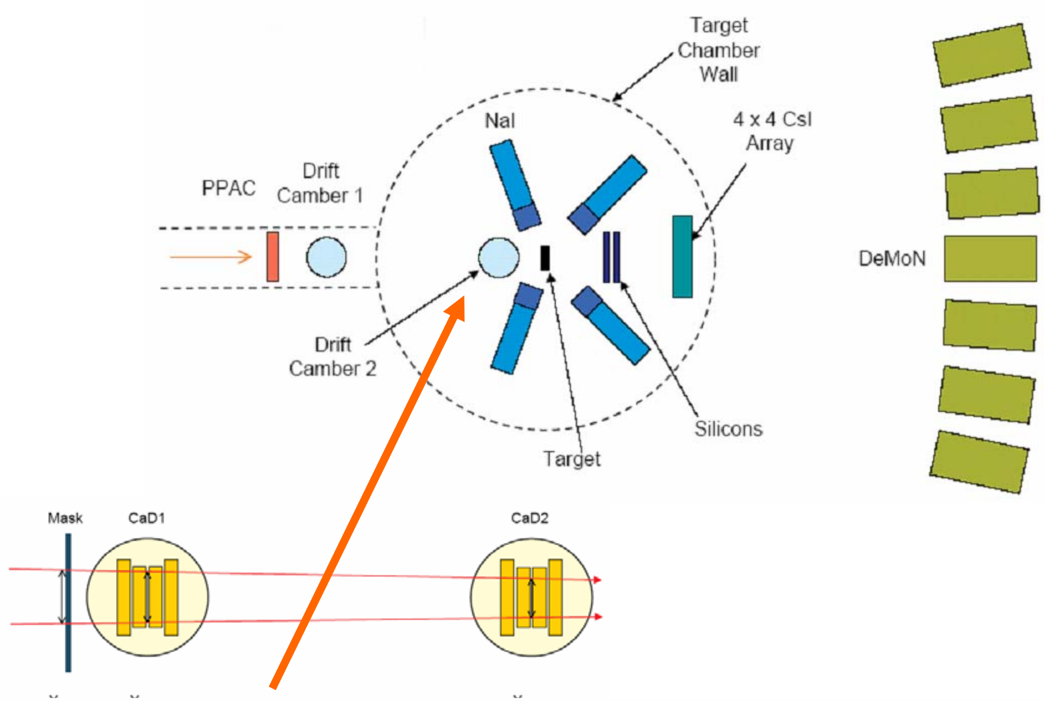
$\rightarrow {}^{25}Ne + p$

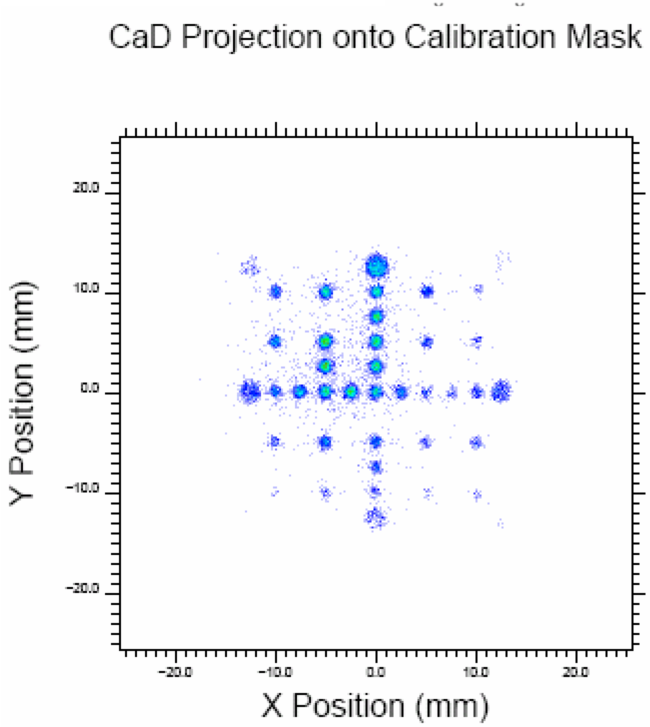
τ = 3.38 min

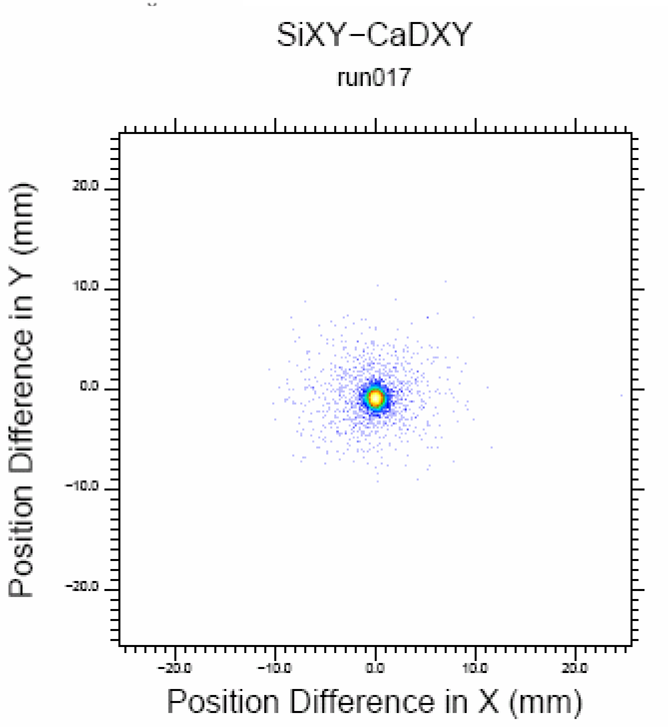
100,000 pps



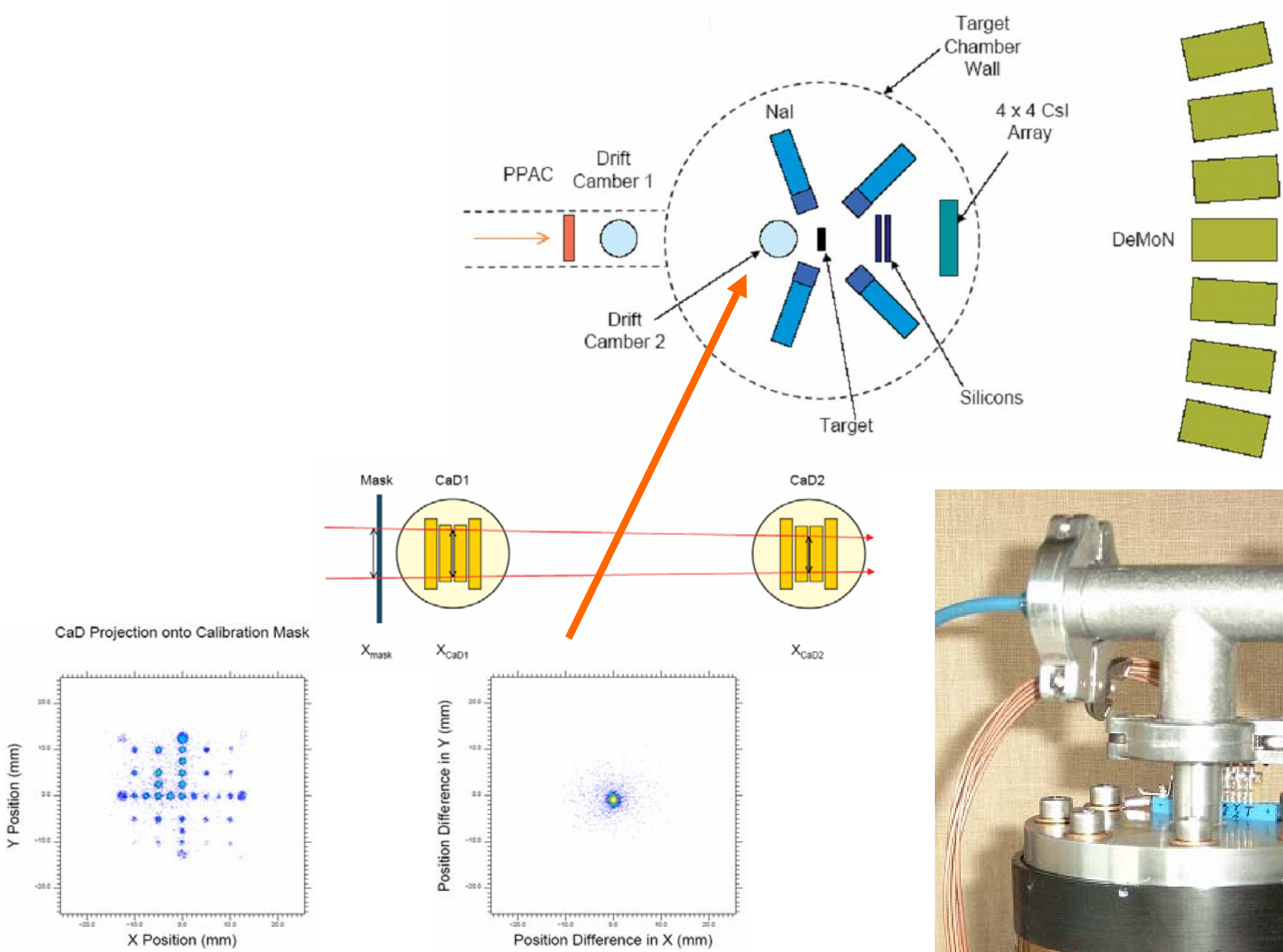
Background Subtracted Gamma-ray Spectrum
Integrated Cross Section = 426(68) mb
dσ/dE (barns/MeV)
Gamma-ray Energy (keV)
PPAC - DeMoN
12Be
PPAC - HF
t.o.f
Target
Chamber
Wall
NaI
4 x 4 CsI
Array
PPAC
Drift
Camber 1
Drift
Camber 2
DeMoN
Silicons
Target
Slow Siganl (a.u.)
Total Signal (a.u.)
Mask
CaD1
CaD2
CaD Projection onto Calibration Mask
Y Position (mm)
X Position (mm)
Position Difference in Y (mm)
Position Difference in X (mm)
Energy Loss in Silicons (MeV)
Residual Energy in CsI (MeV)

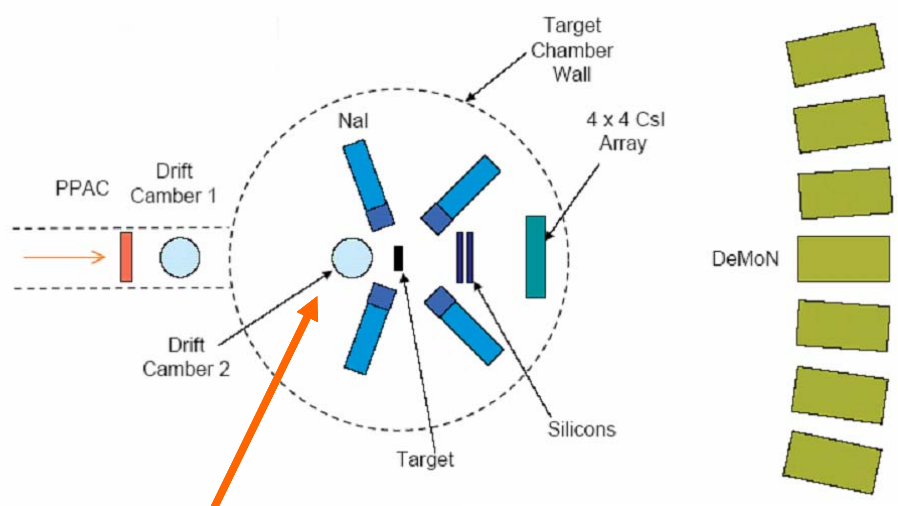


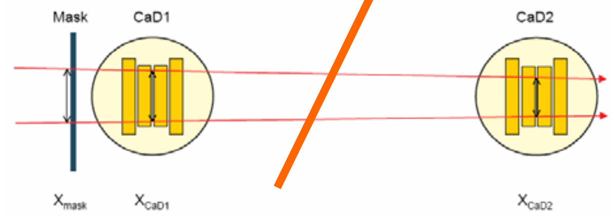




PLOTTED HERE:
difference between position **measured** on Si resistive strips and **projected** point using 2 drift chamber Measurements
FWHM = 0.8 mm


Target
Chamber
Wall
NaI
4 x 4 CsI
Array
Drift
Camber 1
PPAC
DeMoN
Drift
Camber 2
Silicons
Target
Mask
CaD1
CaD2
CaD Projection onto Calibration Mask
X_{mask}
X_{CaD1}
X_{CaD2}
Y Position (mm)
X Position (mm)
Position Difference in Y (mm)
Position Difference in X (mm)

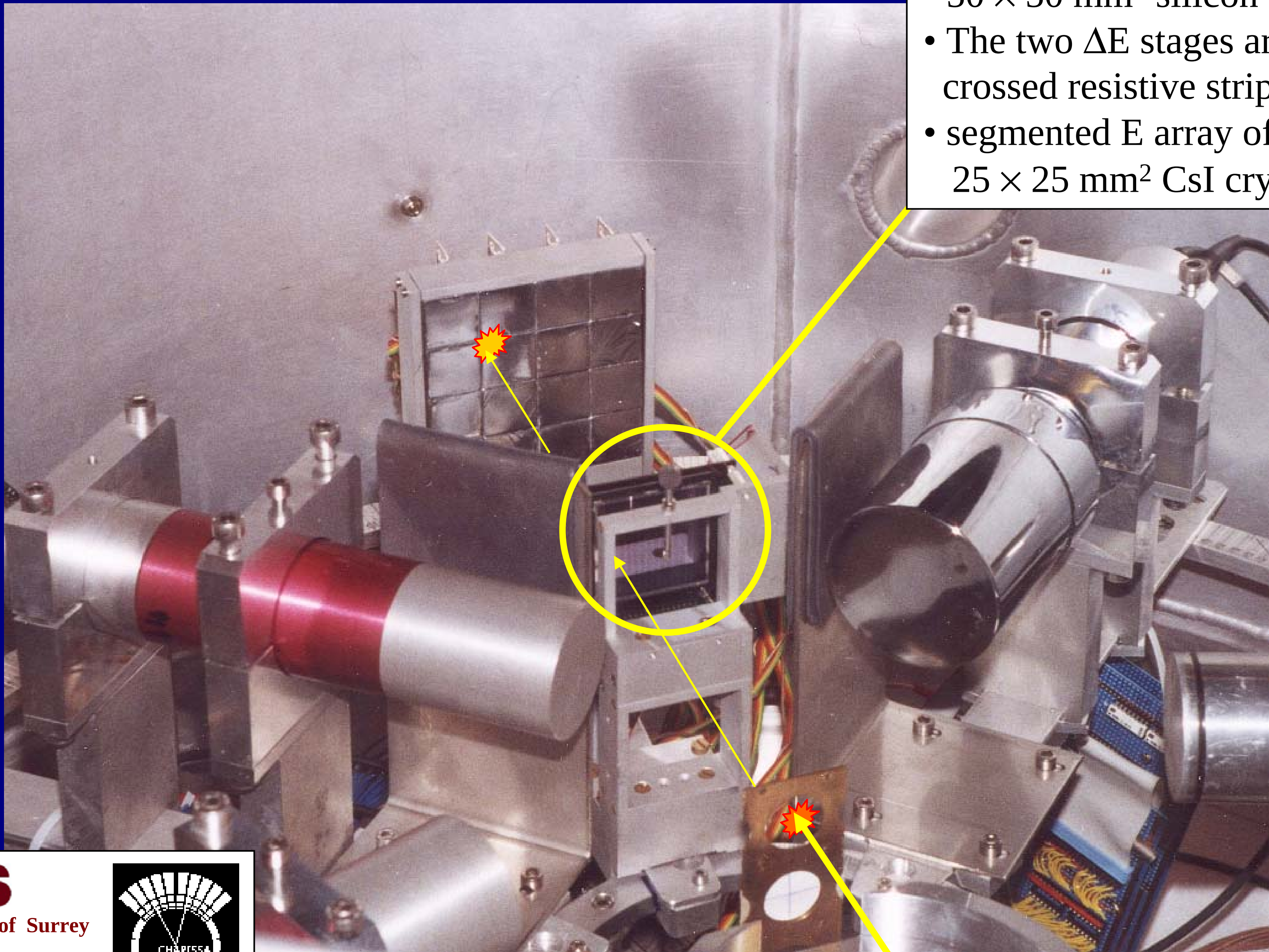




10 µm mylar equivalent thickness

Multistage telescopes used in in-beam studies

- 3 stage telescope
- 50×50 mm^2 silicon
- The two ΔE stages are crossed resistive strips
- segmented E array of 25×25 mm^2 CsI crystals



Steven PAIN thesis

University of Surrey

THE UNIVERSITY OF BIRMINGHAM

UniS
University of Surrey

THE UNIVERSITY
OF BIRMINGHAM

CHARISSA

Position Measurement:

- by charge division
- highly linear

Position Resolution (0.1-1mm):

- proportional to $\tau_{shaping}$
- proportional to 1/E

$$\Delta L[\mathrm{mm}] = 14.8\left[\frac{T\tau}{R_1/2}\left(1+\frac{R_{eq}}{R_1}\right)\right]^{1/2} L/E$$

T and R_{eq} are temperature and equivalent serial resistance at the preamplifer input, τ is shaping time, L (R_1) are the strip length (resistance)

T. Yanagimachi et al., NIM A275 (1989) 307

Position Measurement:

- by charge division
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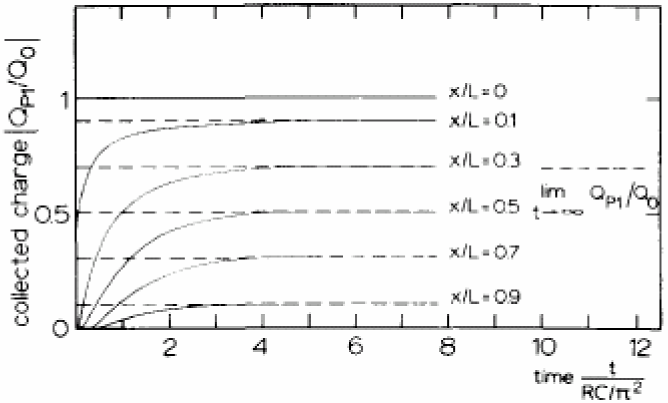
T. Yanagimachi et al., NIM A275 (1989) 307



S. Kalbitzer & W Meltzer, NIM 56 (1967) 301

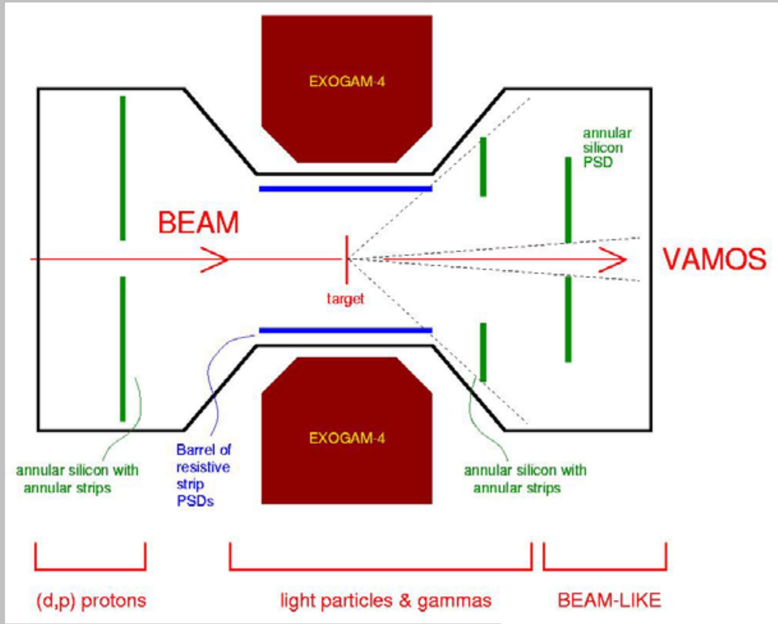
The Design Challenges for TIARA for RNB Studies

"no compromises on geometrical efficiency"

- The physics tells us that all angles have particles we wish to detect so we need to **span as much as possible of 4π**
- When we work out the achievable energy resolution for the final states in the nuclei being studied, it is clear that we need to detect **gamma rays in coincidence**, as well
- It works best to get the high gamma ray coincidence efficiency by using (position sensitive) Ge detectors placed very close
- Hence the new detector must be **extremely compact** – it must fit within diameter 5–6 cm – any "dead space" is very significant
- The required angular resolution is < 2° which translates to about **1 mm resolution** closest to target
- It should not attenuate the gamma rays and hence it should be of **low Z material** and be a **small thickness of material**

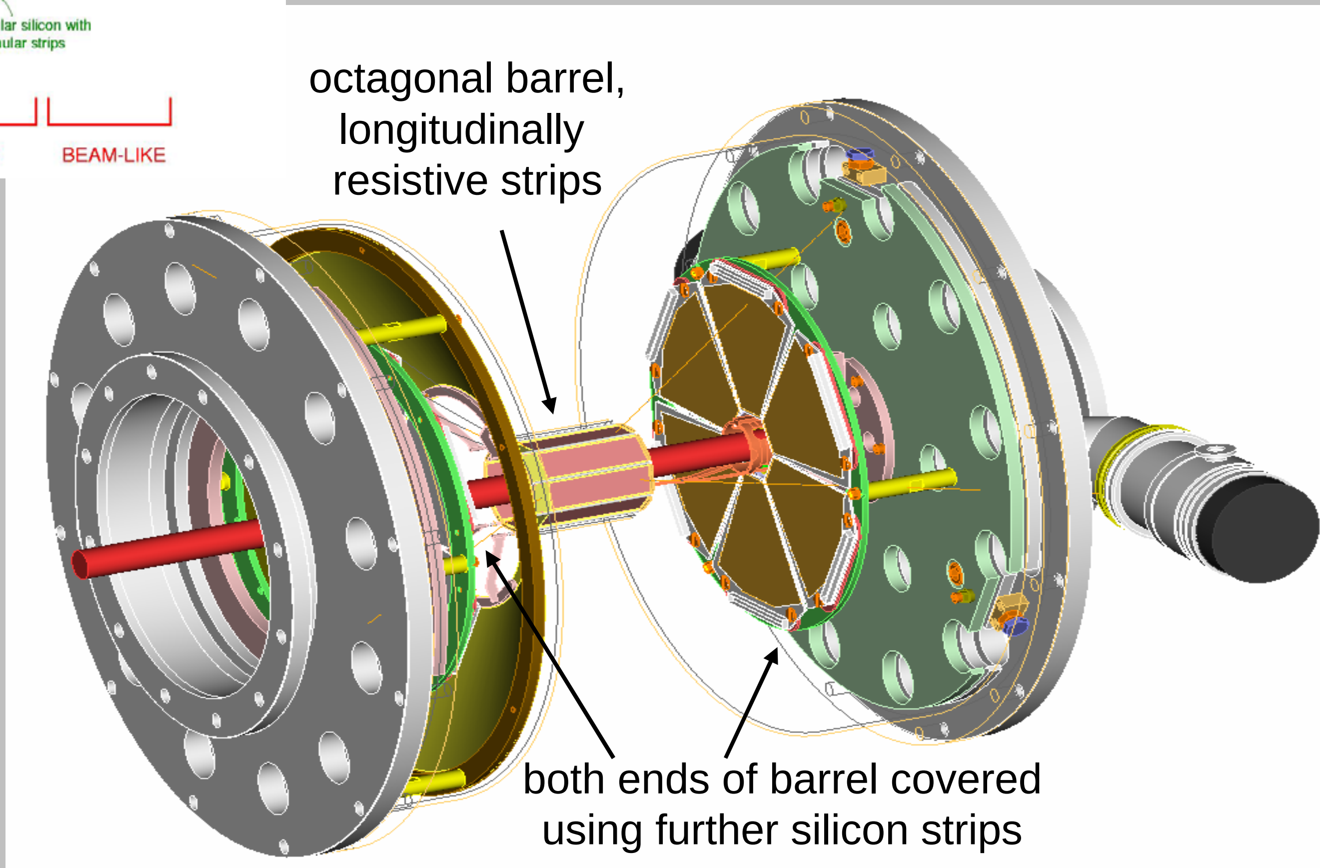
TIARA

How the TIARA array has to fit into the rest of the set-up:

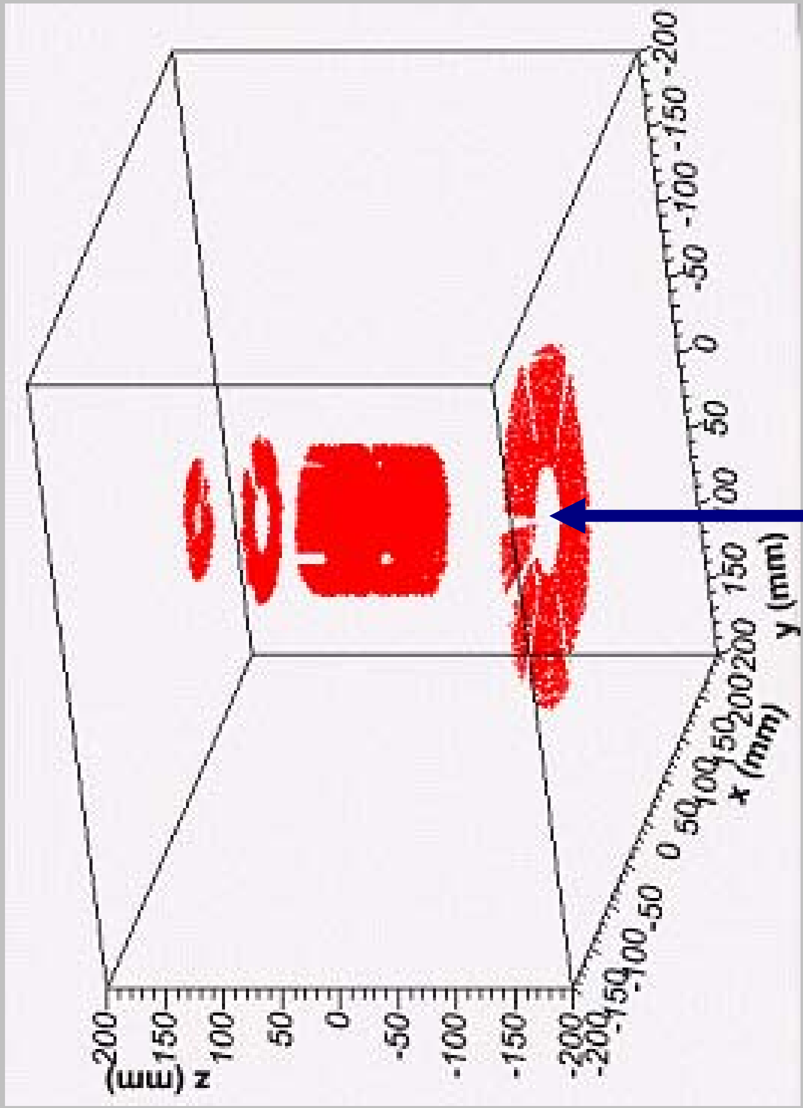


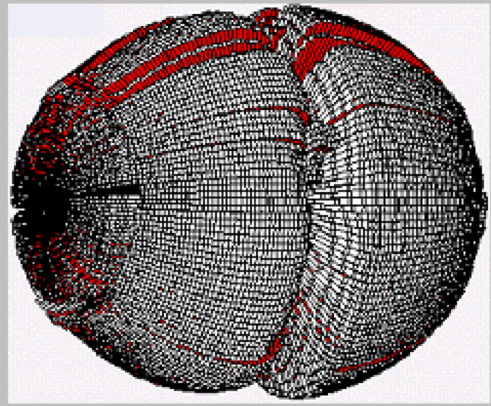
Solution :

- Surround as much as possible of 4π with position sensitive silicon
- Need to achieve 2° angular resolution
- But make this extremely compact, to give to give very high gamma-ray efficiency

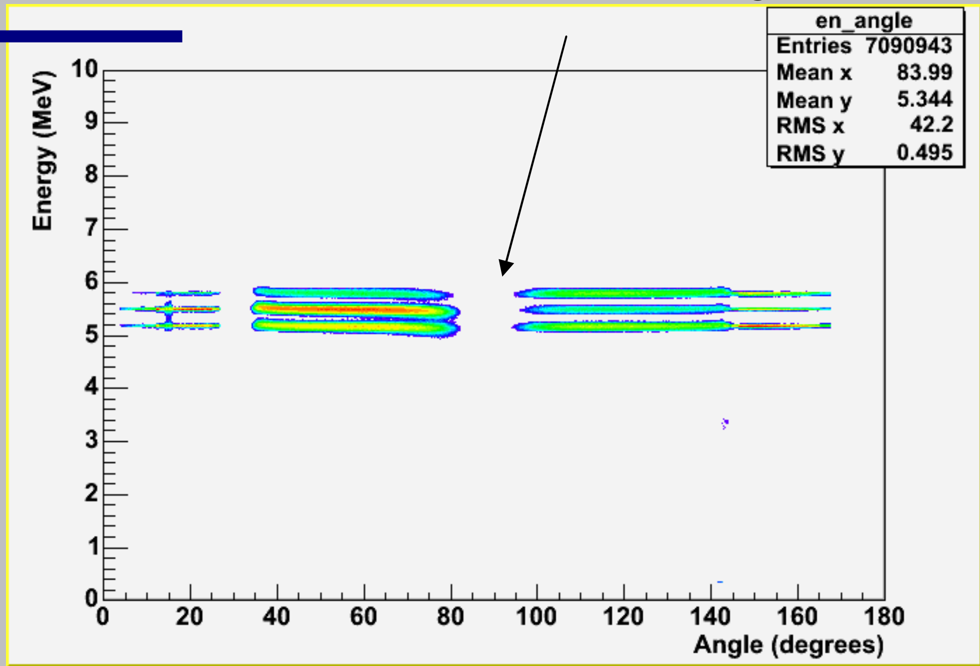


Demonstration of angular coverage by calibrations with triple-α source

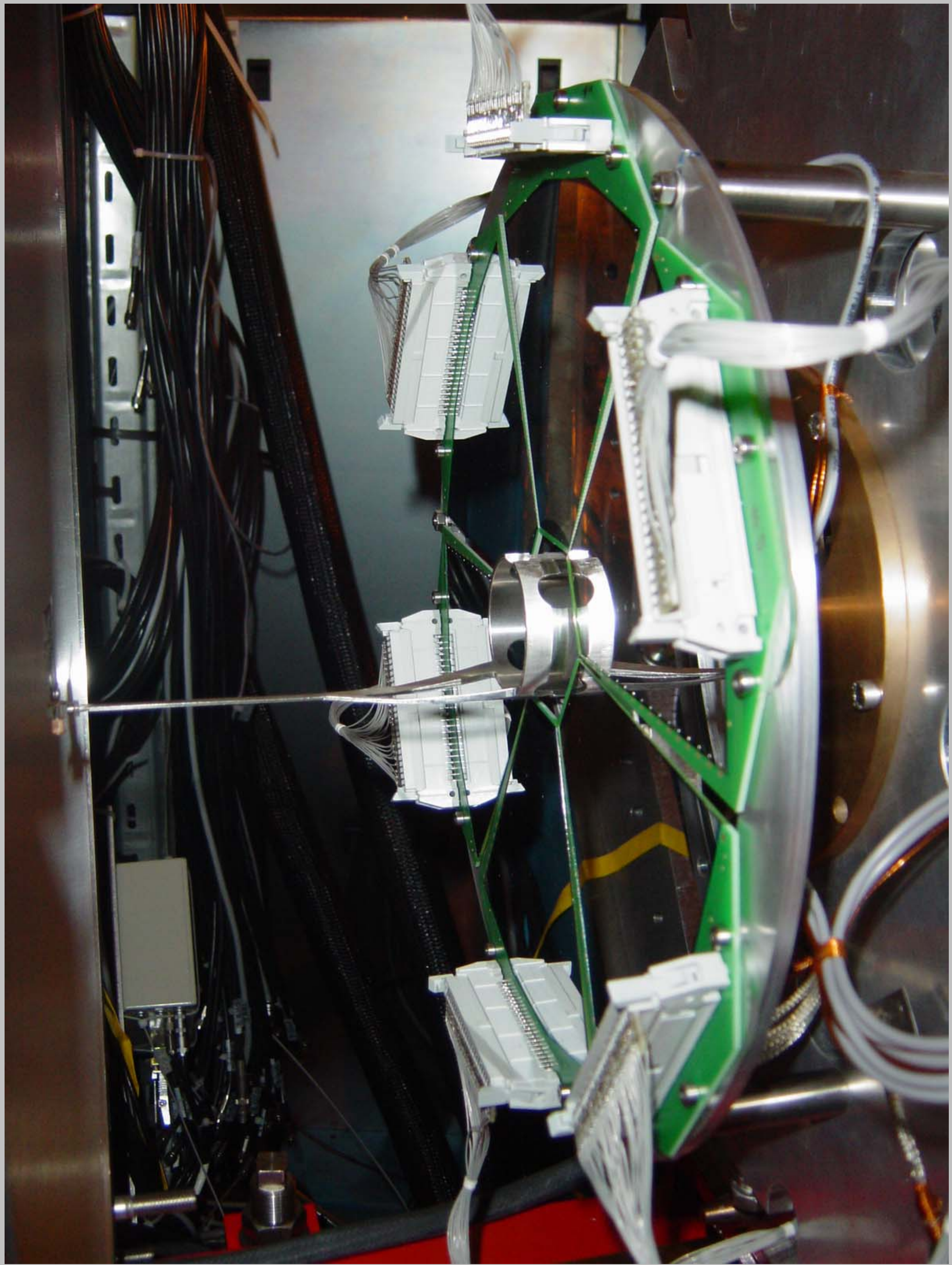




shadow of target frame



TIARA

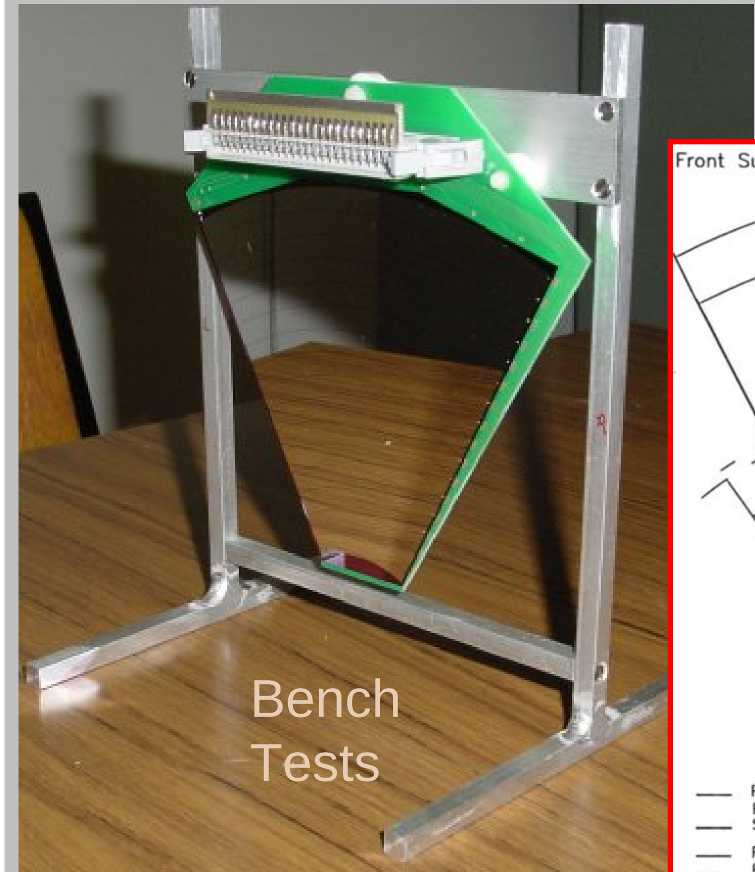


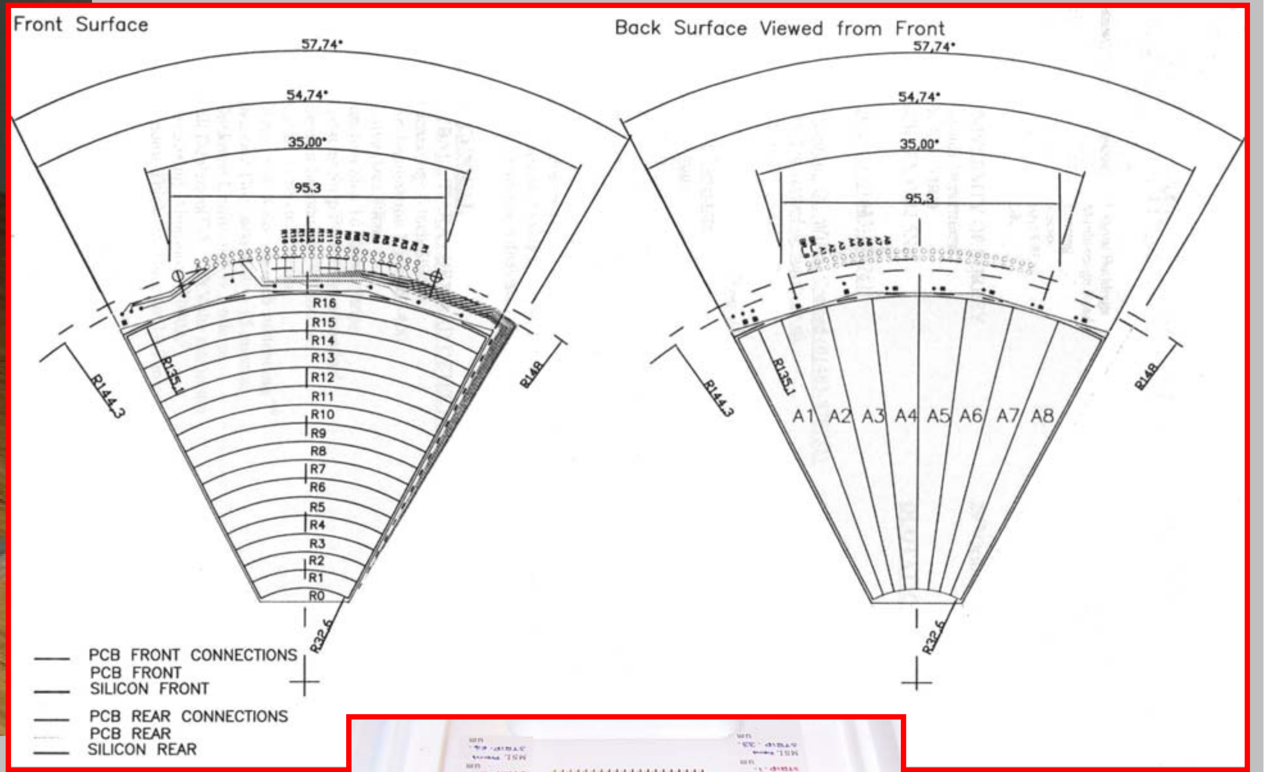
TIARA

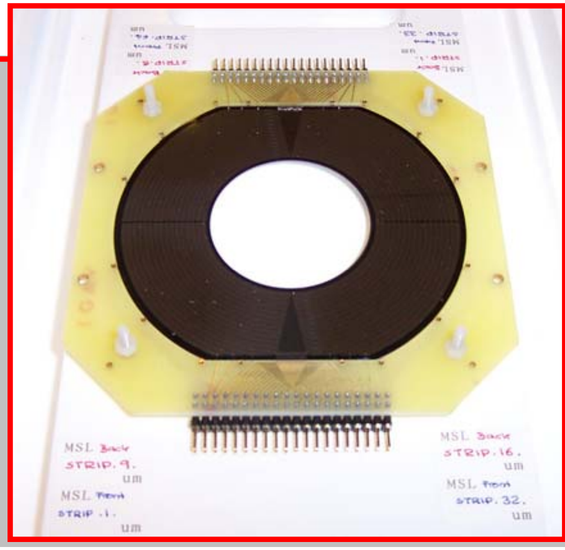
HYBALL – backward angle array

6 wedges
Front : 16 strips
Back : 8 sectors
Thickness ~ 400μm

TIARA







At forward and back angles, we use the

HYBALL Backward Array design from ORNL

plus a Micron S1+S2 for forward angles

TIARA

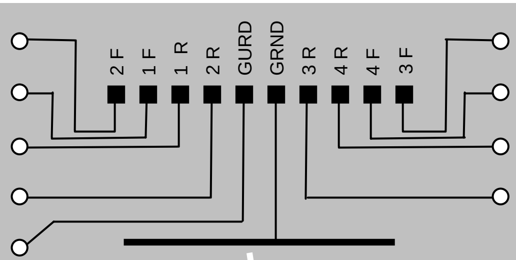
BARREL Detail and Assembly

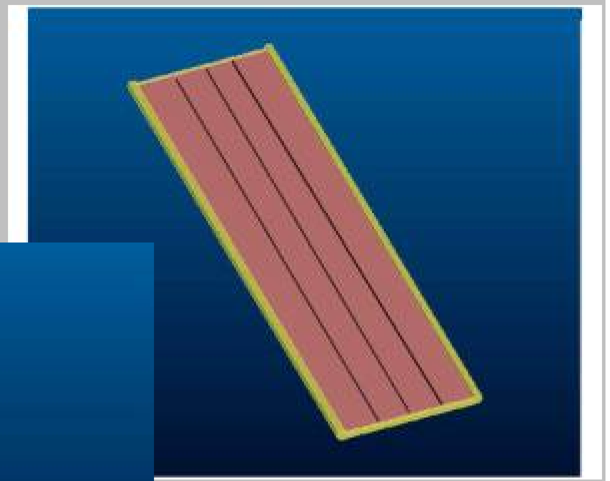
TIARA

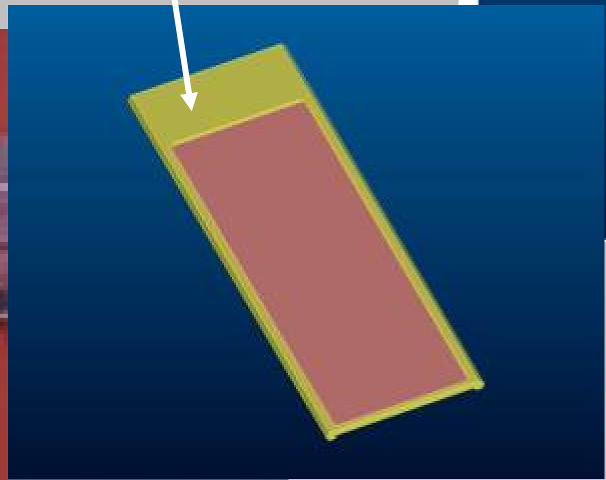
BARREL Detail and Assembly

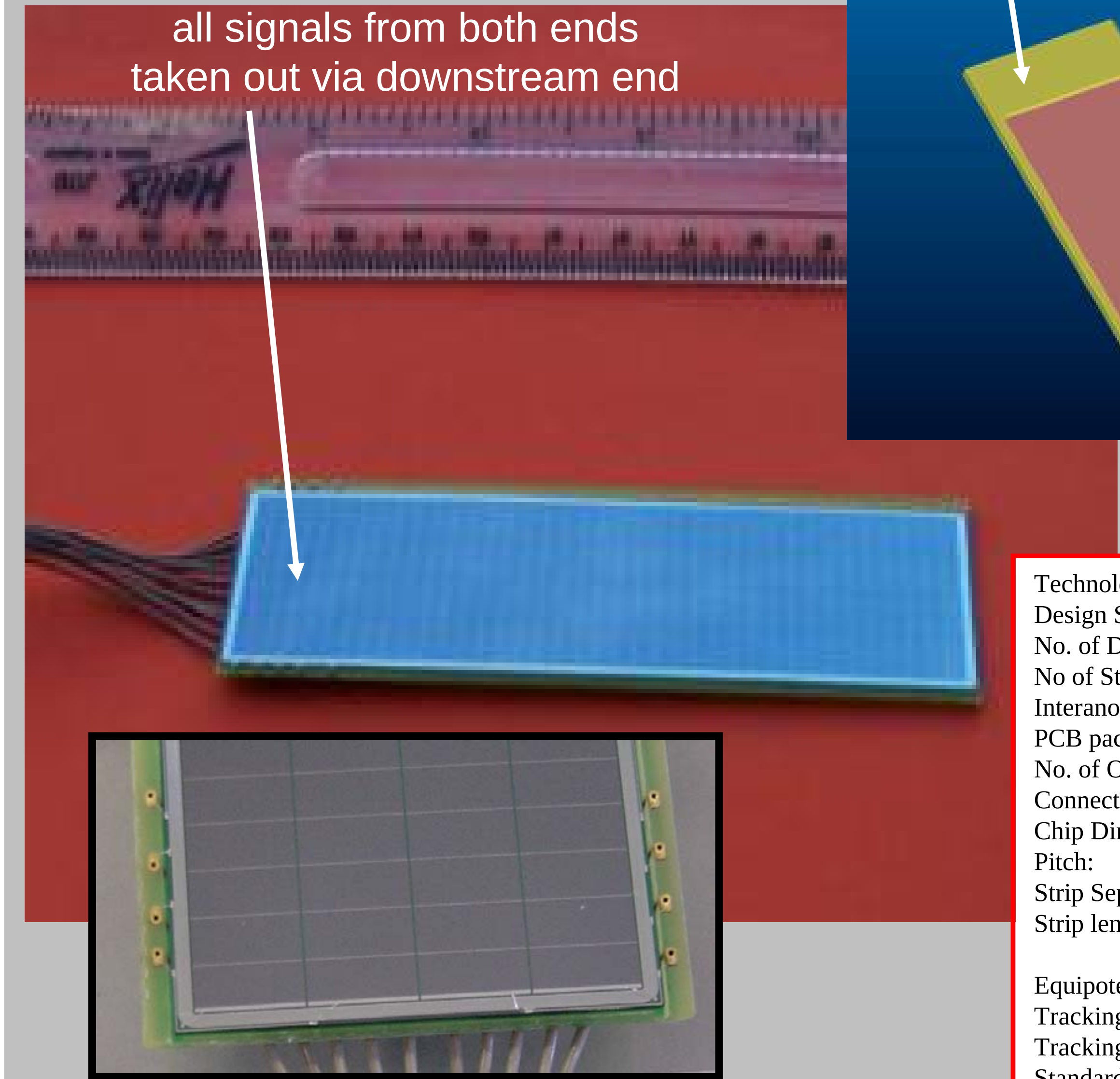
TIARA

Design of barrel minimising dead space





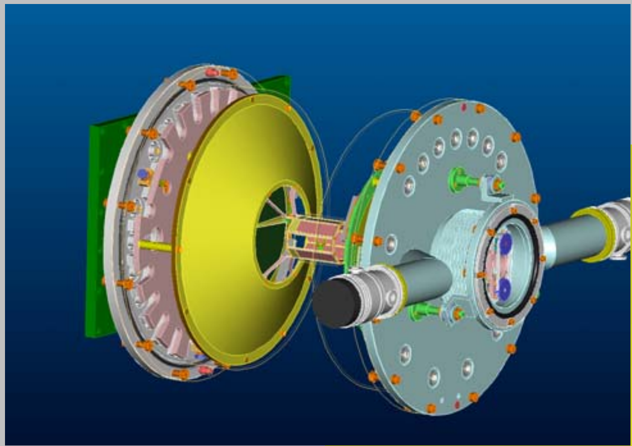


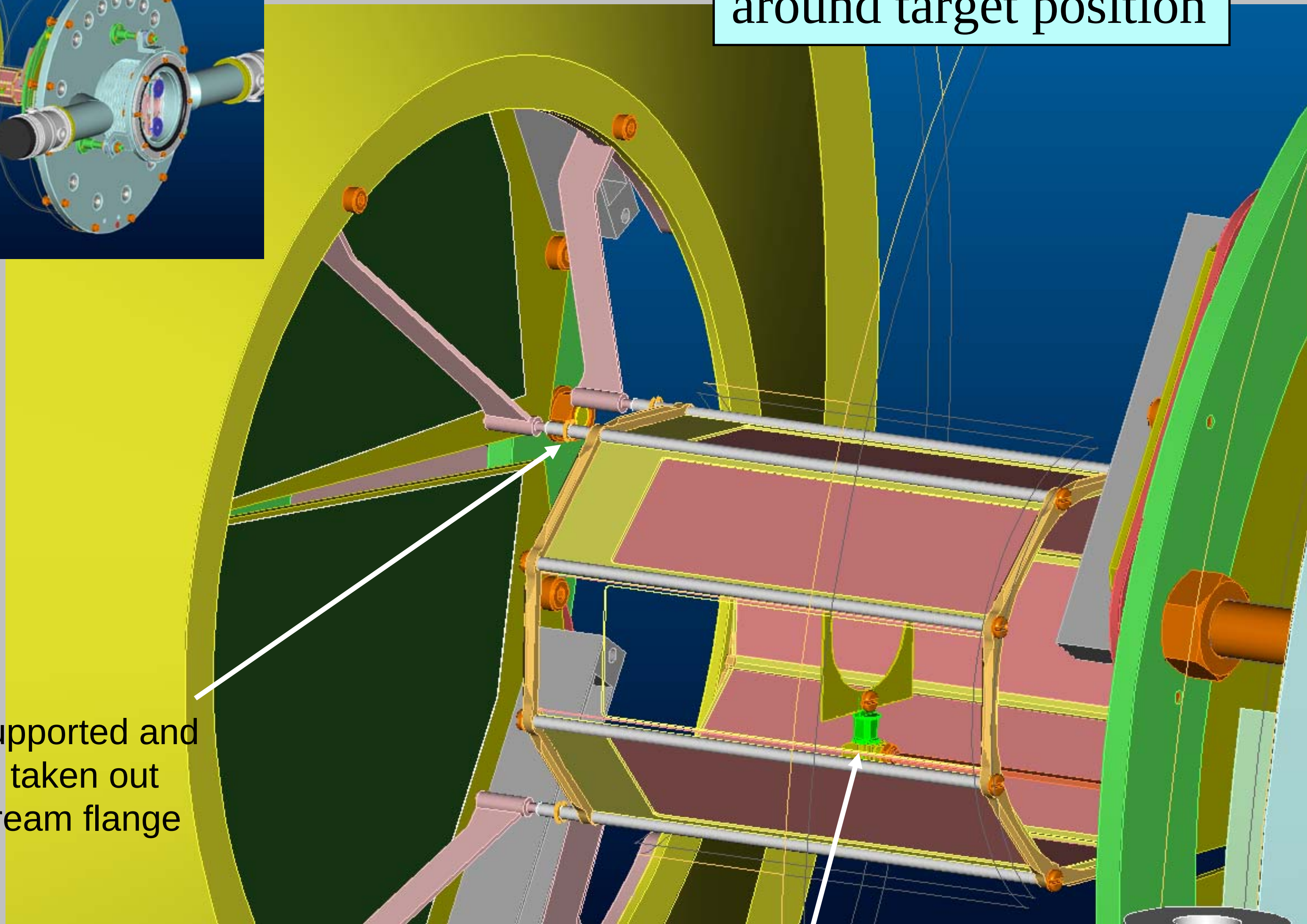


Technology:	6 Inch Silicon
Design Selected:	Custom Microstrip Resistive Division PSD
No. of Detectors:	10 (Including 2 Spare) located in octogon format.
No of Strips:	4
Interanode resistance:	4Kohm nominal 10 Kohm maximum
PCB package:	98mm x 27.6 mm x 1.6mm nominal TBC
No. of Outputs:	8 Anodes+ Substrate
Connector:	Junkosha Miniature Coaxial Cables. Length 50cm
Chip Dimensions:	24.6mm x 96.8mm (clearance 100mm at each end)
Pitch:	5.65 mm
Strip Separation:	100mm
Strip length:	94.8 mm

Equipotential Lines along PS; Equipotential Pitch Width: 50mm
Tracking width 50mm,
Tracking Bond Pads (Standard): 150x400 mm2, (Corner): 150x200 mm2
Standard Multi Guard Ring Design

Mounting of barrel around target position



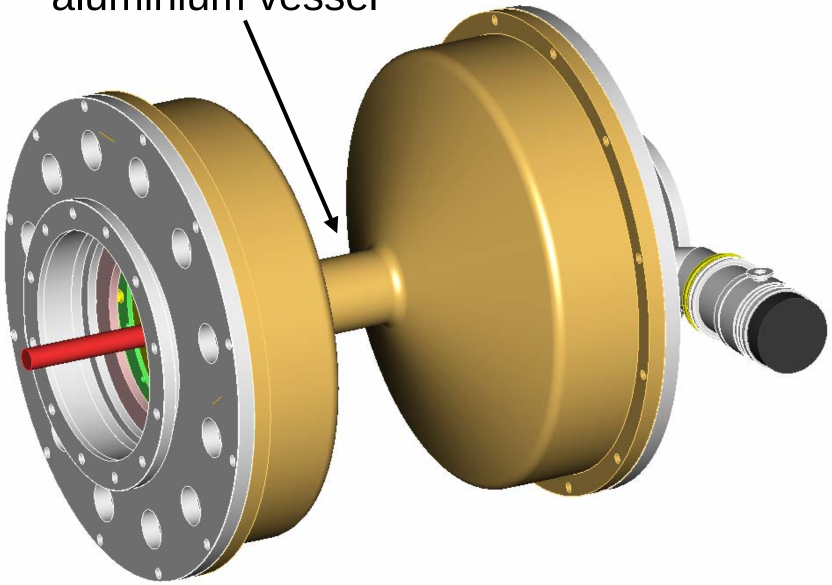


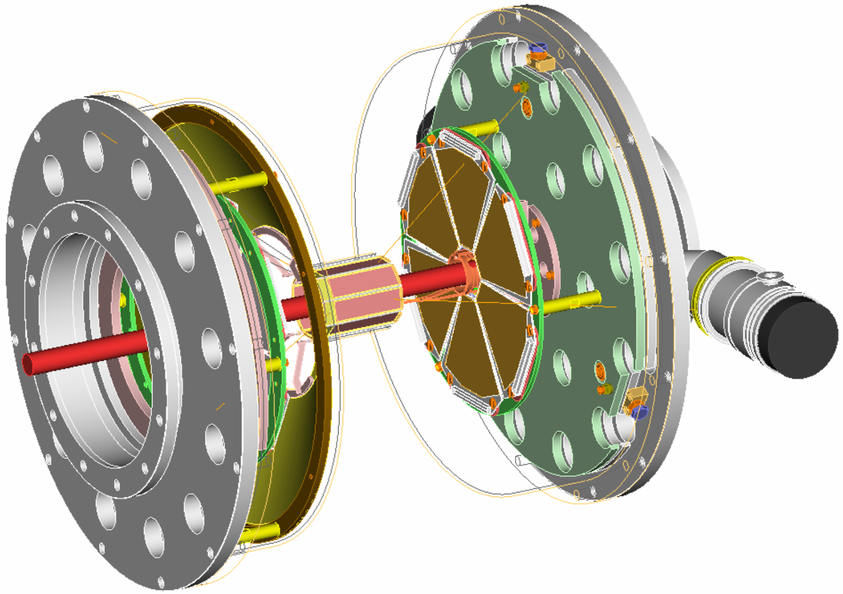
barrel fully supported and
all signals taken out
via downstream flange

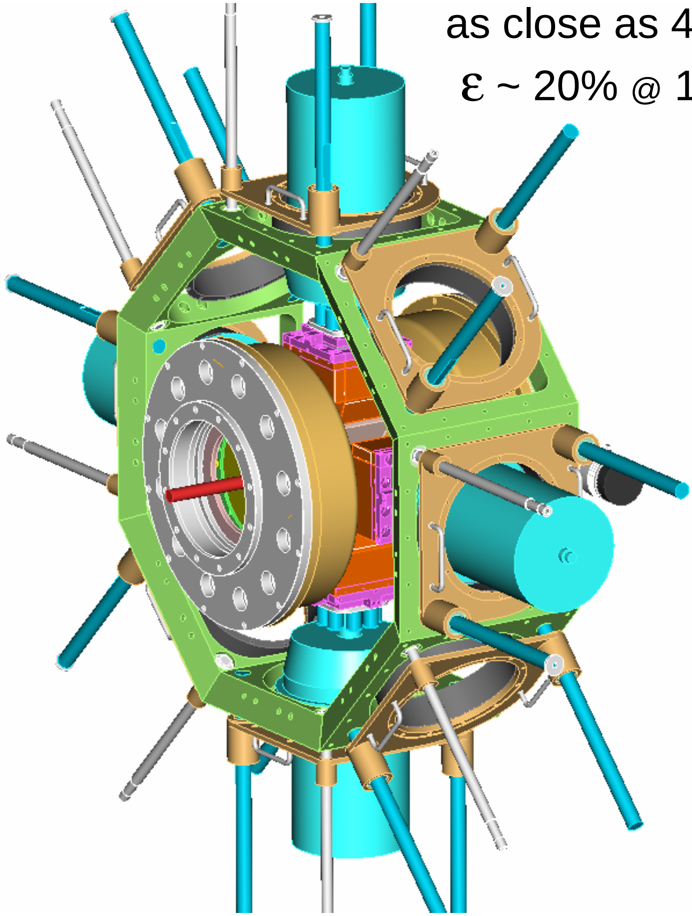
target inserted
by upstream mechanism

TIARA

TIARA + EXOGAM

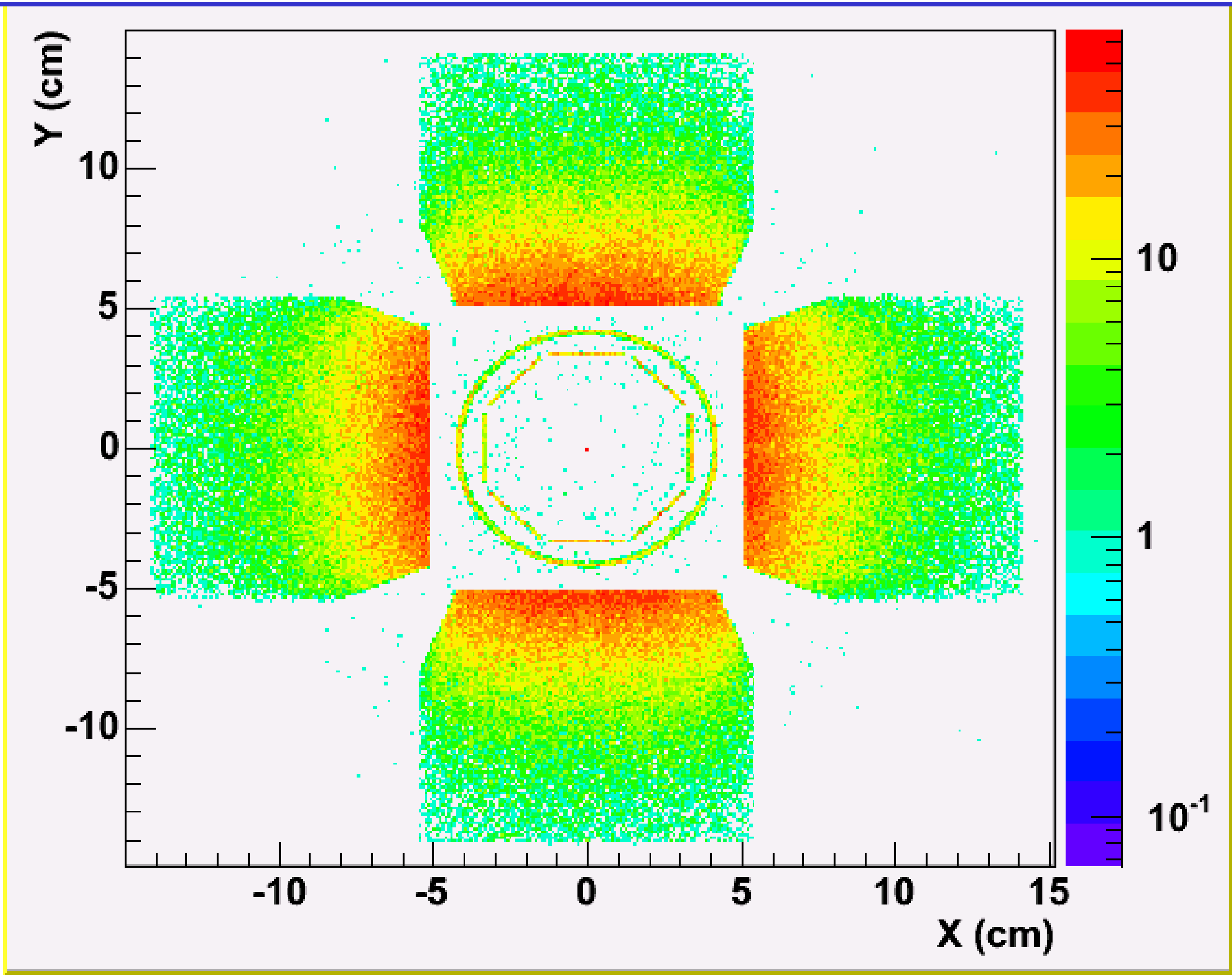


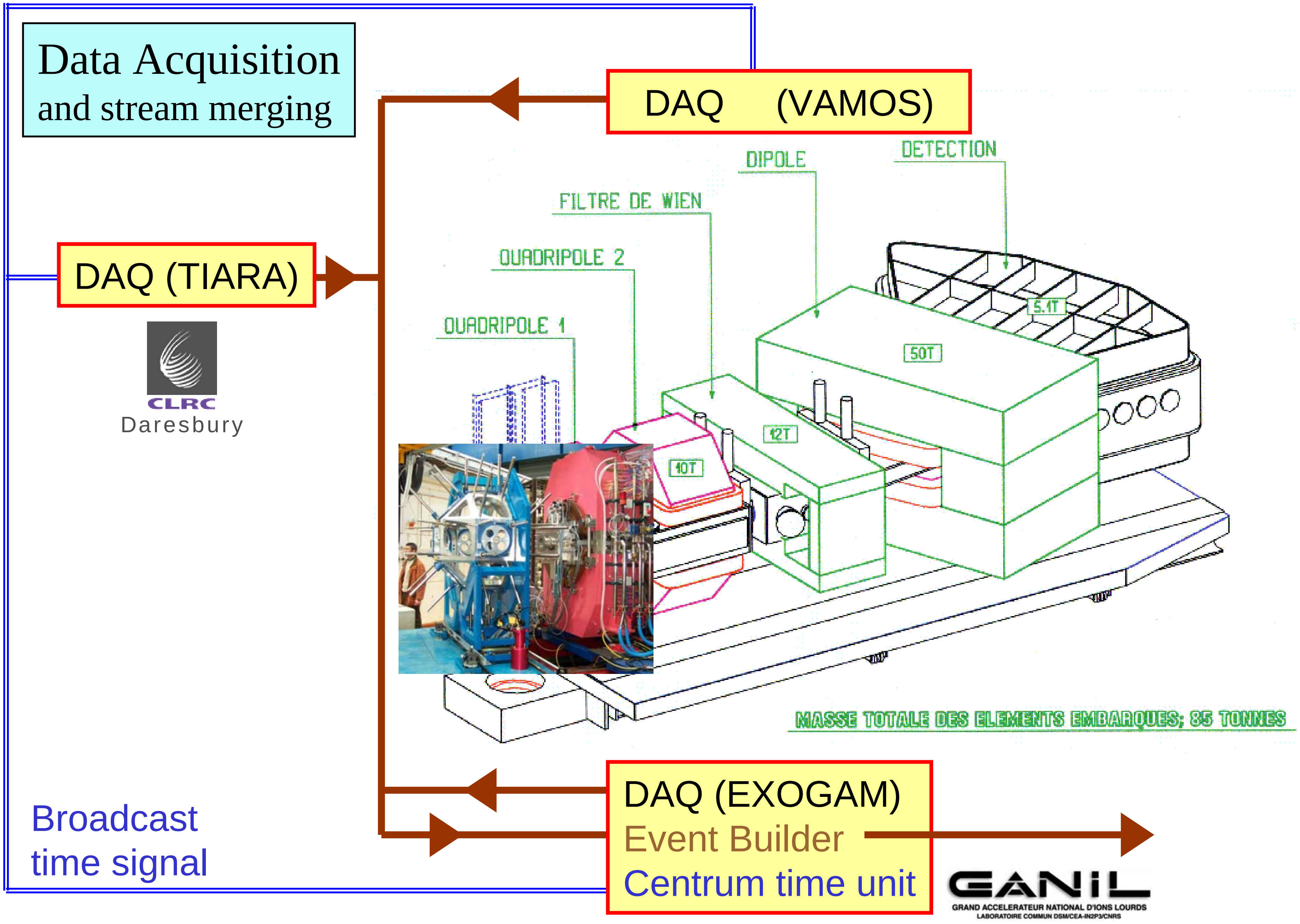




TIARA

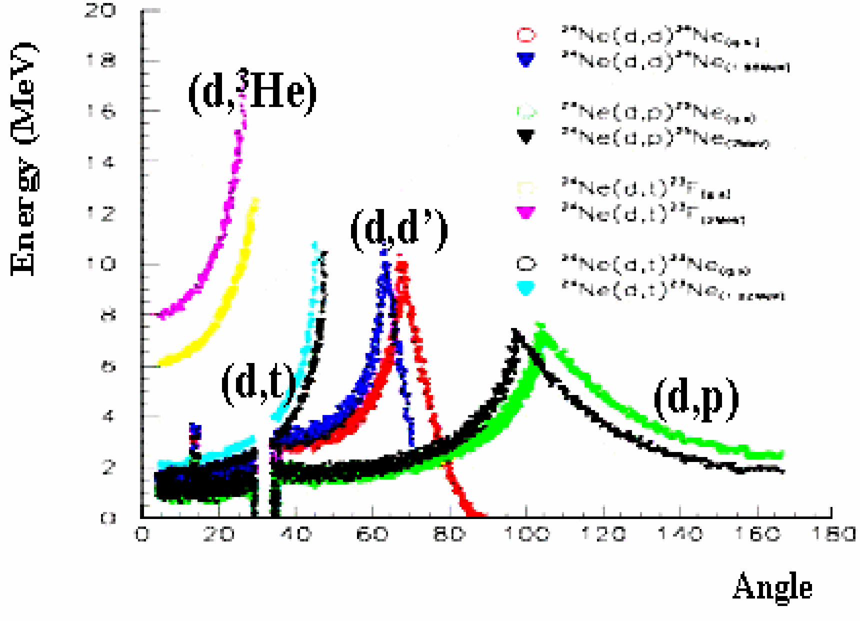
Geant simulation: first interaction point for E(gamma) = 2.05 MeV





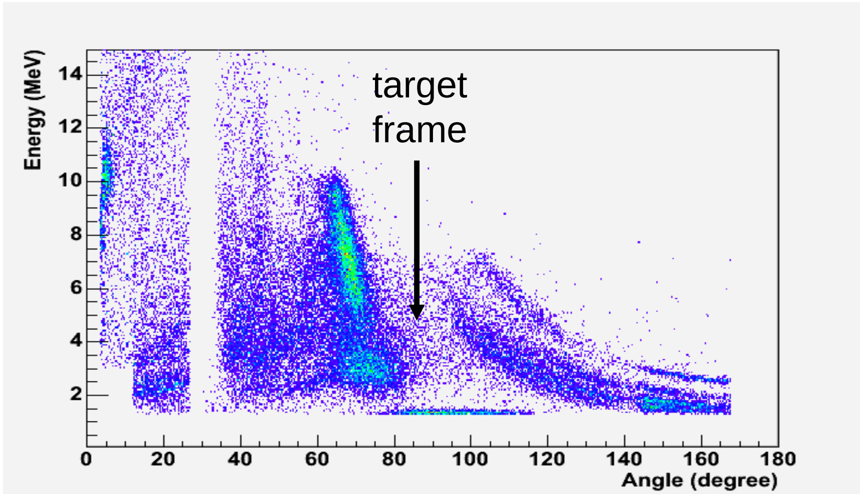
Data Acquisition
and stream merging
DAQ (VAMOS)
DIPOLE
DETECTION
FILTRE DE WIEN
QUADRIPOLE 2
QUADRIPOLE 1
5.1T
50T
12T
10T
DAQ (TIARA)
CLRC
Daresbury
MASSE TOTALE DES ELEMENTS EMBARQUES; 85 TONNES
DAQ (EXOGAM)
Event Builder
Centrum time unit
Broadcast
time signal
GANIL
GRAND ACCELERATEUR NATIONAL D'IONS LOURDS
LABORATOIRE COMMUN DSM/CEA-IN2P3/CNRS

Geant4 Simulation

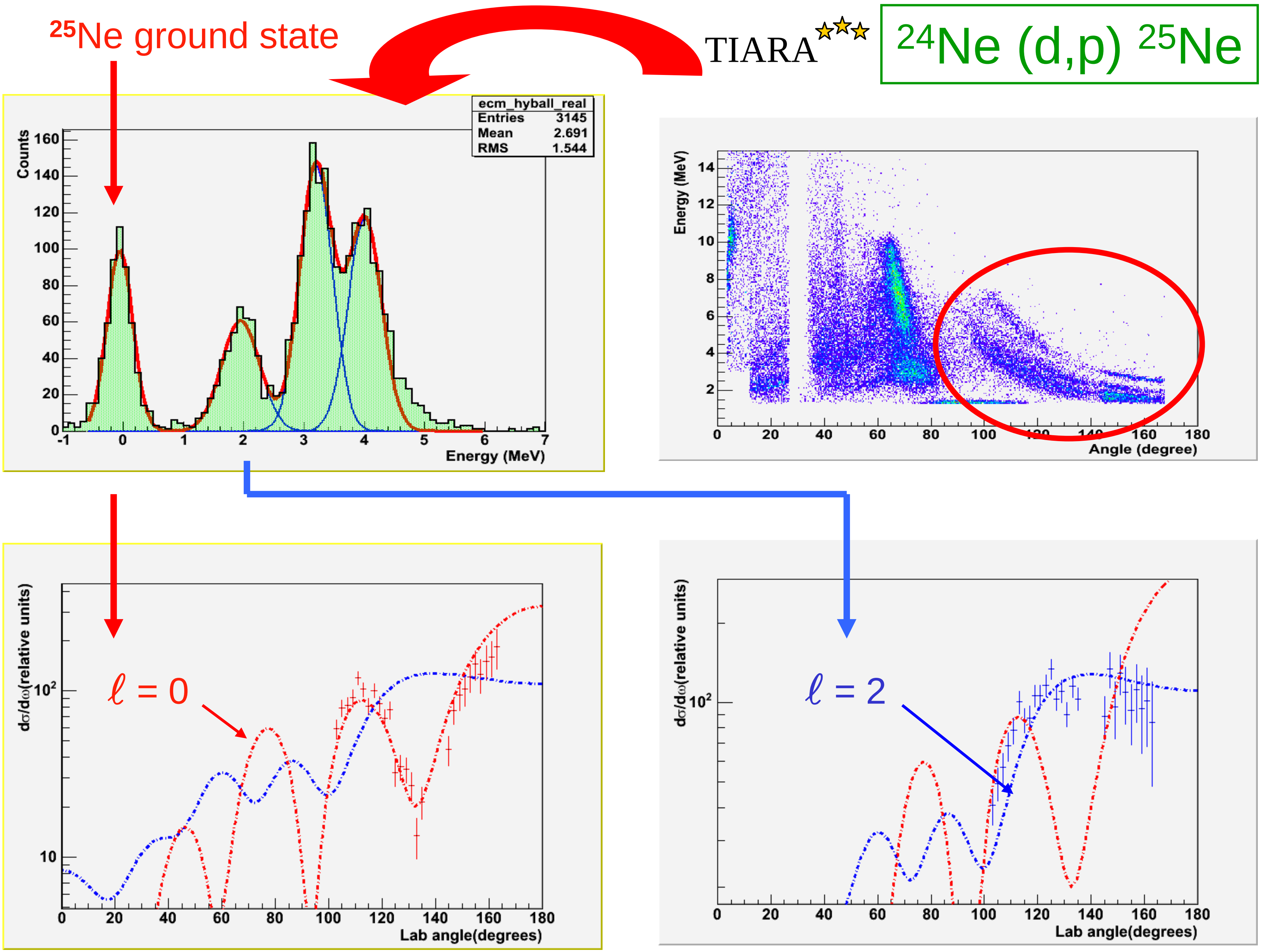


TIARA

^{24}Ne (d,p) ^{25}Ne

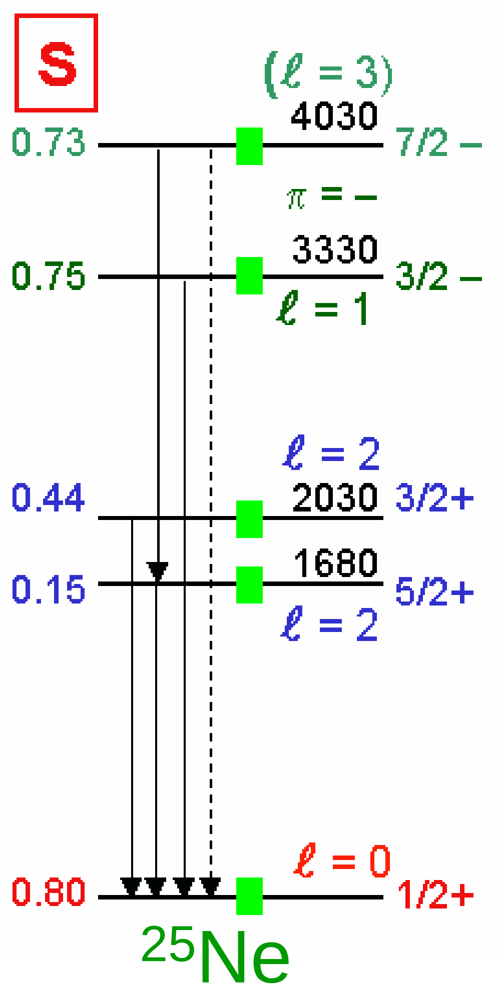


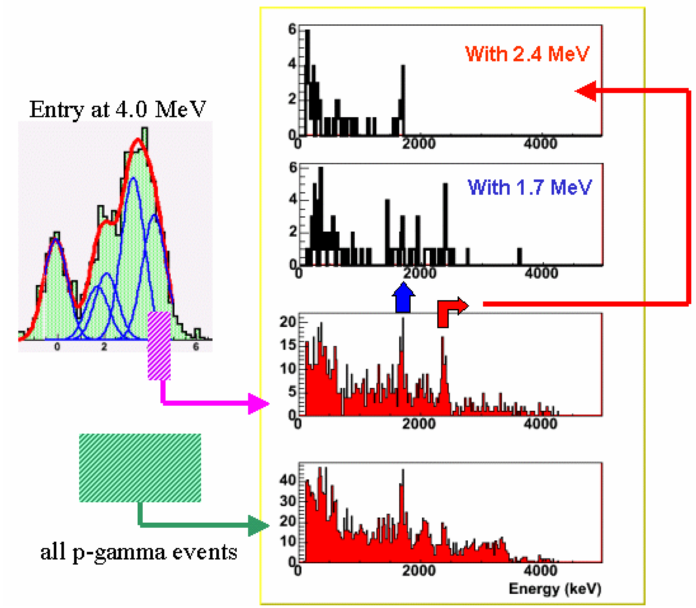
The measured energy versus angle, measured over almost full 4π

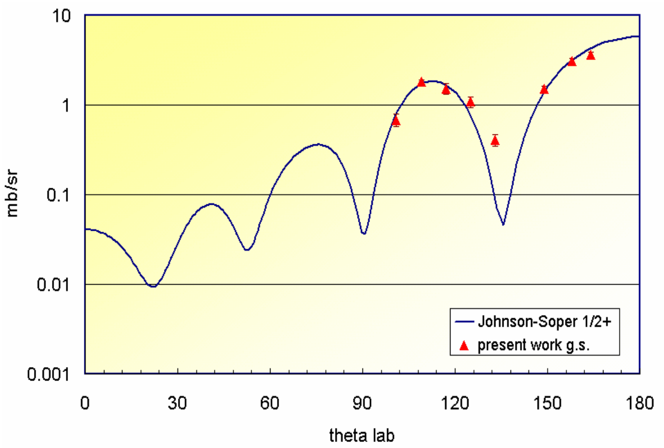


^{25}Ne ground state
TIARA
^{24}Ne (d,p) ^{25}Ne
ecm_hyball_real
Entries 3145
Mean 2.691
RMS 1.544
Counts
Energy (MeV)
Energy (MeV)
Angle (degree)
dσ/dω(relative units)
Lab angle(degrees)
ℓ = 0
ℓ = 2

Experimental Arrangement for Transfer with TIARA







(d,p)

TIARA


CHARISSA
TIARA

Nuclear Structure Studies with Radioactive Beams
at 10-50 MeV/nucleon

Wilton Catford Department of Physics, University of Surrey, Guildford, UK

- **We have** a very successful working system with 82% 4π coverage with 2° angular resolution
  + we plan to extend by surrounding first barrel with second layer
- **If we could have** very many channels quite easily, would we still choose resistive strips? (… recall digital methods)
- **If we use ASICs** then how much do we do in the vacuum? Just preamp? Preamp/Amp/Sample? Full digitisation?
- **Is it still best** (compactness, heat, gamma attenuation) to bring all the signals out immediately?
- **Silicon technology** with either resistive strips or many non-resistive strips offers many possible future developments

CHARISSA

TIARA