First seminar of FRRC Fellows
FAIR — Russia Research Center, Moscow
9-10 June 2009, ITEP Moscow

Long CsI(Tl) detectors for R3B and EXL in frame of NUSTAR

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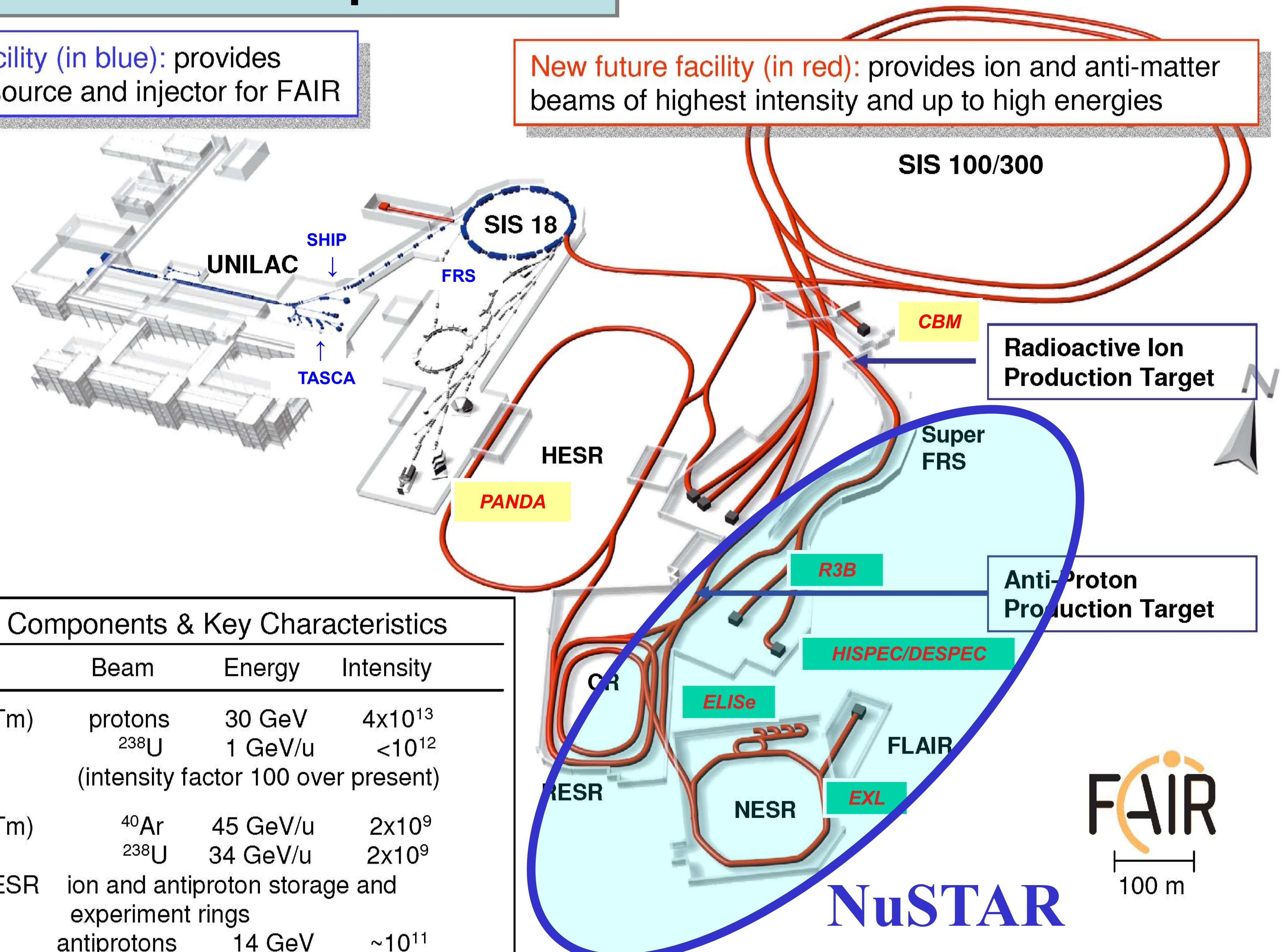
Joint Institute for Nuclear Research
Dubna, Russia

The Technical Concept for FAIR

Existing facility (in blue): provides ion-beam source and injector for FAIR

New future facility (in red): provides ion and anti-matter beams of highest intensity and up to high energies

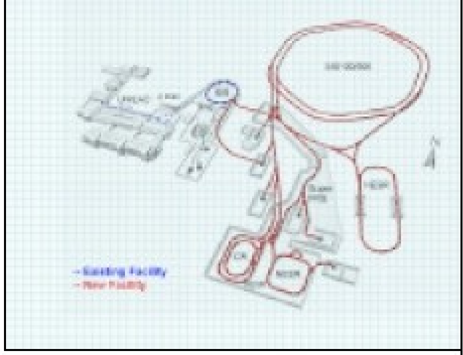


Accelerator Components & Key Characteristics

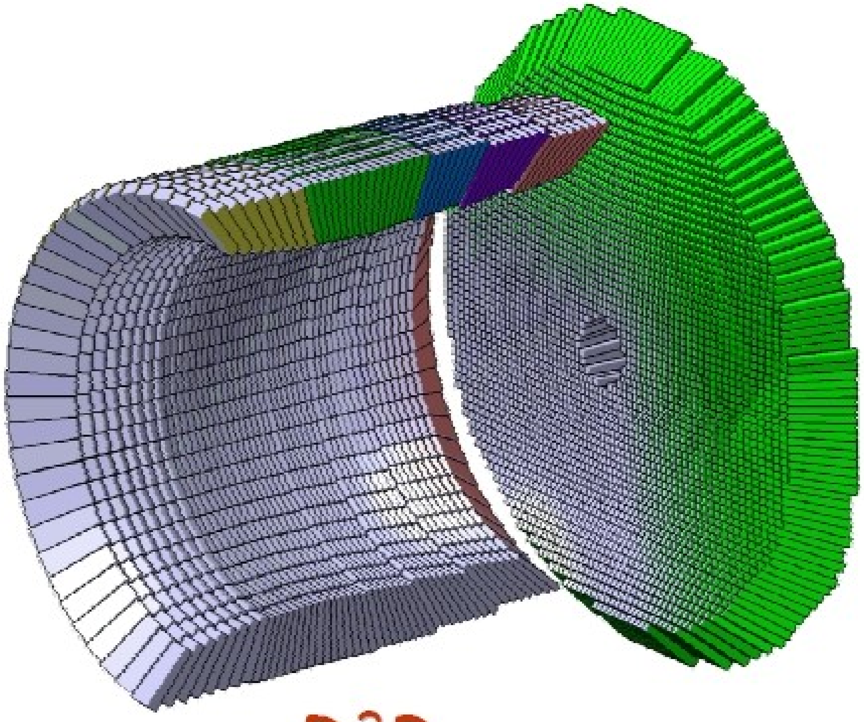
Ring/Device	Beam	Energy	Intensity
SIS100 (100Tm)	protons	30 GeV	$4x10^{13}$
	^{238}U	1 GeV/u	$<10^{12}$
	(intensity factor 100 over present)		
SIS300 (300Tm)	^{40}Ar	45 GeV/u	$2x10^9$
	^{238}U	34 GeV/u	$2x10^9$
CR/RESR/NESR	ion and antiproton storage and experiment rings		
HESR	antiprotons	14 GeV	$\sim10^{11}$
SuperFRS	rare-isotope beams	1 GeV/u	$<10^9$

W.Henning, NuSTAR Meeting 2007, March 21-23

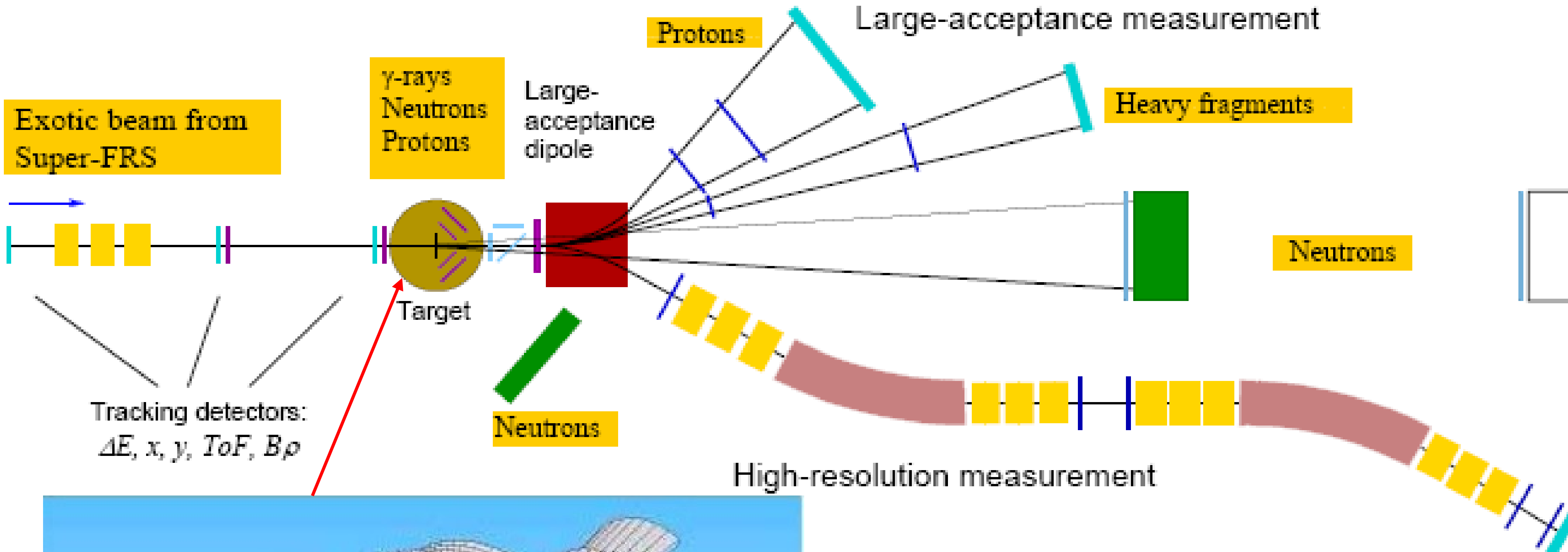
R3B & EXL
Univ of Compostella & IPN Orsay

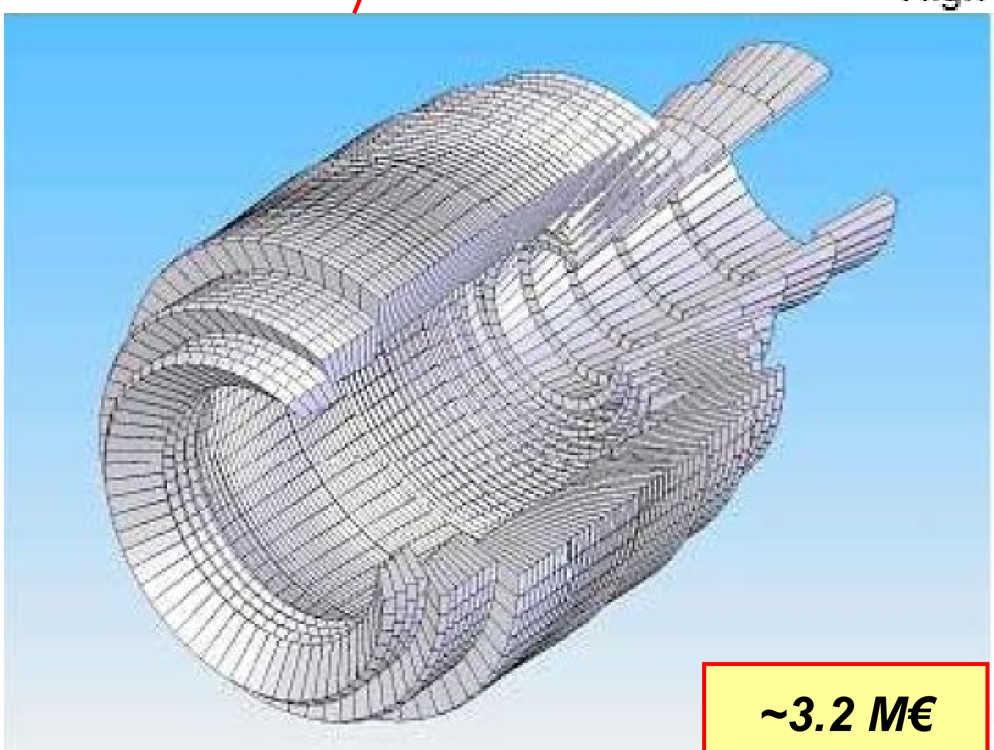


Similar Calorimeters as GASPA



R3B: Reactions with Relativistic Radioactive Beams





New calorimeter based on CsI(Tl) crystals (*1x2x13-20 cm³, 5025 units*) and APD:

ε_γ ~ 80 % @ 15 MeV

ΔΘ ~ 0.018 rad

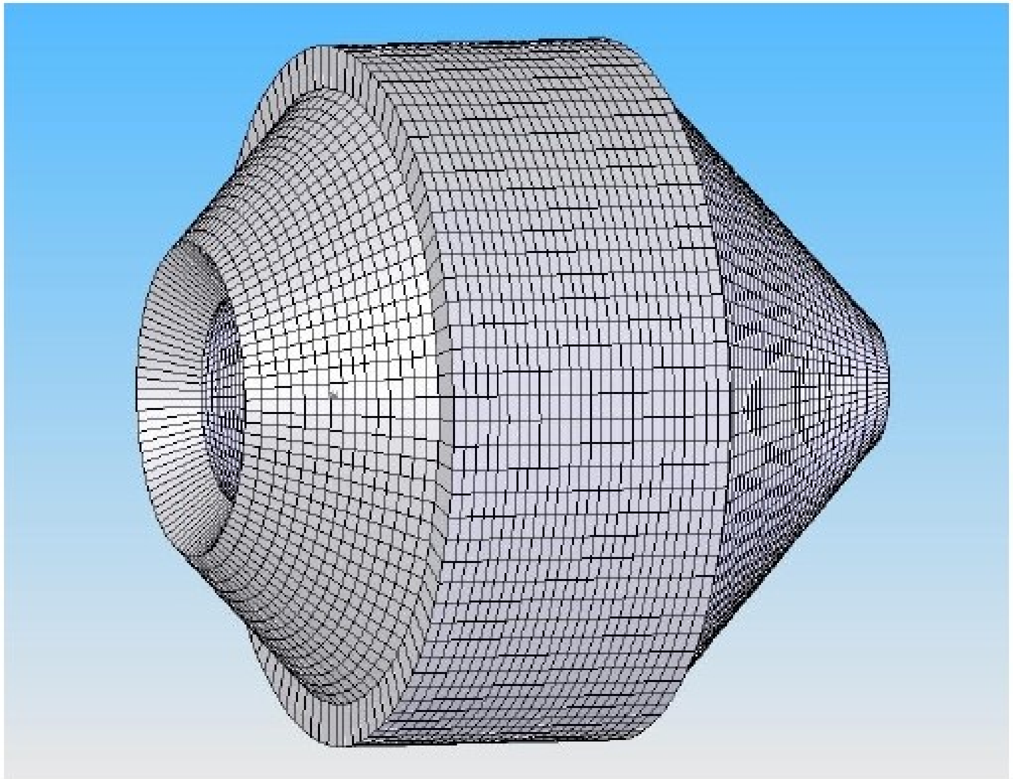
E_γ = 1-30 MeV, ΔE/E ~ 4-5% @ 662 keV

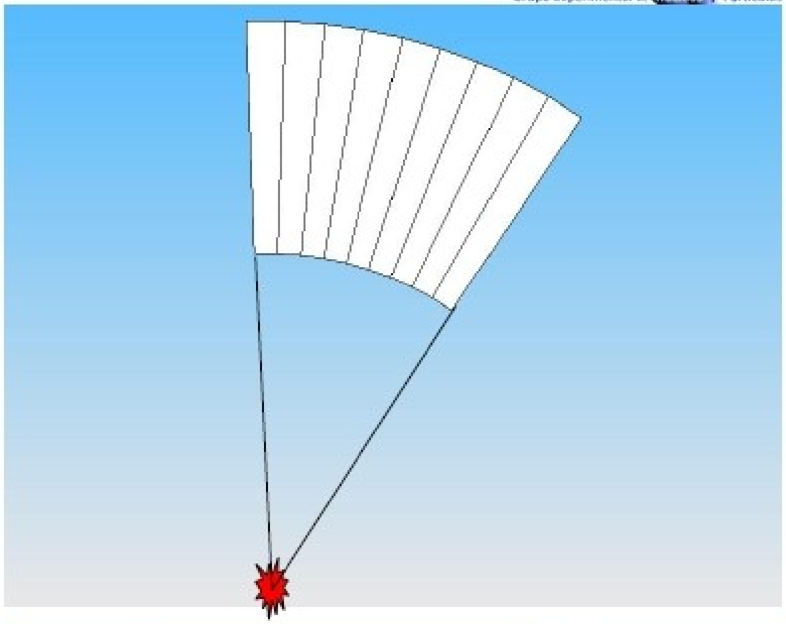
E_p < 300 MeV, ΔE/E ~ 1% or better

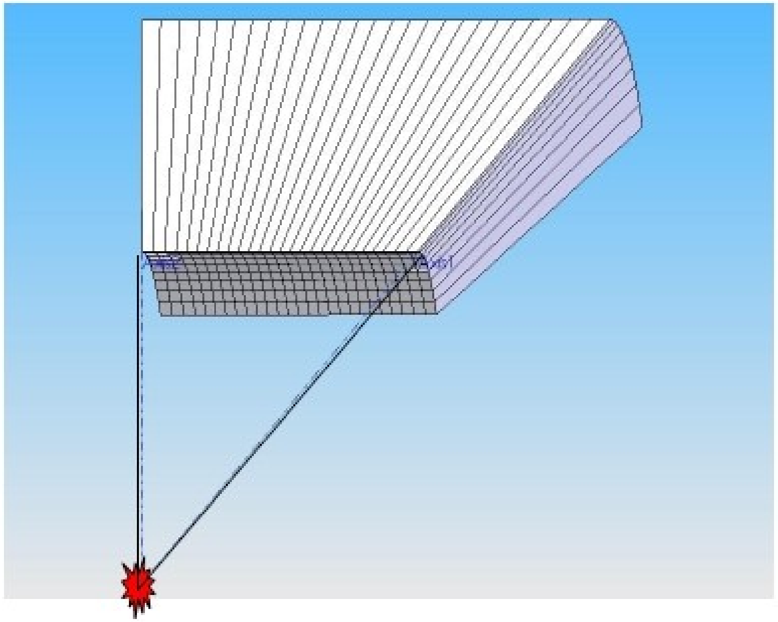
USC (Spain), LU (Sweden)
JINR and Kurchatov Inst.

First design iteration (CALIFA 1.2):

- 6570 crystals in 73 different crystal types
- Covering polar angles between 7º and 133º
- Trapezium-like shaped crystals
- Simple geometry filling the gaps
- Typical crystal volume: 10x20x(130-200) mm^3
- Weight: ~ 1600 Kg; volume: ~ 360 dm^3







CALIFA design v2.0

As we were open to criticism, criticism came soon…

- Azimuthal gaps between crystals
- Too many different shapes of crystals
- Too many channels/crystals…
- Too heavy, …who is going to hold it during the experiment? Students required
- Too small crystal section (also affects to the capability to cover the shower in a crystals of few crystals)

…so, a second iteration in the design

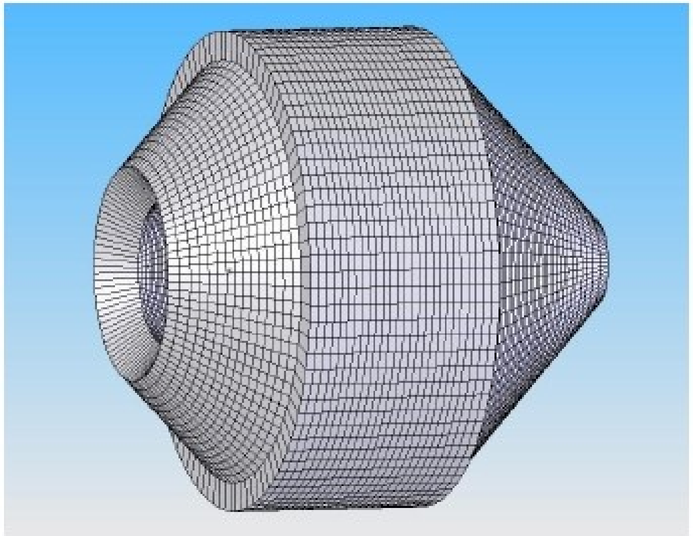
→ Irregular crystal shape

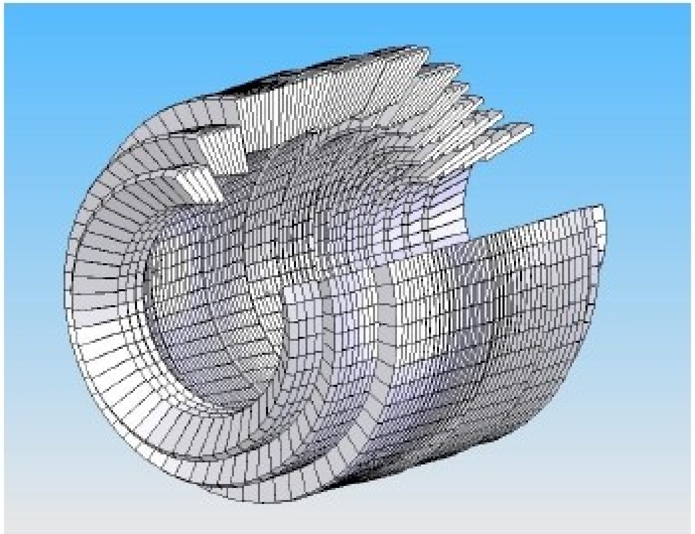
→ From 73 types in CALIFA 1.2 we moved to **10 types** in CALIFA 2.0

→ Reduction from 6570 to **less than 4500** crystals

→ Ongoing discussion on support systems and crystal wrapping (carbon fibre alveolus?)

→ Slightly larger crystal section, slightly farther away from the target (but approx. the same polar angle resolution)





CALIFA 2.0

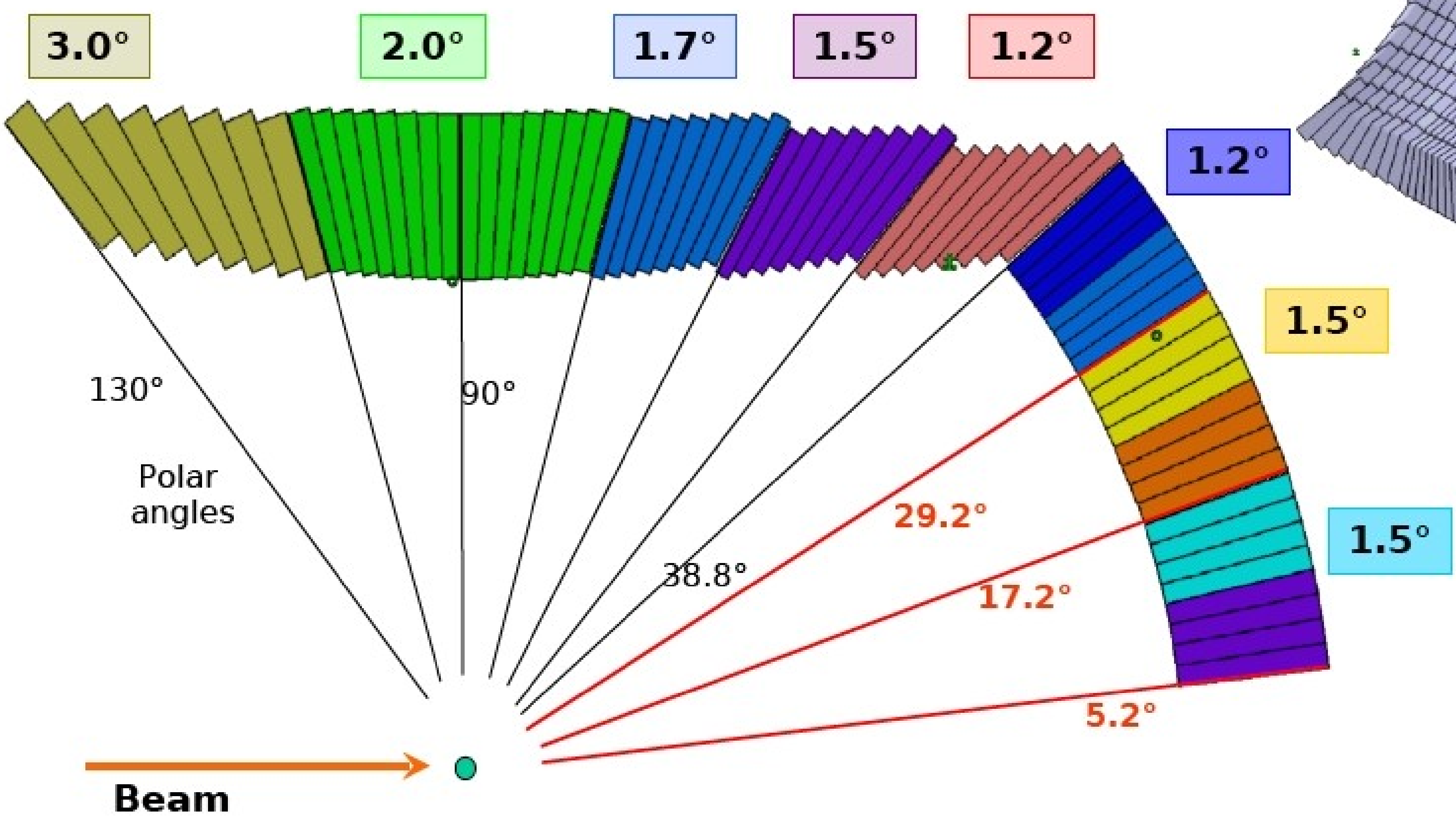
- 4500 crystals
- 10 different types
- No azimuthal gaps
- Unsolved problems on forward region

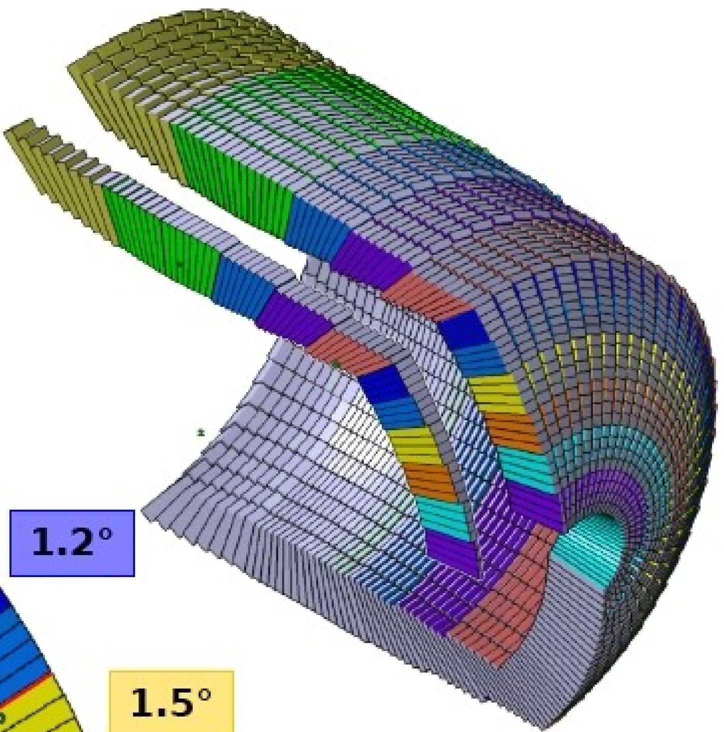
CALIFA design v4.0a, b, c (IPN Orsay, USC)

- Collaboration from IPN Orsay and USC
- Less (wider) crystals, better gamma eficiency (no holes)
- Nice solution for BARREL, not so good for EndCap:

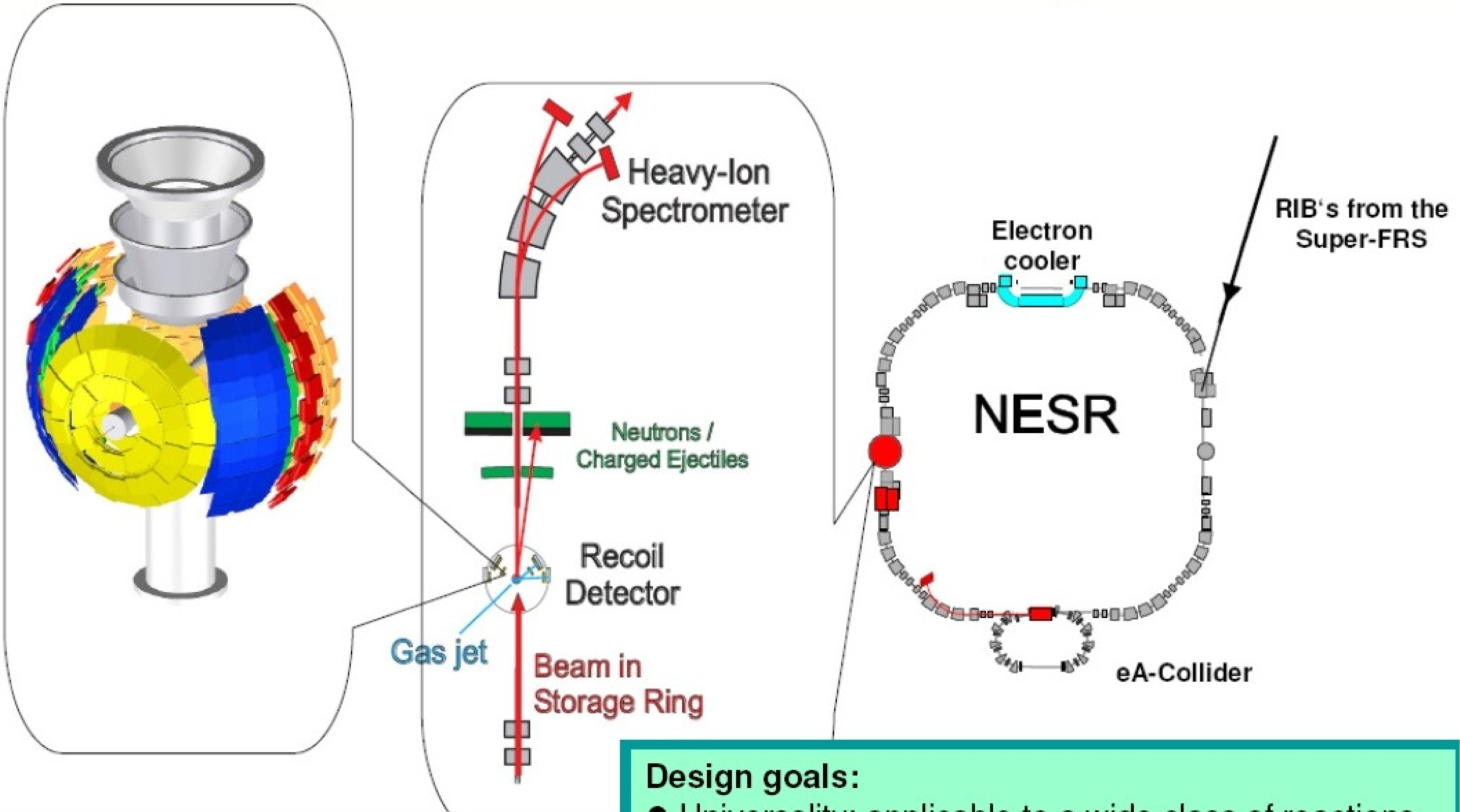
many different crystals types, still not optimized

- Radius too large (minimum ~ 45 cm)





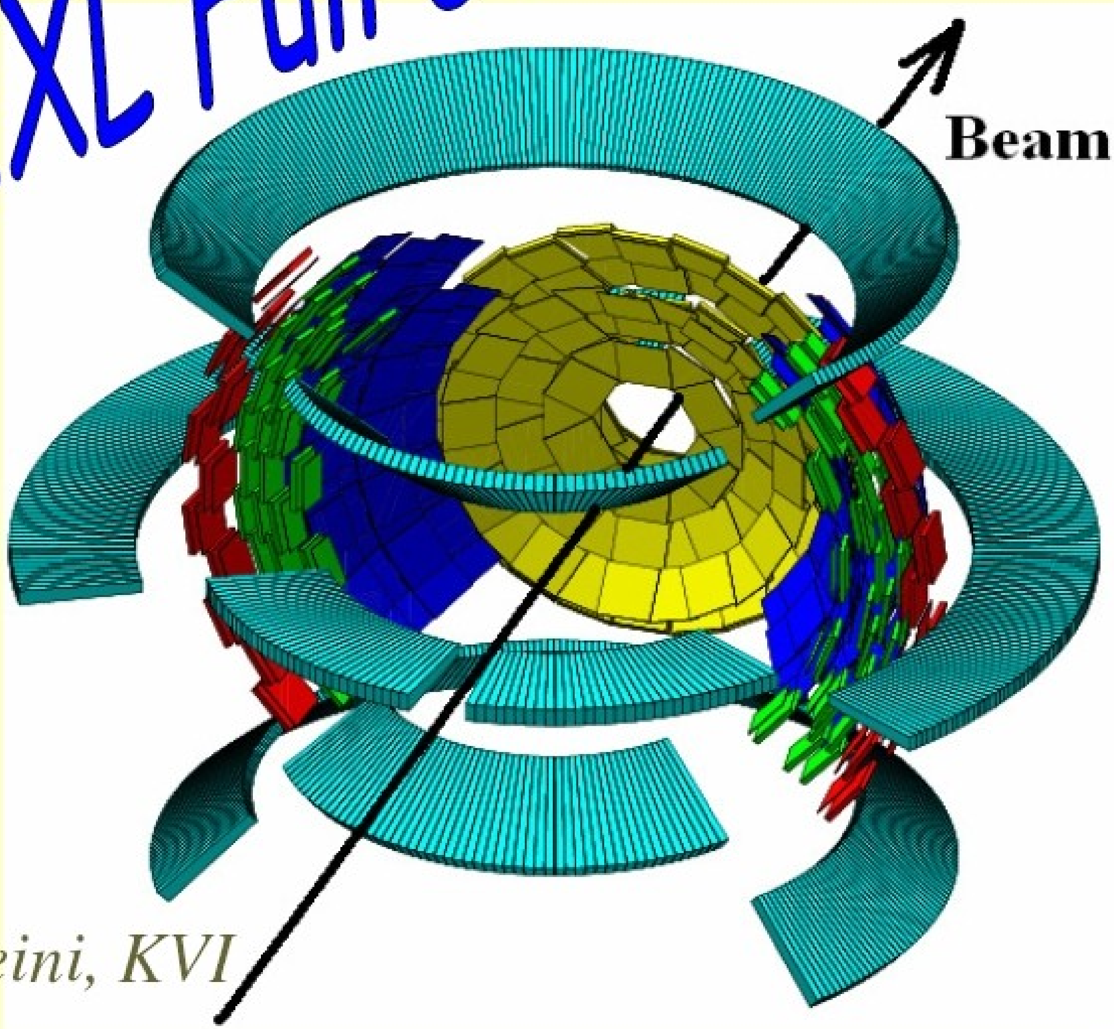
Details of the EXL setup



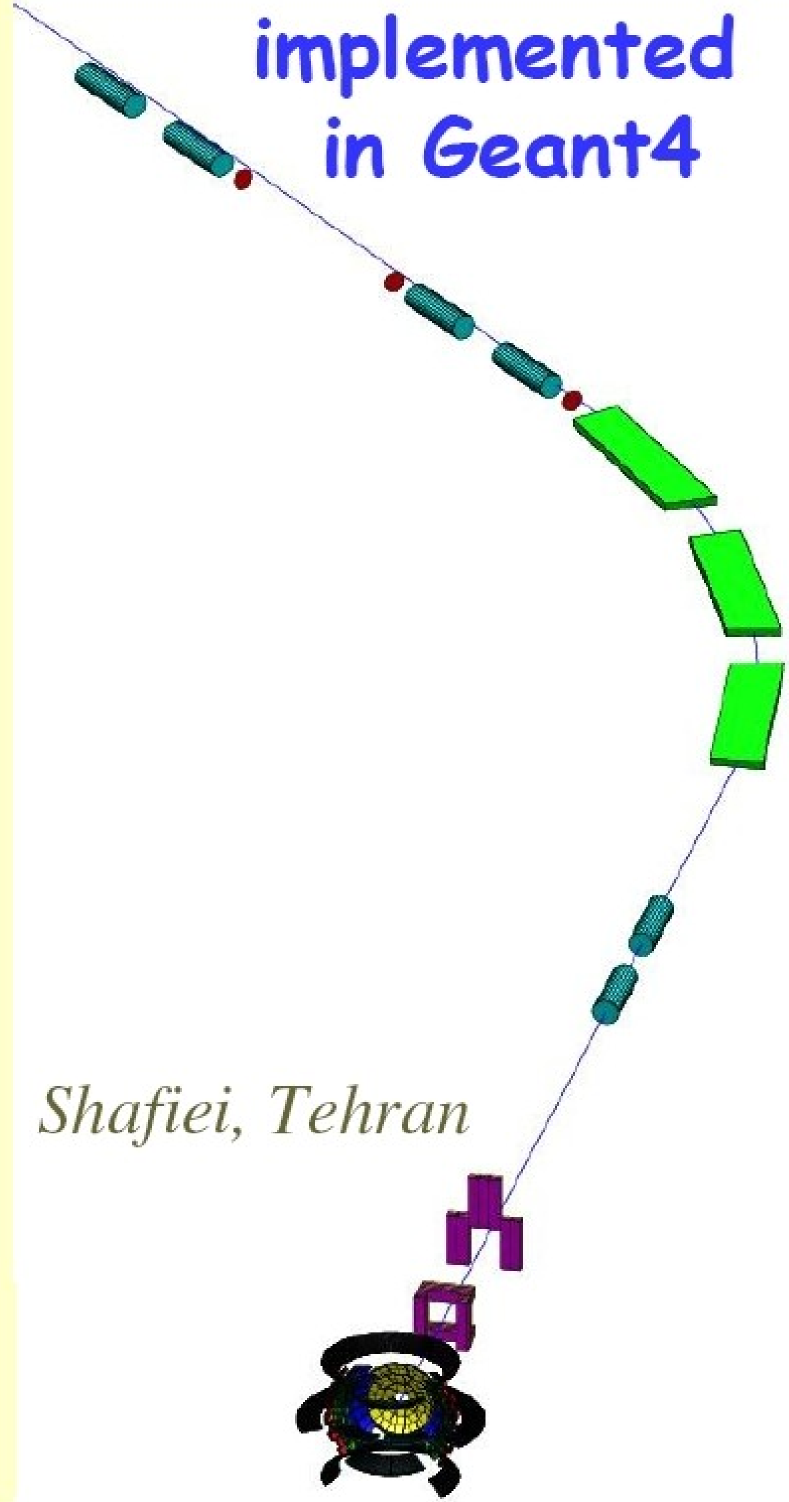
Detection systems for:
- Target recoils and gammas (p,α,n,γ)
- Forward ejectiles (p,n)
- Beam-like heavy ions

Design goals:
- Universality: applicable to a wide class of reactions
- Good energy and angular resolution
- Large solid angle acceptance
- Specially dedicated for low q measurements with high luminosity (> 10^{28} cm^{-2} s^{-1})

EXL Full Geometry



Moeini, KVI

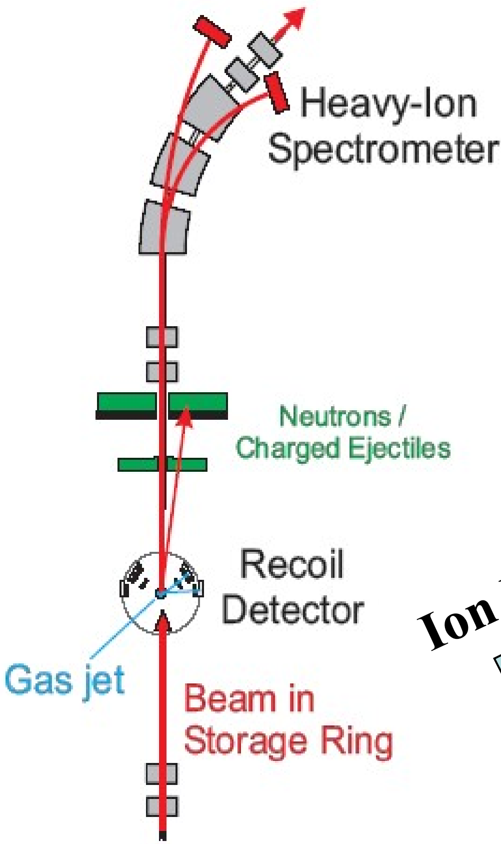


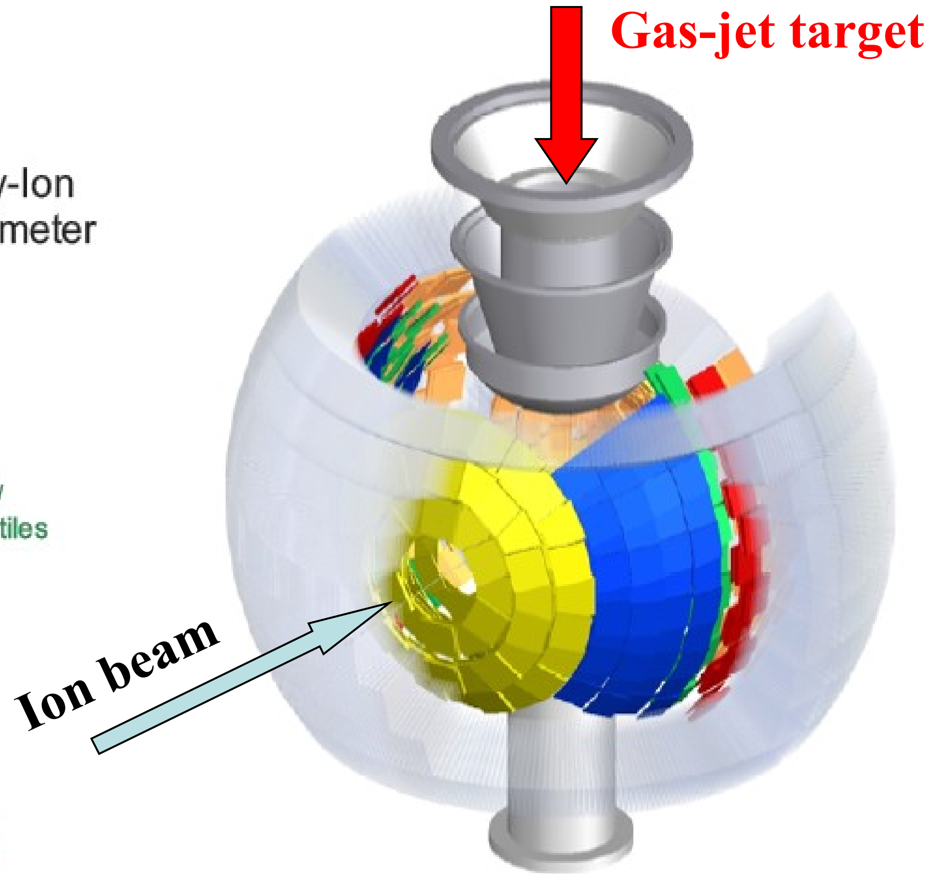
Shafiei, Tehran

Approximately 560000 channels for Si-detector setup (~700 elements) and calorimeter crystals (~2500 crystals)

KVI

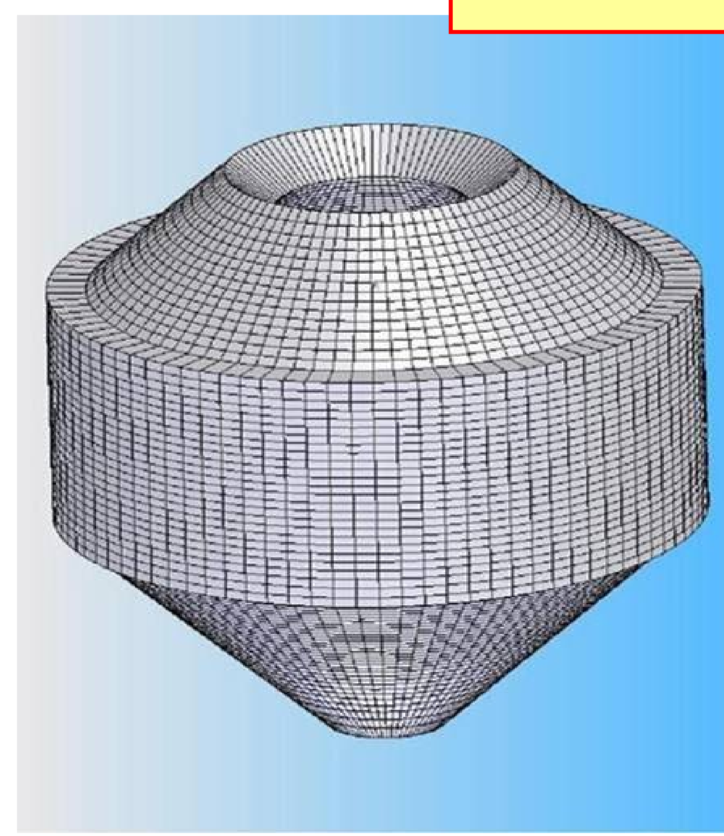
EXL: EXotic Nuclei Studied in Light-Ion Induced Reaction at the NESR





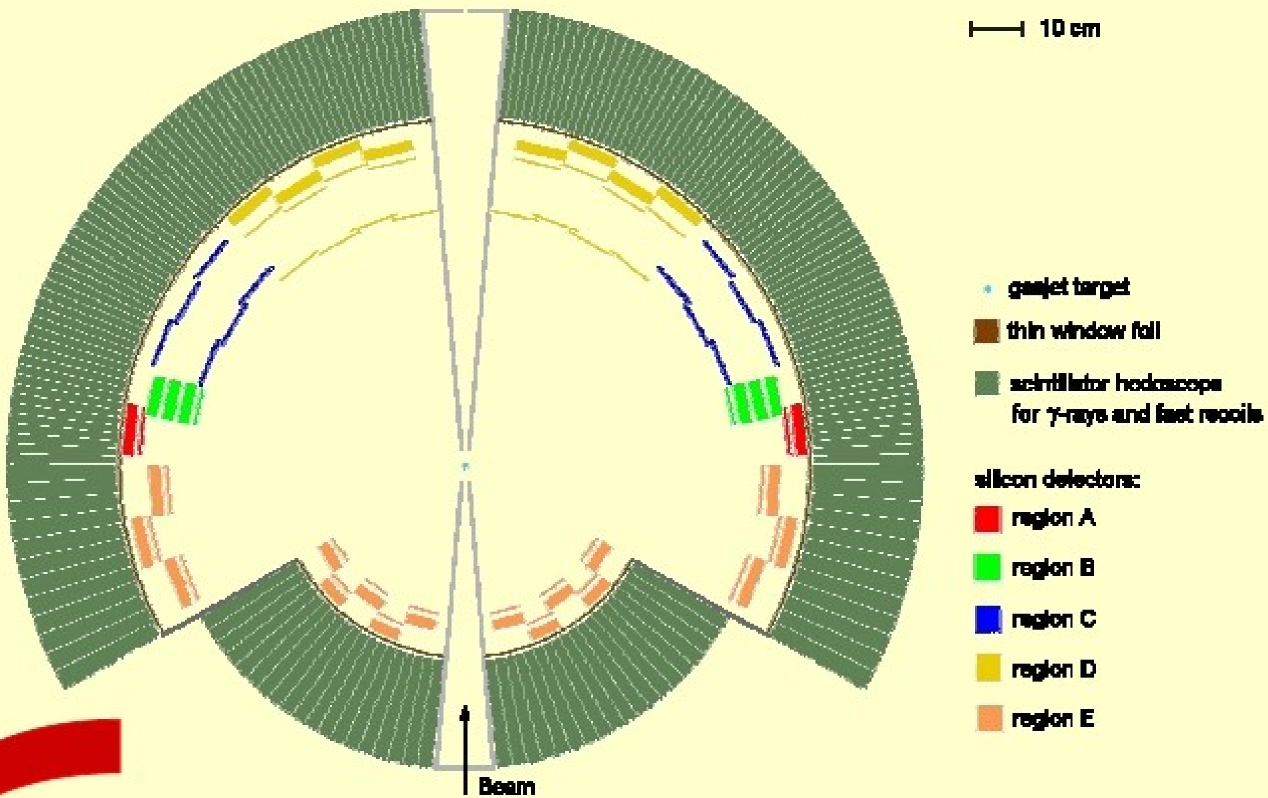
Completely new setup:
Si shell (~ 700 items)
CsI shell (~ 2000 items)

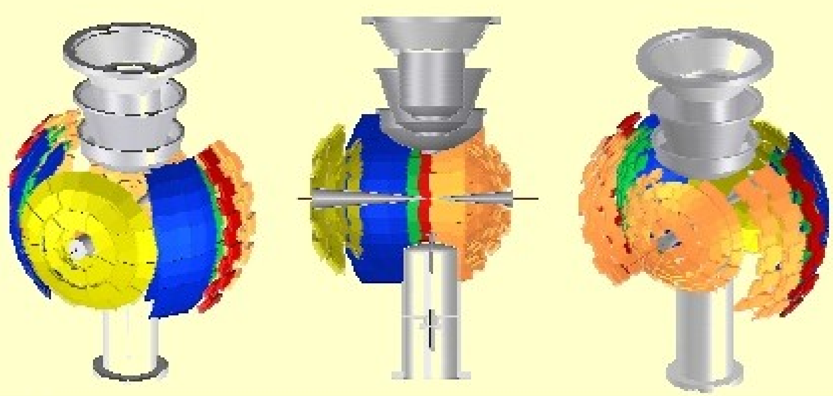
~2.6 M€



PTI (St.Petersburg) – silicon detectors
VNIIEF (Sarov) – mechanical support & temperature stabilization system
JINR and Kurchatov Institute – CsI shell
JINR – in-ring instrumentation

The EXL Recoil and Gamma Array





Si DSSD ⇨ **ΔE, x, y**
300 μm thick, spatial resolution better than 500 μm in x and y, ΔE = 30 keV (FWHM)

Thin Si DSSD ⇨ **tracking**
<100 μm thick, spatial resolution better than 100 μm in x and y, ΔE = 30 keV (FWHM)

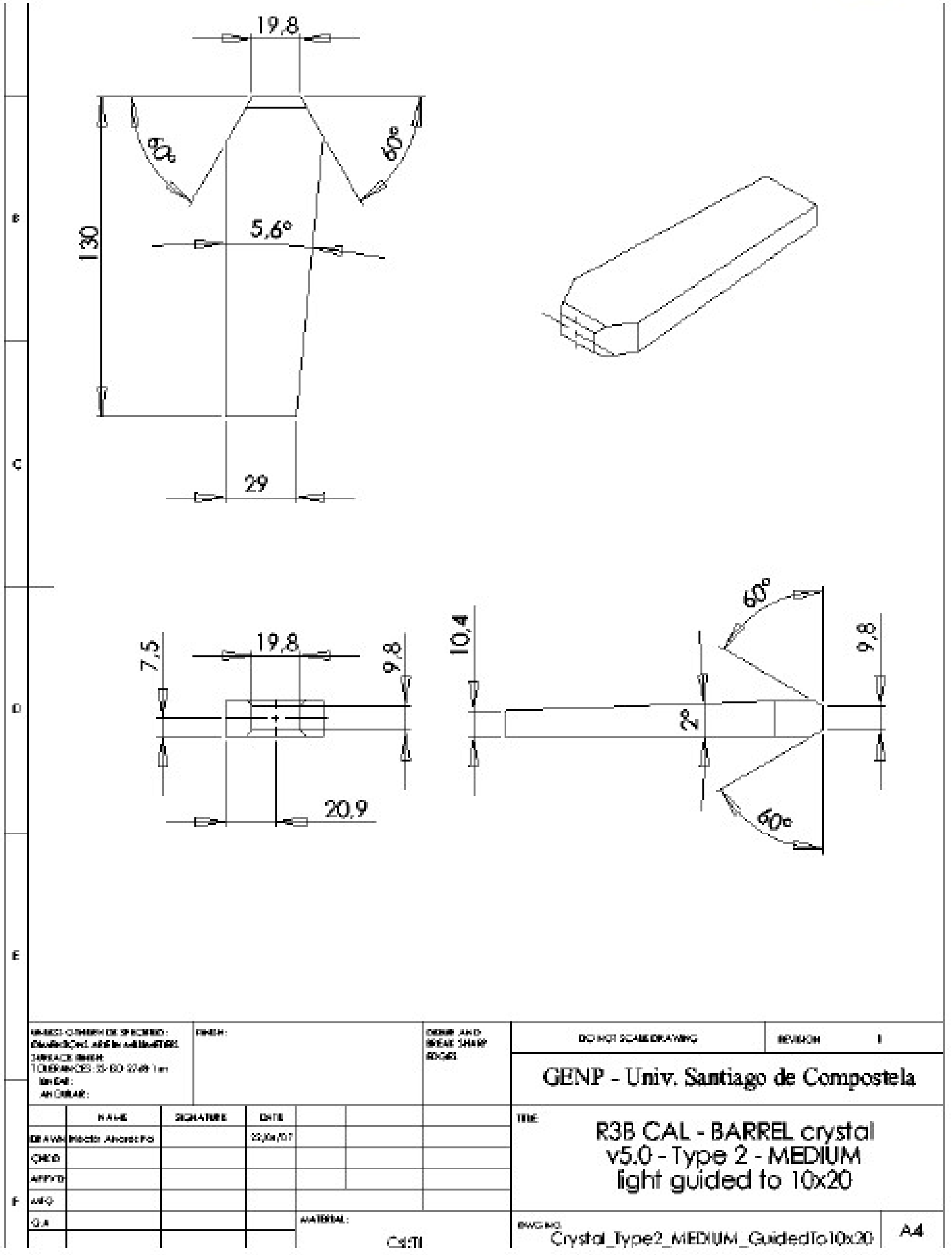
Si(Li) ⇨ **E**
9 mm thick, large area 100×100 mm^2, ΔE = 50 keV (FWHM)

CsI crystals ⇨ **E, γ**
High efficiency, high resolution, 20 cm thick

CALIFA v5.0 - Barrel

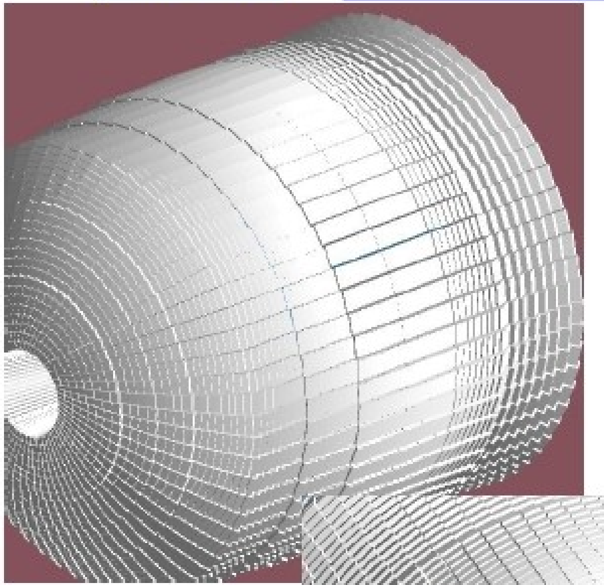
Crystal features (v5.0):

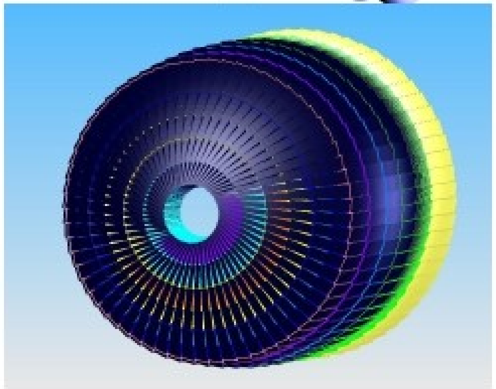
- Only five different crystal types in Barrel
- Three different crystal size combinations (**SHORT**, **MEDIUM**, **LONG**). Medium proposed for prototype
- Variable length with polar angle, according to the Lorentz boost results
- Terminated to ~20x10 mm to connect with Hamamatsu APD S8664-2010 (*)
- A "triedrum" corner facilitates mechanical production and measurements of the crystal
- Inner calorimeter radius 300 mm (minimum)
- Technical drawings available for production



(*) Not on catalogue, production depends on a research contract with Hamamatsu company

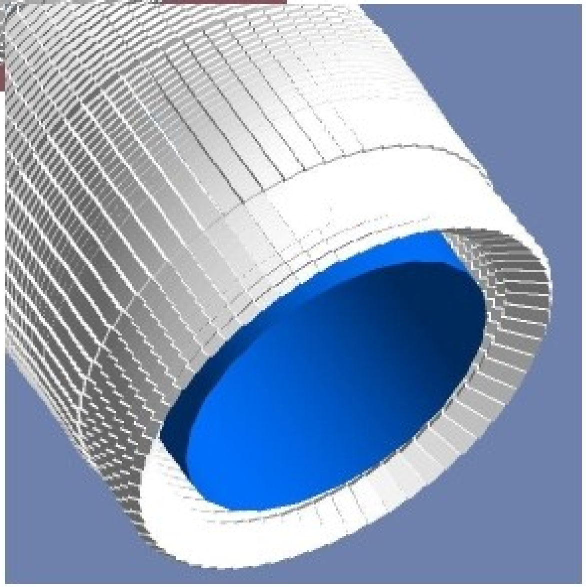
Detectors in R3BSim: CALIFA geometry





Available geometries in R3BSim:

- v1.2 initial design as described in `R3B_CAL_01/05`
- v4.0b presented by J.Peyre at Orsay Cal WG meeting
- v4.0b with corrected lengths for the crystals



Crystal length selection (v4.0b):

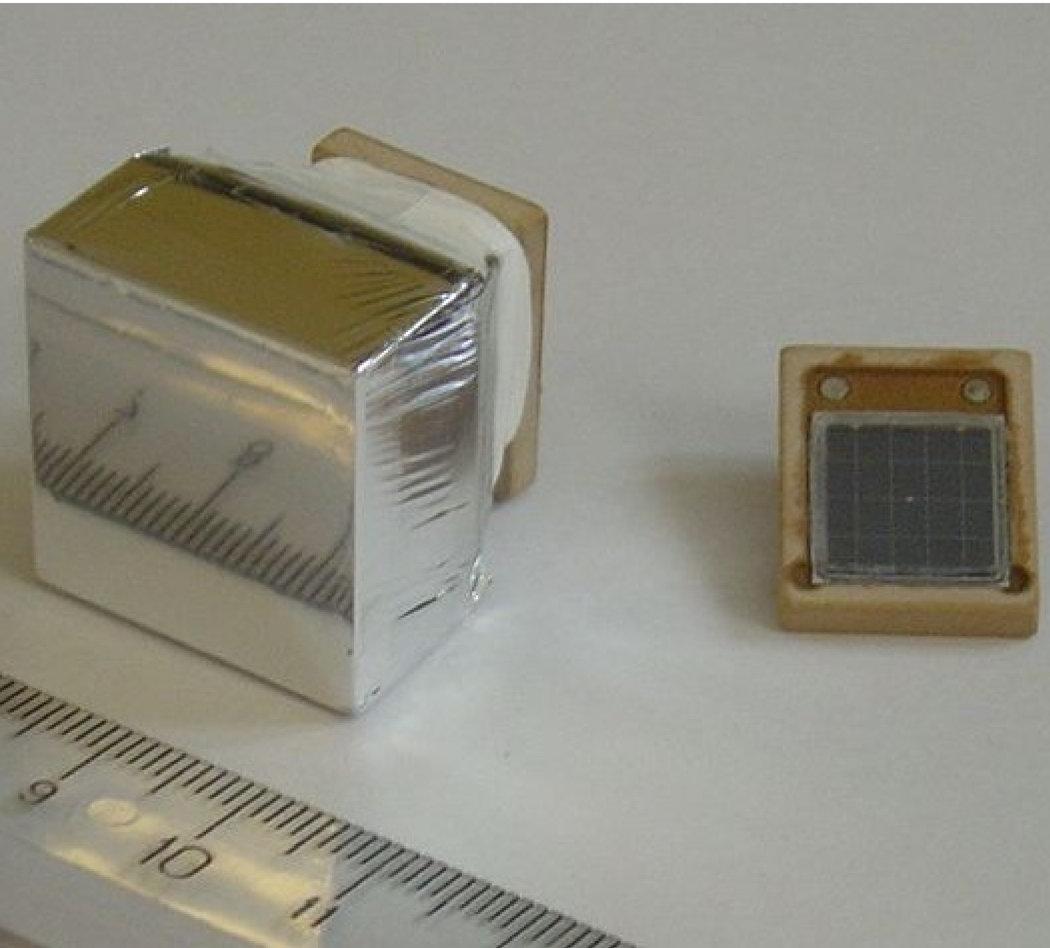
- Three calorimeters with different crystal size combinations have been simulated (**SHORT**, **MEDIUM**, **LONG**)
- For each calorimeter, lengths are selected to cover approx. the same photopeak efficiency @ 5MeV CoM
- Overlap problems, corrected in simulation (temporal solution)

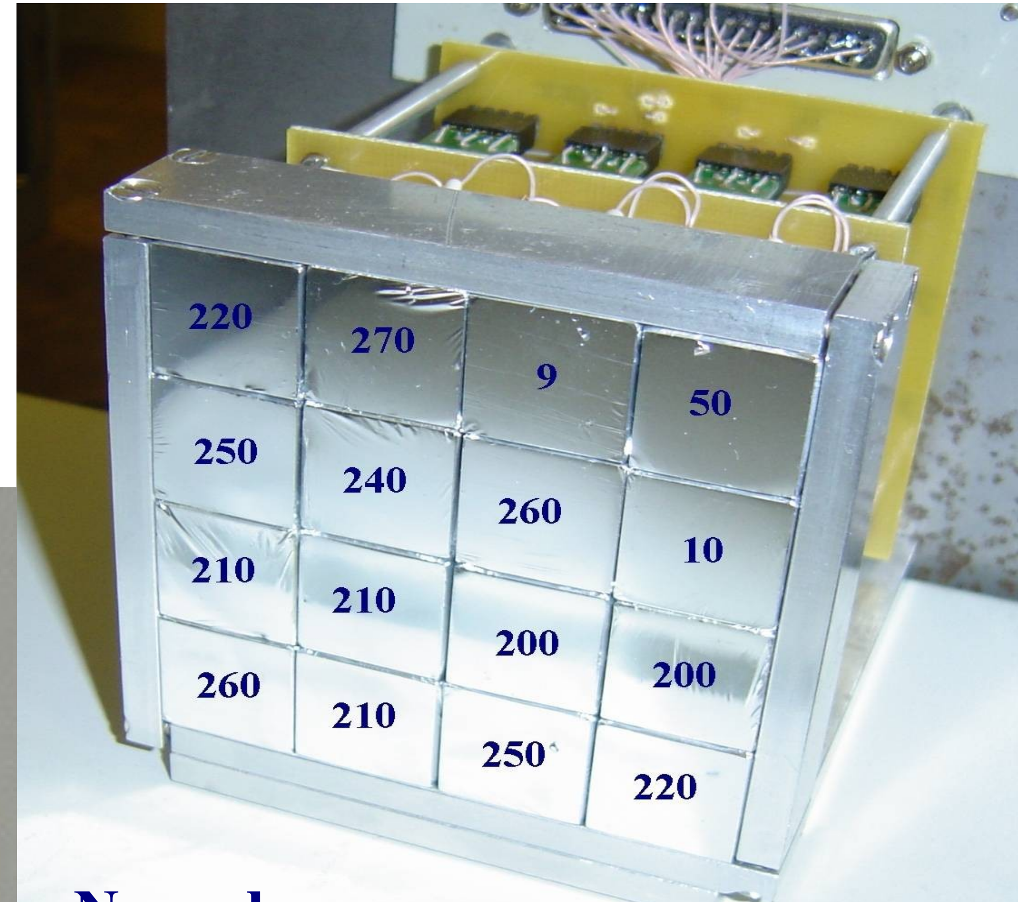
ee different models: Short, Medium and Large — Energy 700 AmeV — Chosen for approx. 60%, 70% and 80% PE @ 5MeV CoM

	10	15	20	25	30	35	45	55	65	90	120	Angle (deg)
	2.97	2.75	2.49	2.23	1.97	1.74	1.36	1.08	0.88	0.57	0.41	E_lab/E_CM
	14.85	13.75	12.45	11.15	9.85	8.7	6.8	5.4	4.4	2.85	2.05	E_lab for 5 MeV CM
	1.32	1.25	1.2	1.14	1.1	1.05	1.01	1	0.99	0.95	0.8	Approx. Multiplicative factor
rt	15	14	13	13	12	12	11	11	11	10	9	Crystal length (cm)
lium	18	18	17	16	15	15	14	14	14	13	11	
g	22	21	20	19	19	18	17	17	17	16	14	

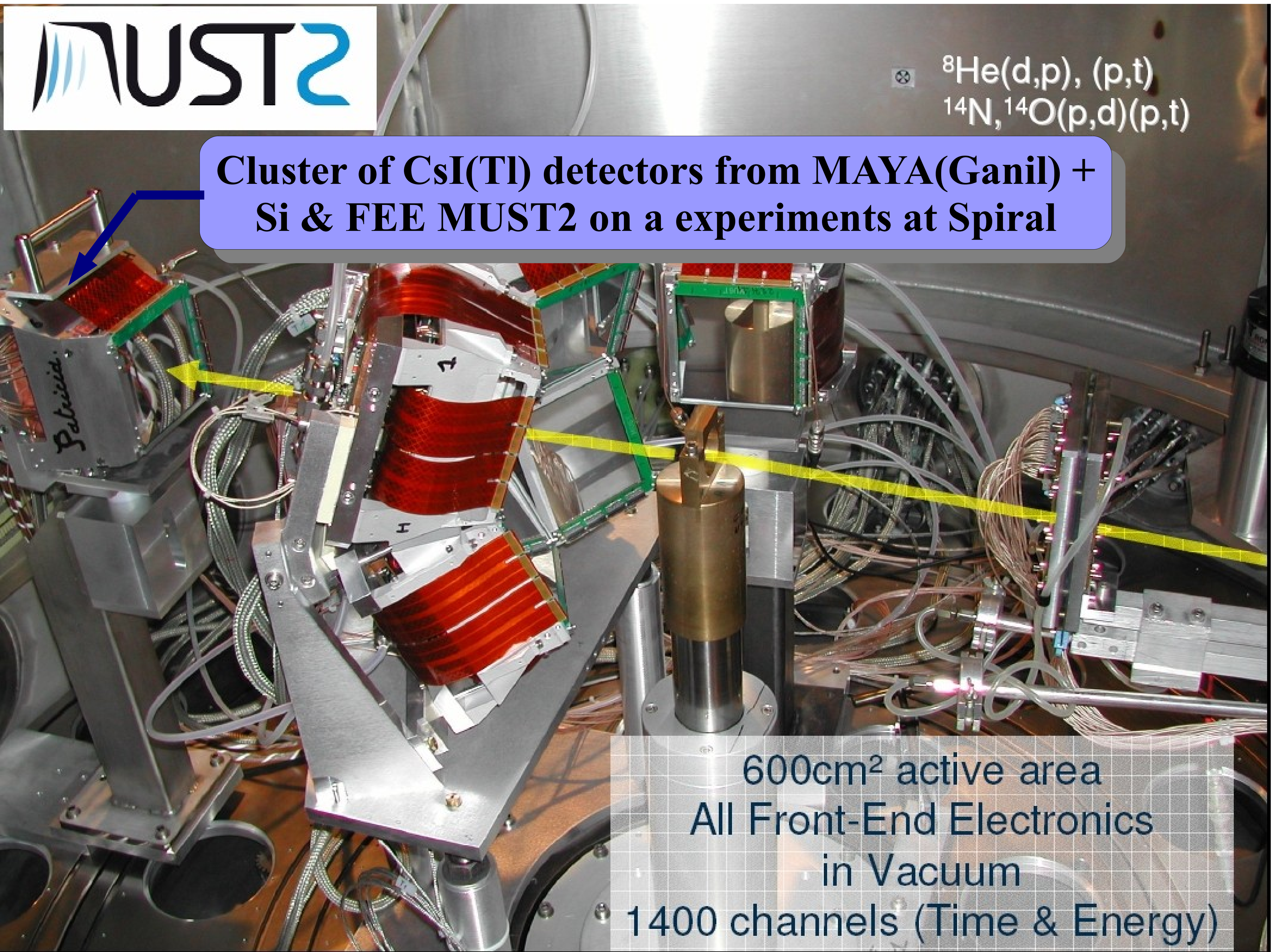
Where are our place?

JINR FLNR experience:
First successful steps start in 2004
<u>Complete production</u> of CsI(Tl) detectors from cutting solid cristal to final preparation of surfaces, wraping and coupling.





Nowadays:
- **3 sizes of compact detectors of charge particles with high resolution done.**
- **4^{th} type of coaxial geometry under production**
- **Small mass production tehnology**


MUST2
^{8}He(d,p), (p,t)
^{14}N,^{14}O(p,d)(p,t)
Cluster of CsI(Tl) detectors from MAYA(Ganil) +
Si & FEE MUST2 on a experiments at Spiral
600cm² active area
All Front-End Electronics
in Vacuum
1400 channels (Time & Energy)

Comparing tipical Crystals

		$LaBr_3$	$LaCl_3$	NaI(Tl)	CsI(Tl)	CsI(Na)	BGO	LYSO	PWO	CsI (pure)*
Density (g/cm^3)		5.29	3.86	3.67	4.51	4.51	7.13	7.10	8.29	4.51
Light Output (ph/MeV)		63,000	49,000	39,000	52,000	45,000	9000	32,000	100	16,800
ΔE/E (FWHM) @662keV	PMT	<3%	3.5%	7%	6%	7.5%	10%	7.1%	>10%	7.5%
	APD	N/A	N/A		4.9 %	N/A	8.3%	N/A	N/A	4.3 %
Peak λ (nm)		380	350 430	310 ***fast*** 415	550	420	480	420	420	315
Fast Decay (ns)		25	25/213	620 ***fast*** 230	1000	630	300	41	6	35/6
Hygroscopic		yes	yes	yes	slightly	yes	no	no	no	slightly
Cost (per cm^3)		$30	$30	$2	$4.50	$4.50	$9	$25	$2	$4.50
Radiation lenght (cm)		N/A	N/A	2.9	1.86	1.86	1.1	1.2	0.85	1.86

!?

What`s wrong in long cristal?

•Big length refer to cross section make the great difference in light collection from different interaction positions
•Loses of light in absorption and reflections
•Differnce of concentration of activator Tl

Summary:
•Total low lightoutput collection
•Great uniformity on lenght

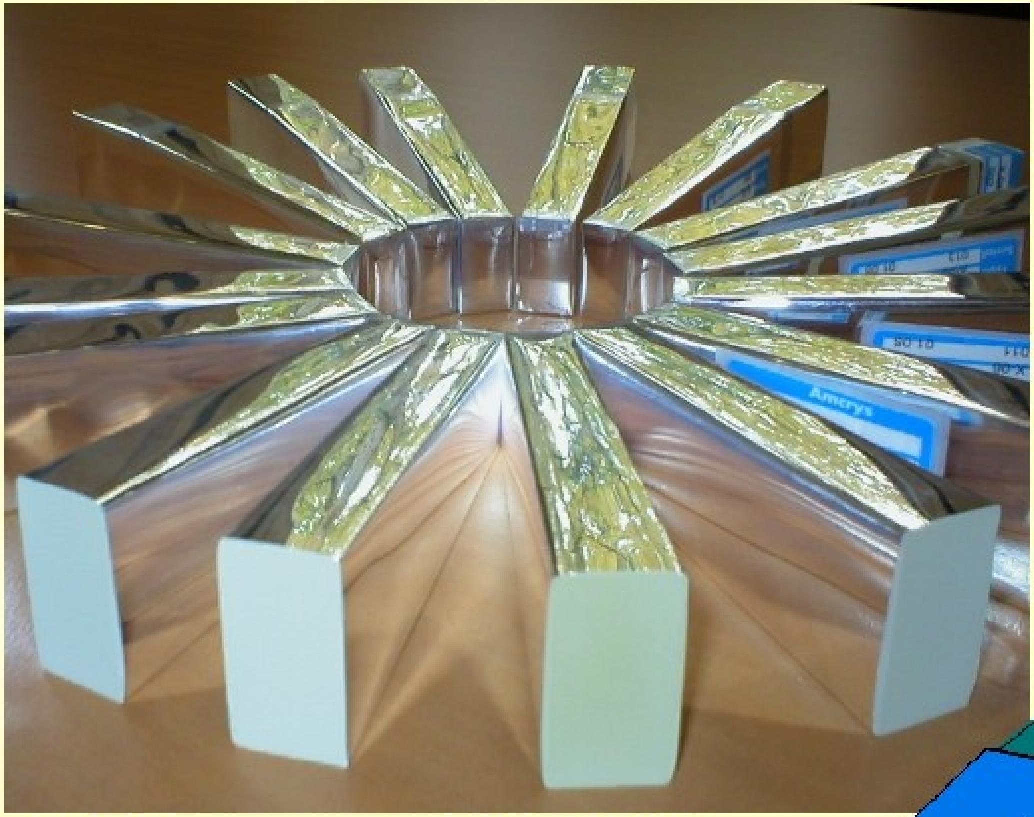
Activity in R'n'D

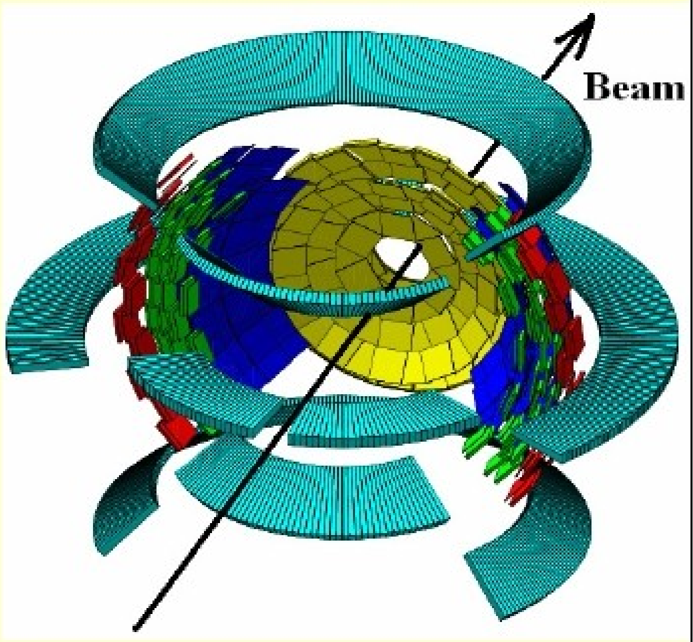
WGs uses typical path:
Buy the CsI(Tl) with shape close to nessesery
Wraping or not
with optimized surface or not

Subjects of investigation:
Wraping and coupling
compabality with fotodetectors

General quest:
Optimization of uniformity — best energy resolution

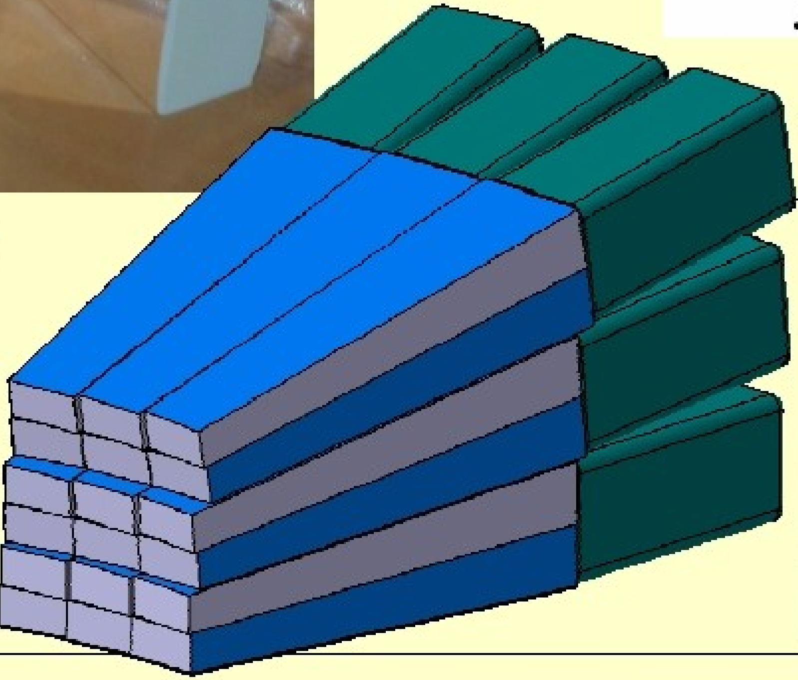
Demonstrator calorimeter R3B-EXL @ Orsay

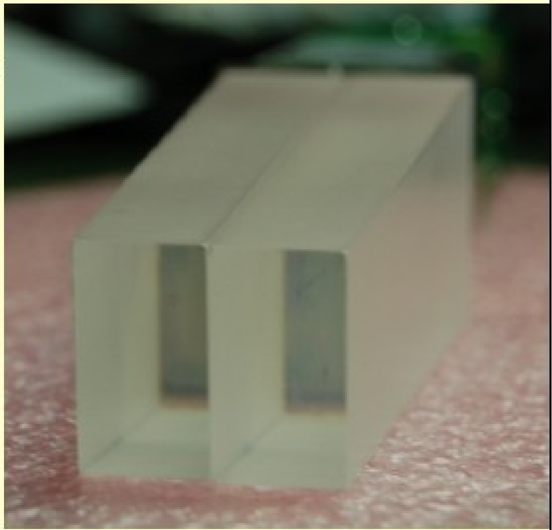




We have received 18 CsI(Tl) crystals from Amcrys.

Scarpaci et al., Orsay



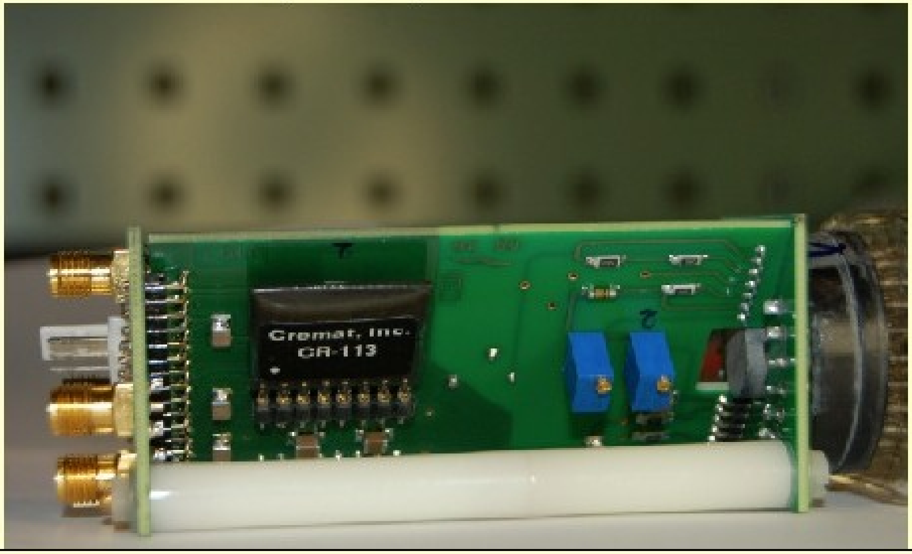


Prototype parts

CsI crystal from Amcrys

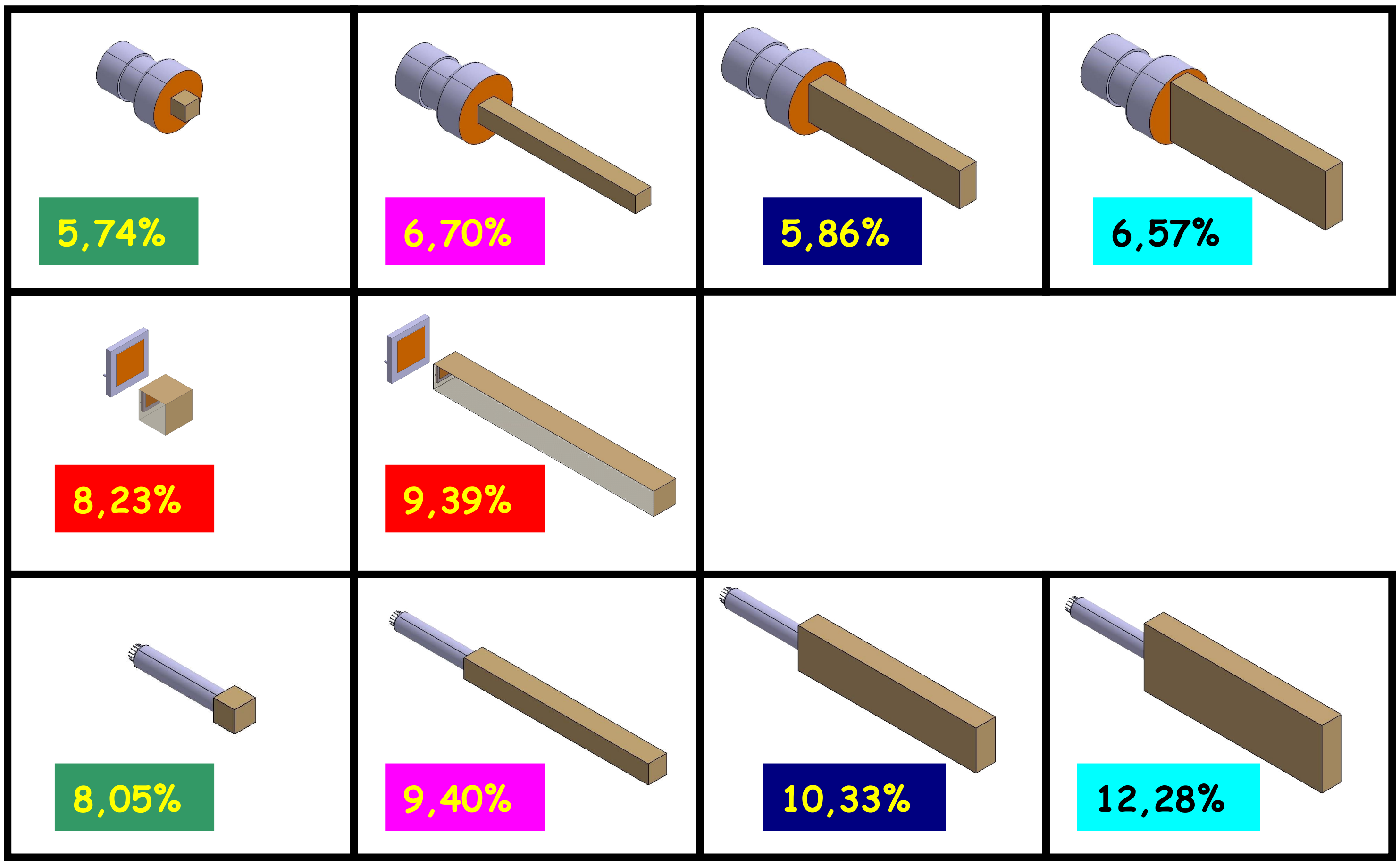
Double PMTs from Photonis

CREMAT preamps and bases



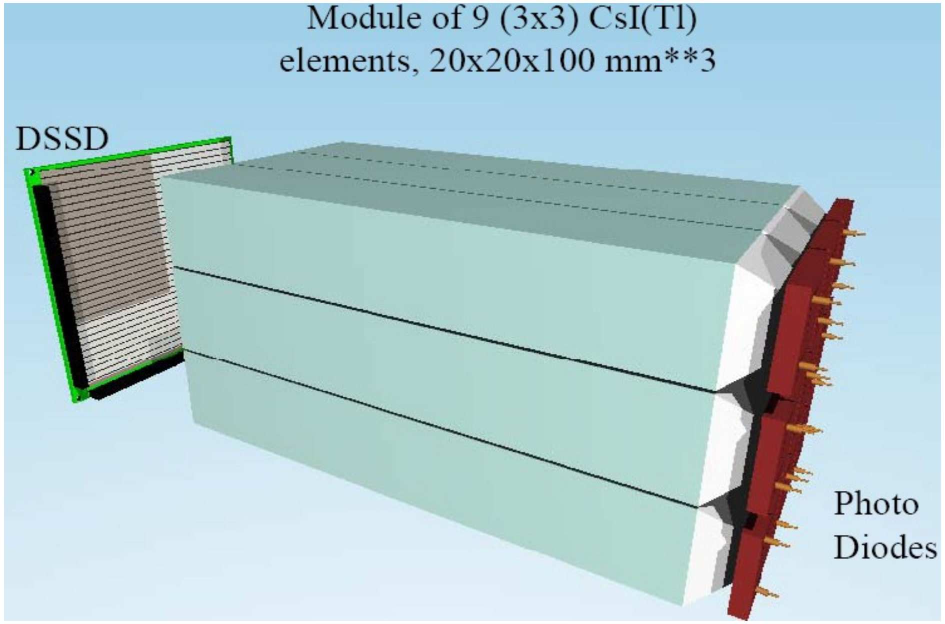
Scarpaci et al., Orsay

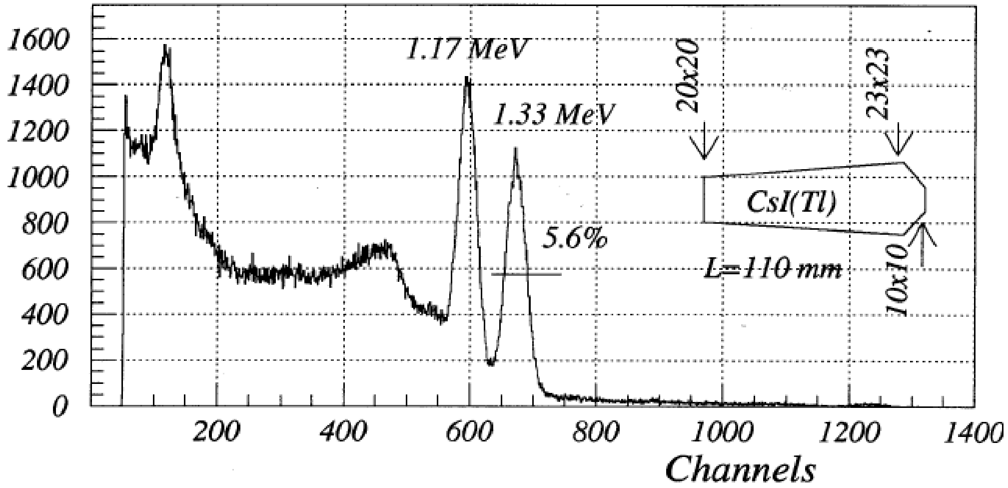
Energy Resolutions CsI(Tl) +VM2000+APD/PMT+^{137}Cs

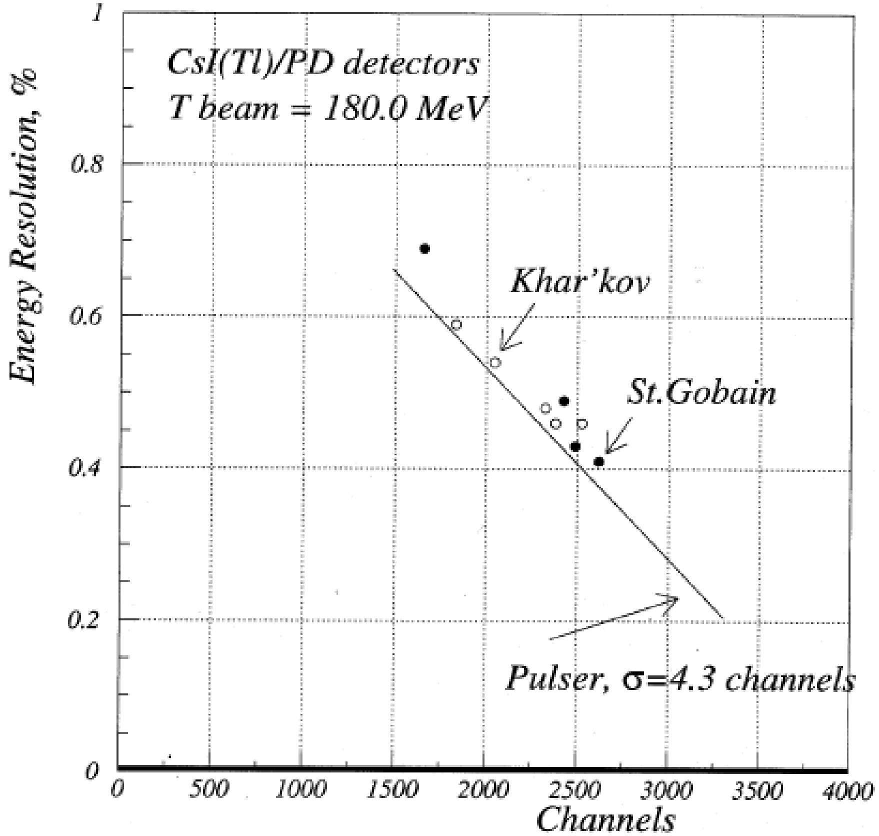


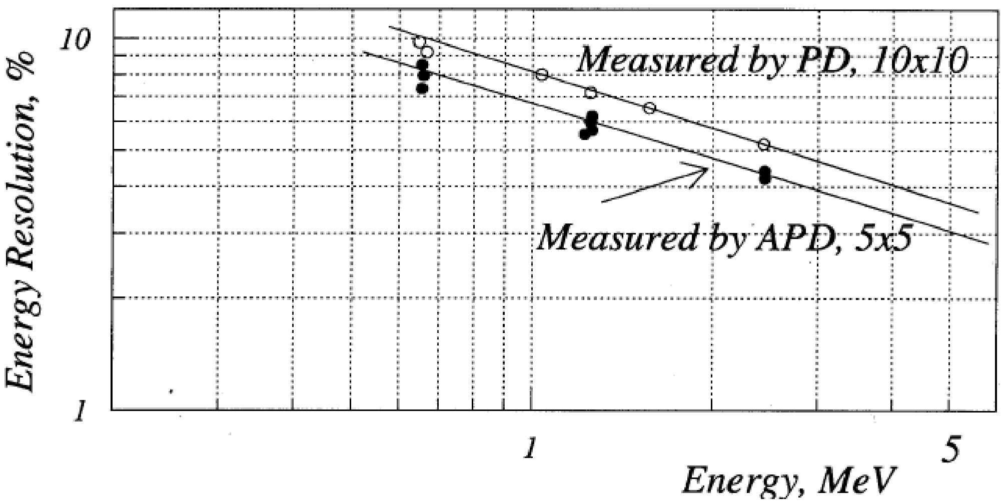
	22x22x22	22x22x220	44x22x200	66x22x200
XP5300B	5,74%	6,70%	5,86%	6,57%
APD S8664-1010	8,23%	9,39%		
XP1912	8,05%	9,40%	10,33%	12,28%

First results for R3B/EXL demonstrator obtained in collaboration GSI - Lund Univ. - FLNR JINR

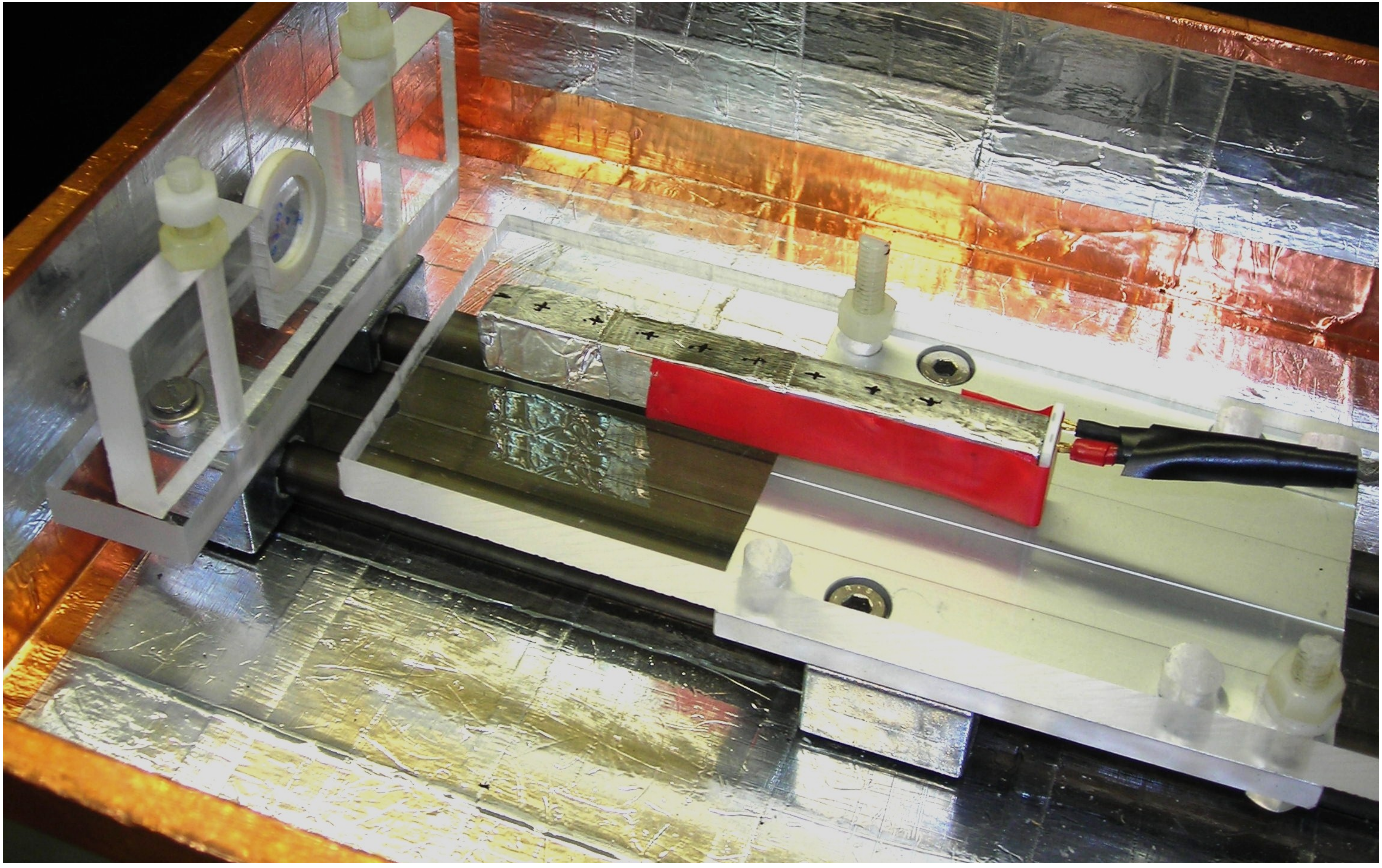








Uniformity measurment



Our posibilities:

- Reflector materials: Maylar, PTFE, Tyvec, ESR Vikuity
- Photodetectors: PIN-diodes from 5x5mm^2 to 20x20mm^2(Hamamatsu and Moscow), Hamamatsu APD & LAAPD, PMTs
- CsI(Tl) Cristals different shapes from 10x10x15mm3 to 50x20x250mm^3
- Different optical coupling materials: Epo-tex, Bicron, RTV
- Technology of surface mating and polishing

What can we do new?

General key: Integrated investigation of
•surface preparation
•wraping materials and tehnolodgy
•«botle neck» shape
•coupling and choosing photodetectors

according economics
and
technolodgical aspects.

Summary:

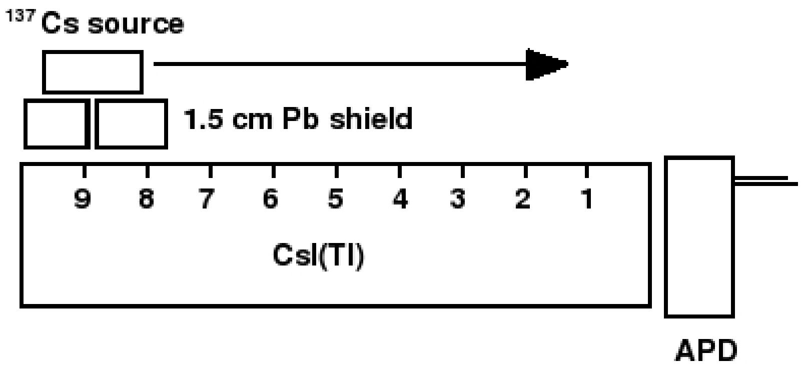
Results of proposal investigation could be useful in TDR and mass production of CsI(Tl) detectors for calorimeters R3B and EXL

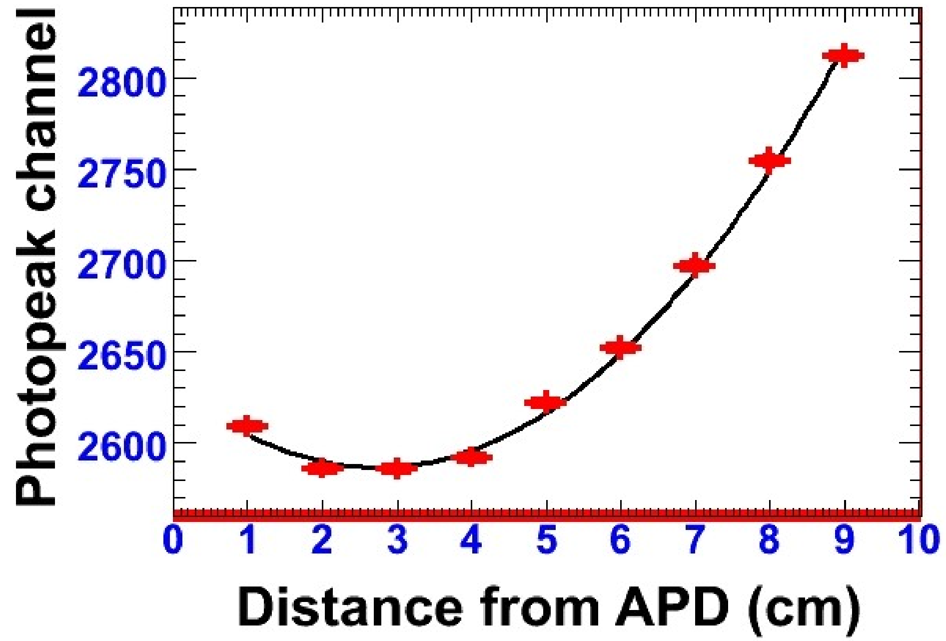
Minimal posible profit — specify and taxonomy results of different WGs

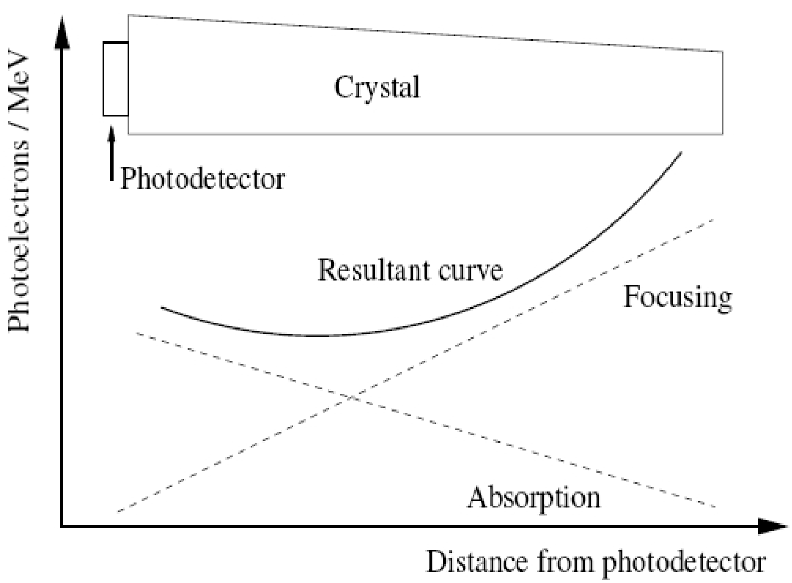
Thank for your atention!

Study of the non-uniformity

Energy resolution dependence on the first interaction point







Non-uniformity ~ 8.4 %, to compare with < 3% measured by St. Gobain

Light collection uniformity CMS CAL

P. Sempere PhD Thesis

ACCULINNA Fragment Separator

Max magnetic rigidity	3.6 Tm
Solid angle	0.9 msr
H/V acceptance angle	20/14 mrad
Momentum acceptance	4.2-8.4 %