FAIR — Russia Research Center, Moscow
21-22 June 2011, ITEP Moscow

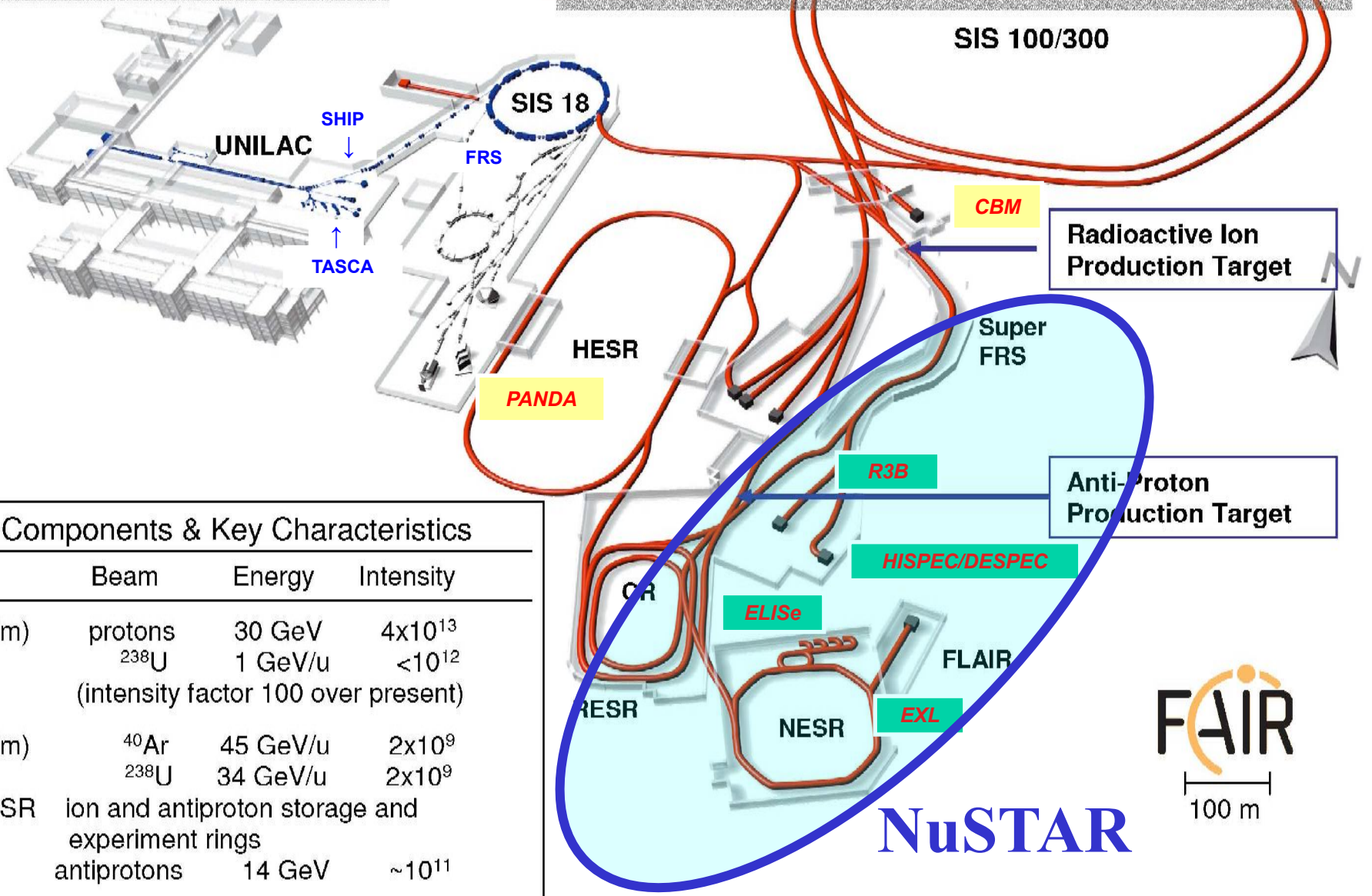
# R3B and EXL γ-calorimeters design in frames of NuSTAR

*Sergey Krupko*
Flerov Laboratory of Nuclear Reactions
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 | $4\times10^{13}$ |
| | $^{238}U$ | 1 GeV/u | $<10^{12}$ |
| | (intensity factor 100 over present) | | |
| SIS300 (300Tm) | $^{40}Ar$ | 45 GeV/u | $2\times10^{9}$ |
| | $^{238}U$ | 34 GeV/u | $2\times10^{9}$ |
| 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*

# The R³B/FAIR experiment

**Reaction with Relativistic Radioactive Beams 700 MeV/nucleon**

Nuclear structure far from stability

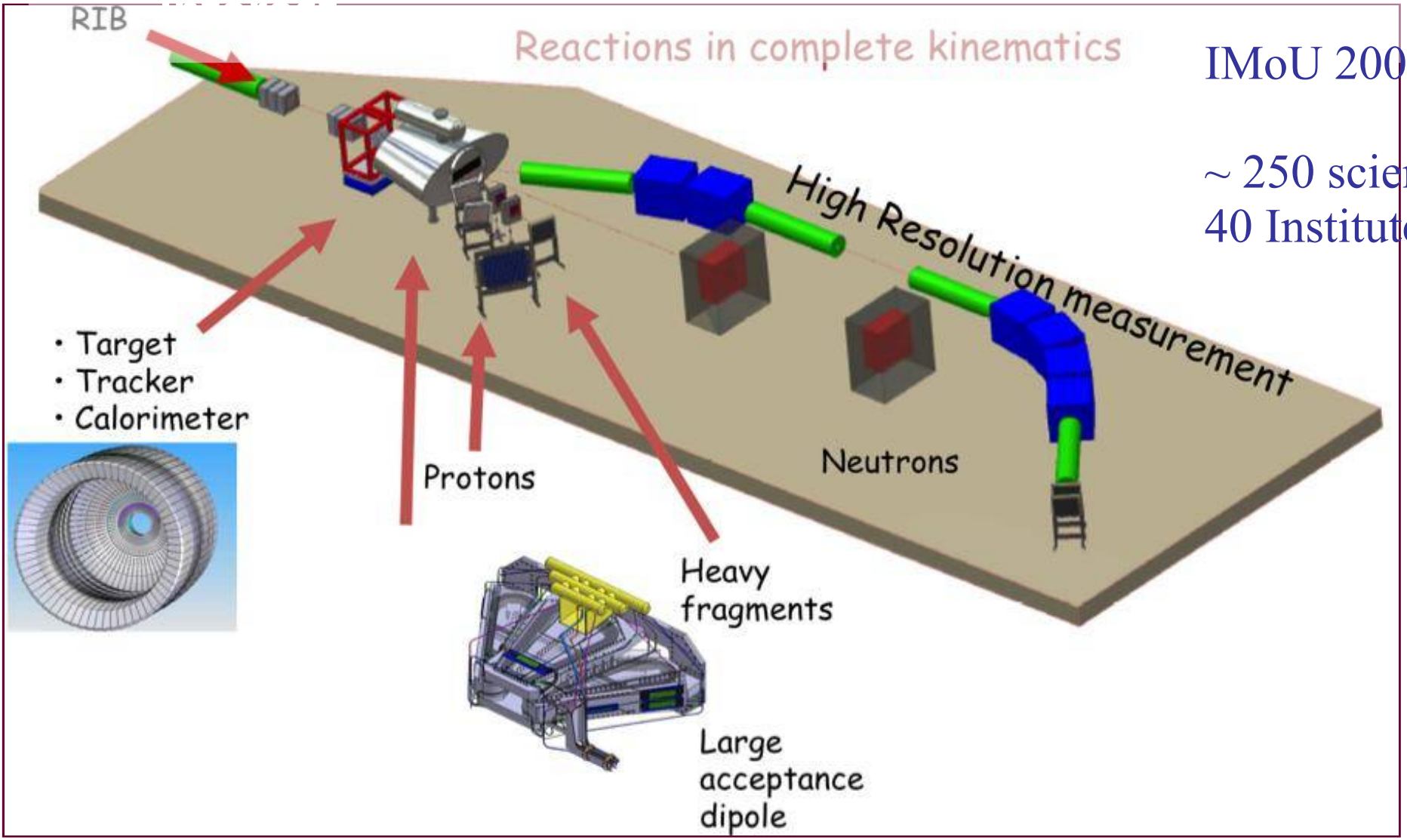
Reactions of astrophysical interest

Equation of state of asymmetric nuclear matter

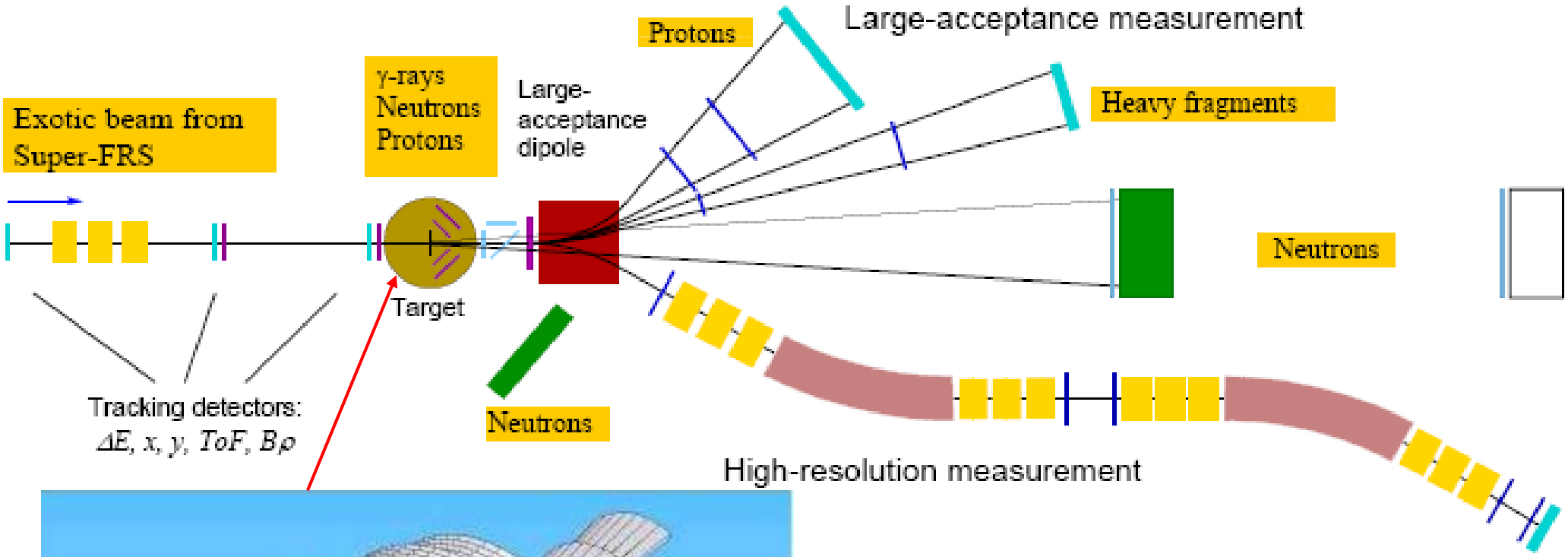
Technical Proposal
December 2005

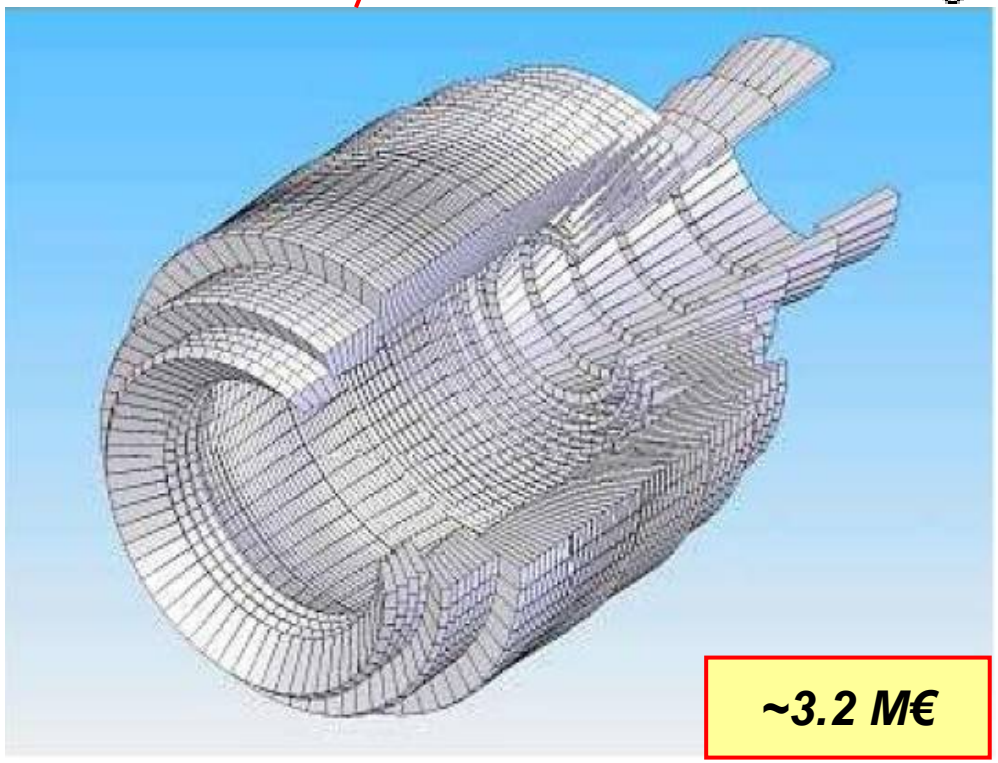
IMoU 2008

~ 250 scientists
40 Institutes



# R3B: Reactions with Relativistic Radioactive Beams



~3.2 M€

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

**$\varepsilon_\gamma$ ~ 80 % @ 15 MeV**

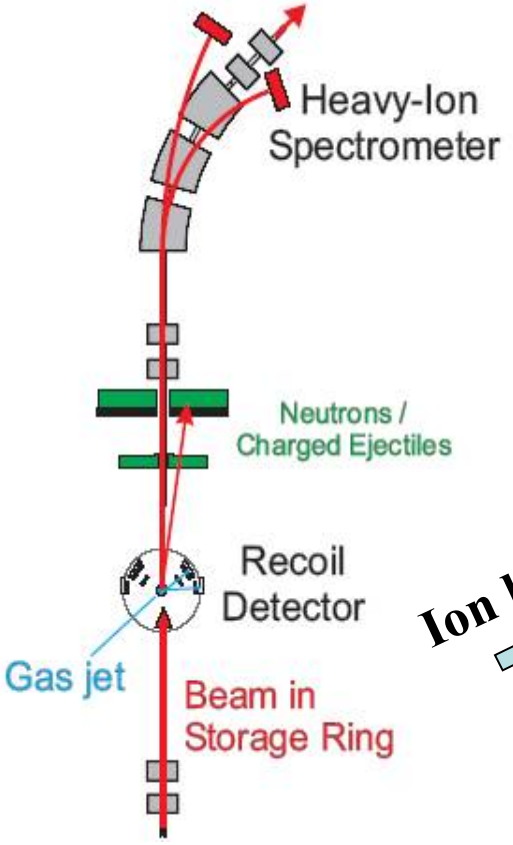
**$\Delta\Theta$ ~ 0.018 rad**

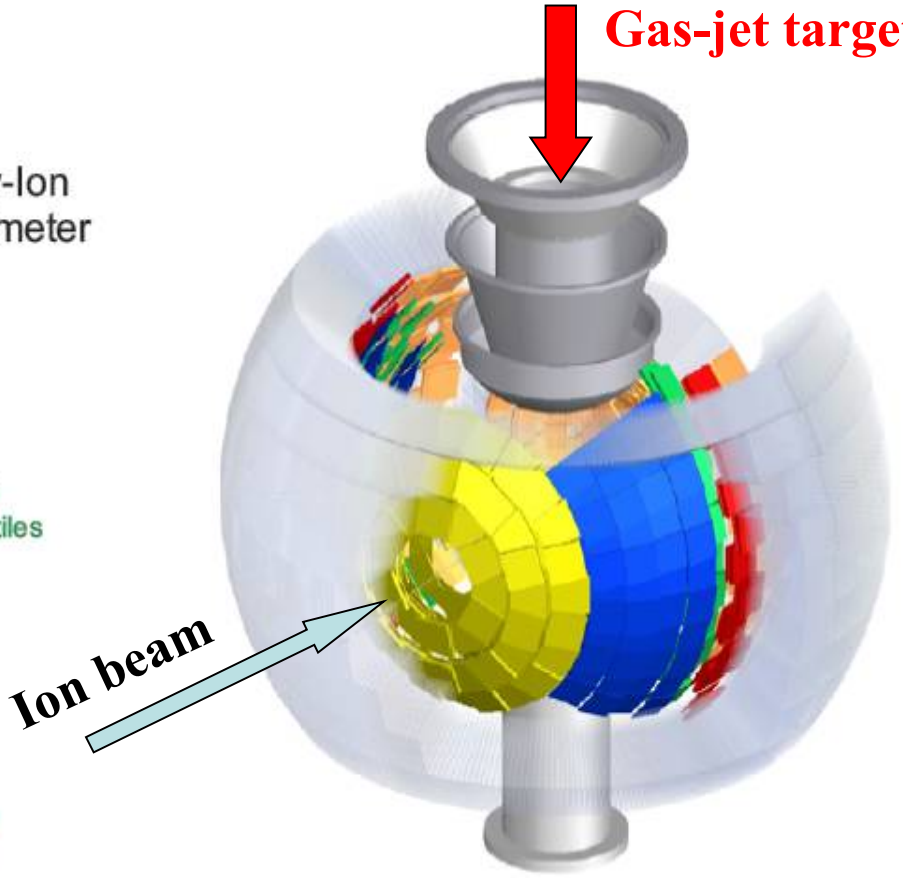
**$E_\gamma$ = 1-30 MeV, $\Delta E/E$ ~ 4-5% @ 662 keV**

**$E_p$ < 300 MeV, $\Delta E/E$ ~ 1% or better**

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

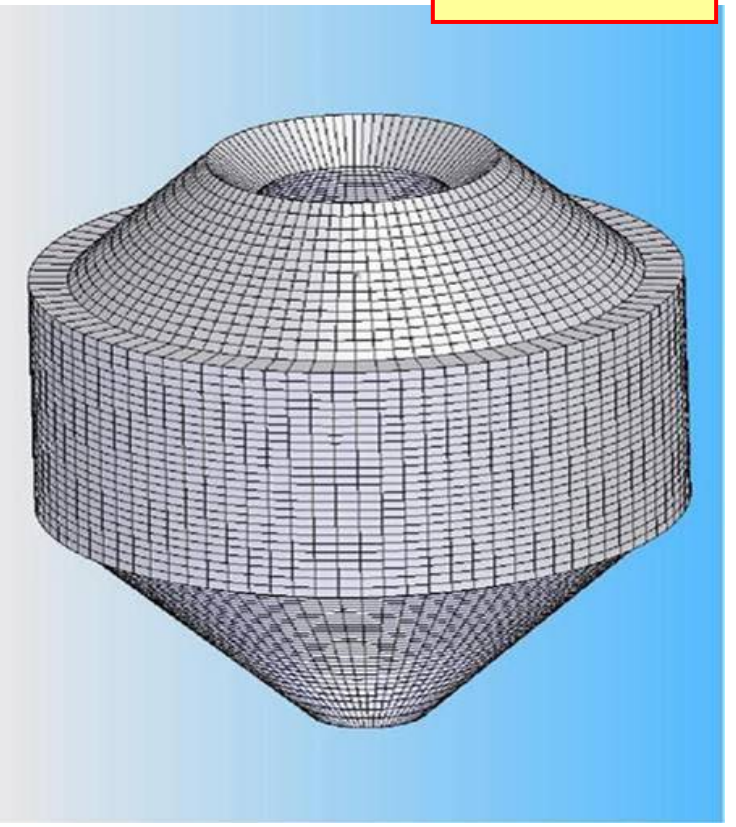
# EXL: EXotic Nuclei Studied in Light-Ion Induced Reaction at the NESR



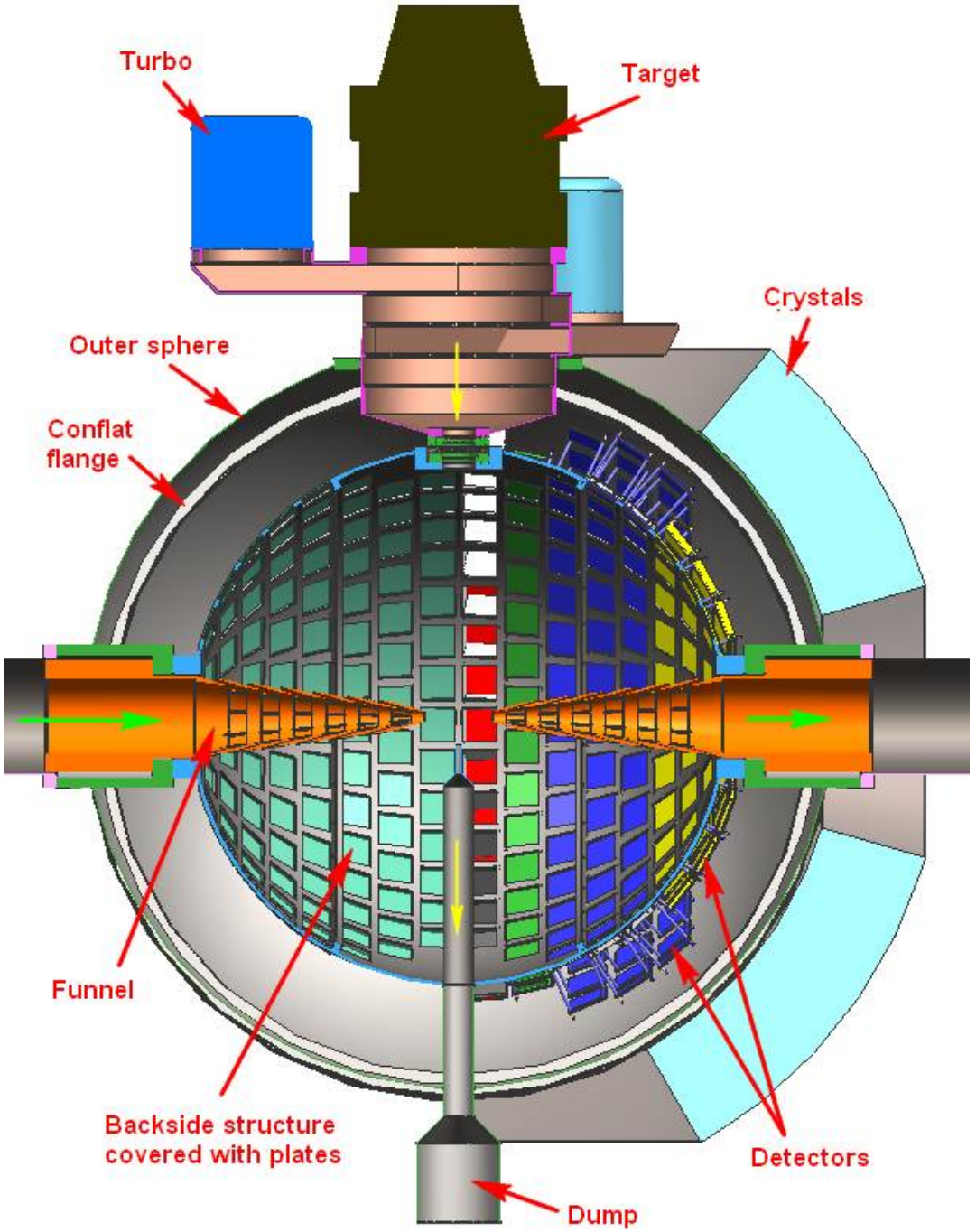

**Completely new setup:**
**Si shell (~ 700 items)**
**CsI shell (~ 2000 items)**

***~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***

# EXL conceptual mechanic design

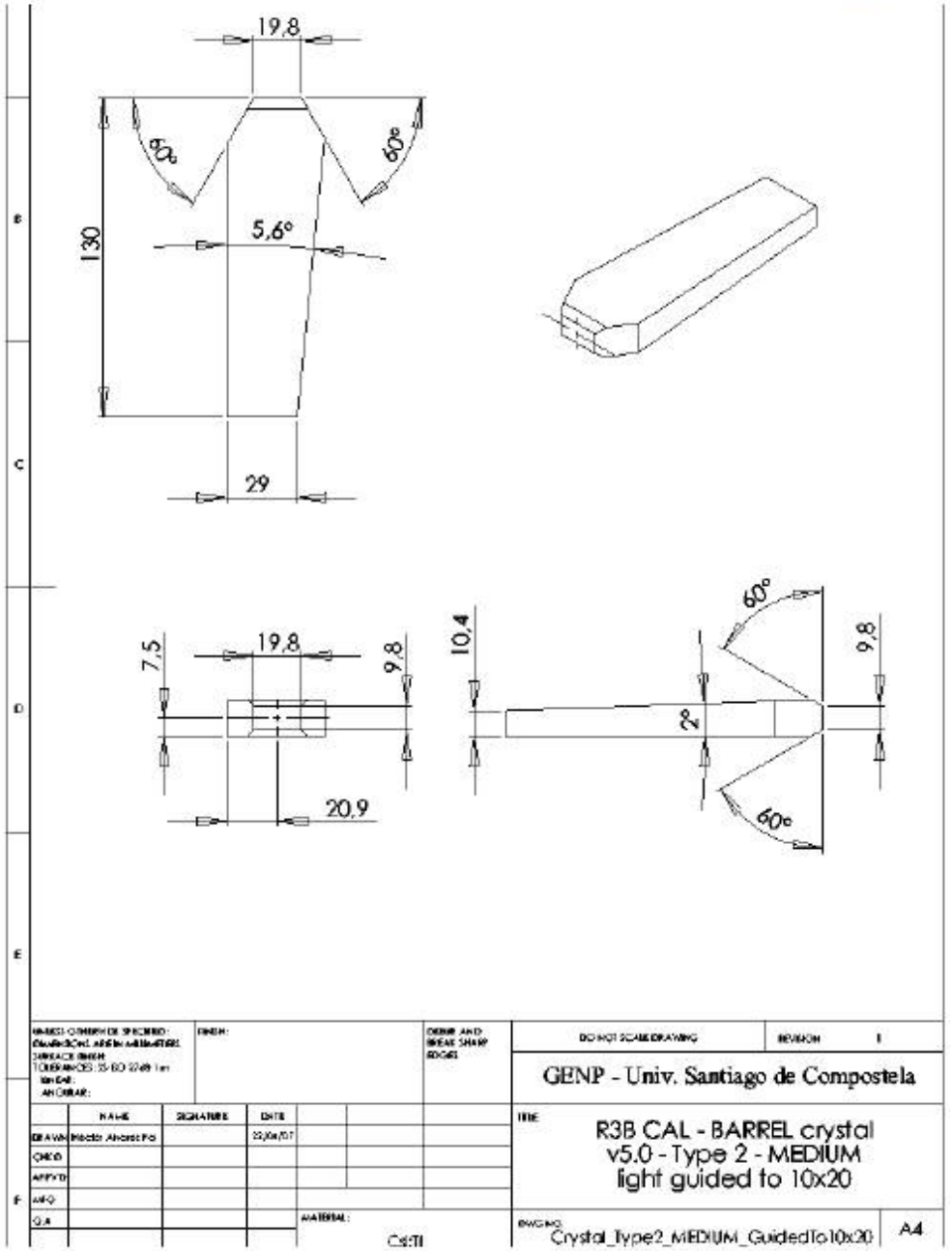


# CALIFA v5.0 - Barrel

**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



# Requirements from experiment simulation

| | |
|---|---|
| •High energy resolution | •5% @ 662keV for 1 detector |
| •High lightcollection linearity | •1% @ total lenght |
| •High stability | •<1% or continius control |
| •High efficiency | •Lenght 150-250 mm |
| •High granularity | •Relativity small 20x40 mm2 |
| •High counting rate | •Up to 50 000 Hz each |
| •Low threshold | •100 keV |
| •Wide dynamic range | •1000-10000, γ and LCP |
| •Low cost welcome | •Limited budget |
| •Magnetic field insensible | •Location near magnet |

# R3B Comparing typical Crystals EXL

| | | $LaBr_3$ | $LaCl_3$ | 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<br>430 | 310 ***fast***<br>415 | 550 | 420 | 480 | 420 | 420 | 315 |
| *Fast Decay (ns)* | | 25 | 25/213 | 620 ***fast***<br>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 absortion and reflections
- Differnce of concentration of activator Tl

Summary:

- Total low lightoutput collection

=

bad energy resolution for low energy

- Great nonuniformity on lenght

# Next steps: looking for alternative

**This year activity:**

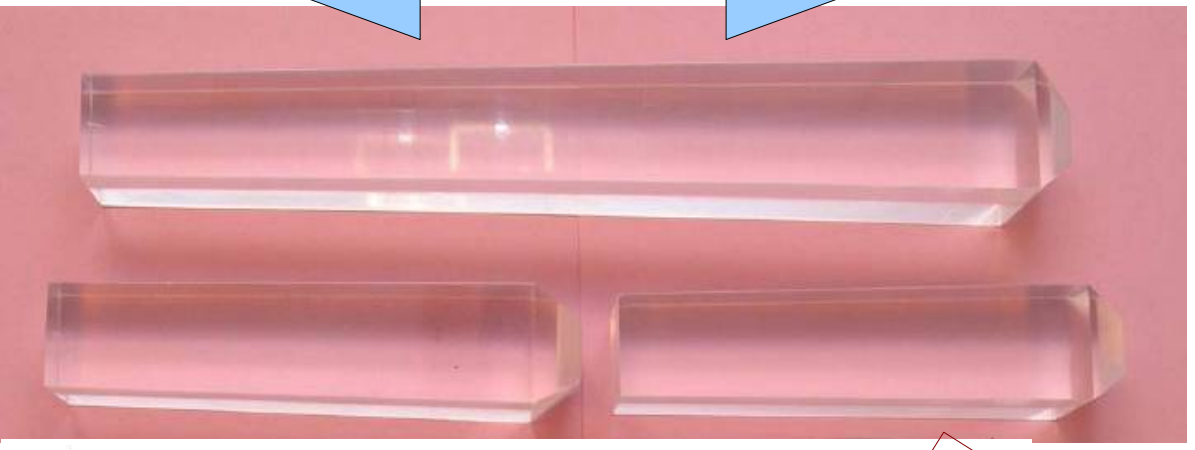
- **BGO, CsI(pure), Prelude, Brillance: Is it alternative or not?**
- **Temperature down to -40 °C: New quality or problems?**
- **PMT Hamamatsu R7600U-100: best candidate PMT**
- **APD: Thermal stability or thermal control for APD by Mesytec**

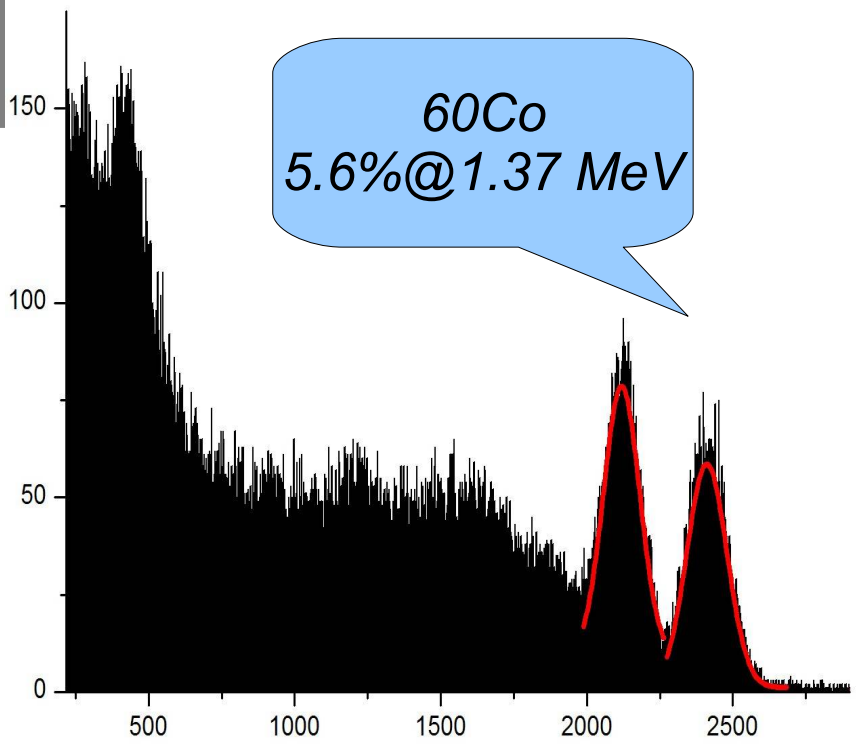
**Far perspective:**

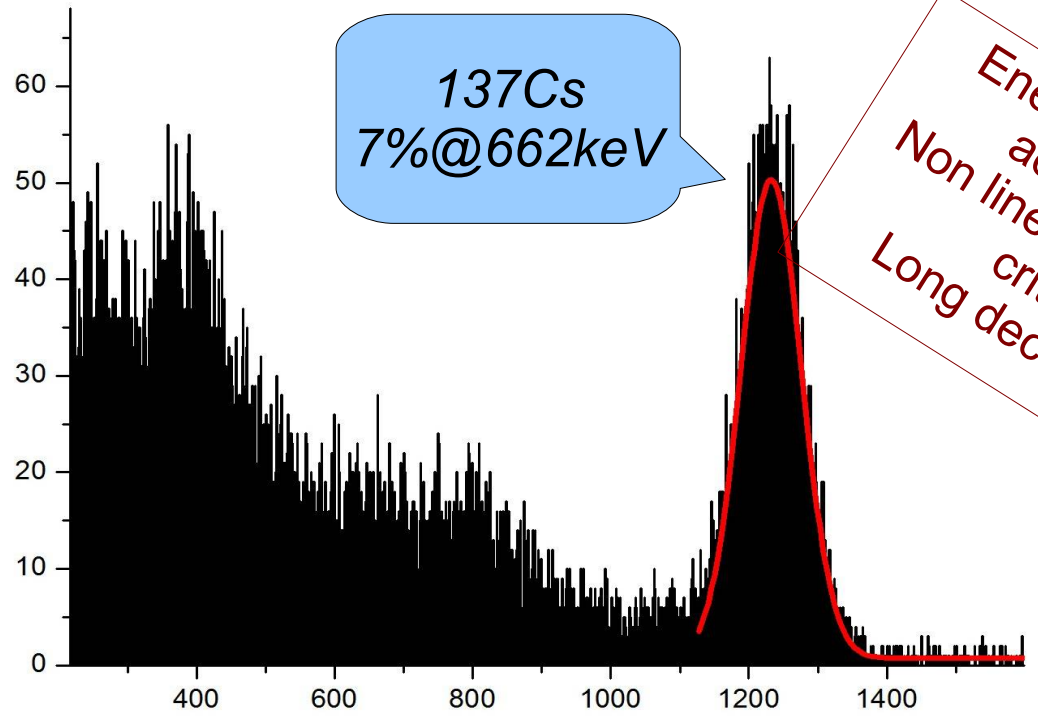
- **Calibration procedure and control of stability**
- **Principal scheme of measuring electronic**
- **Mechanical design of support and interaction with other parts**

# CsI(Tl)

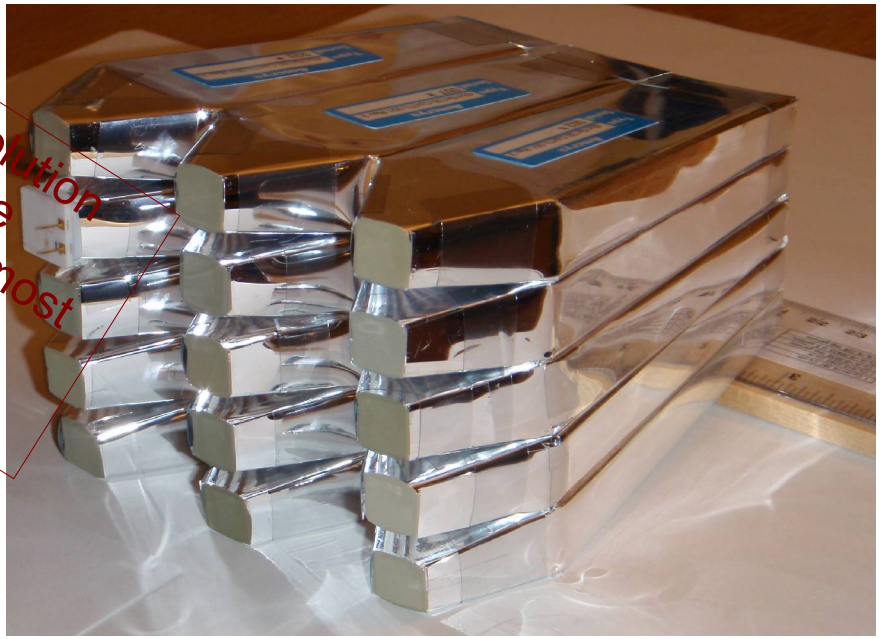
*Lenght: 130 — 200 mm*
*nonlinearity blur total resolution*





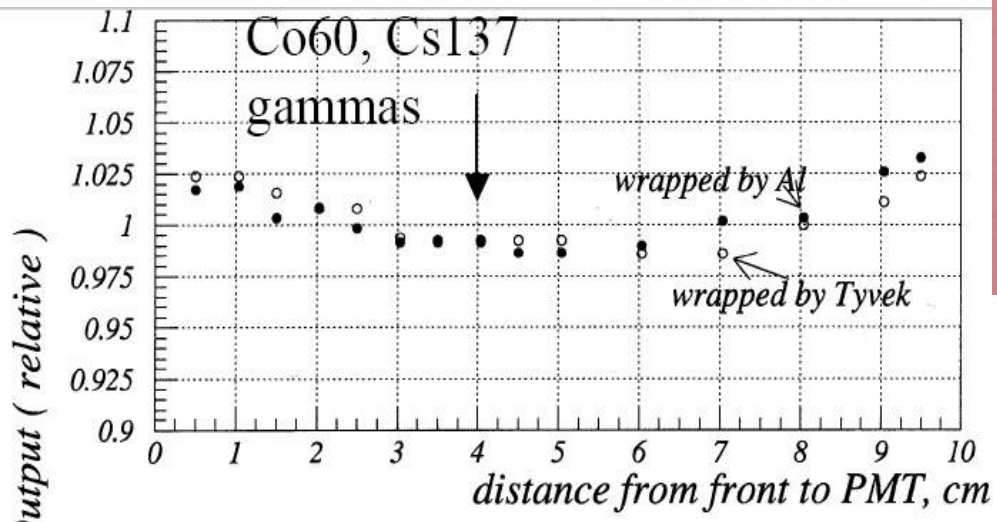



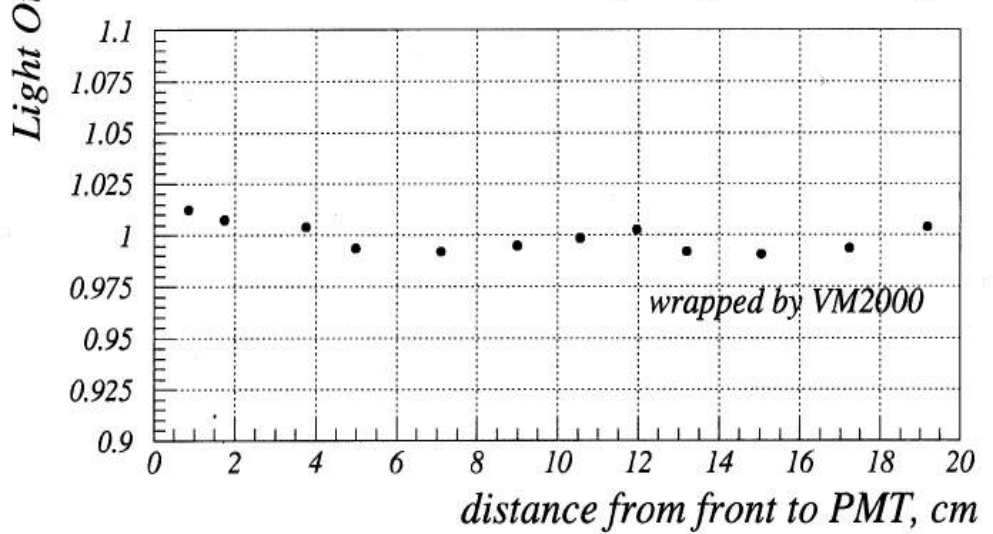

Energy resolution acceptable
Non linearity is most critical
Long decay time



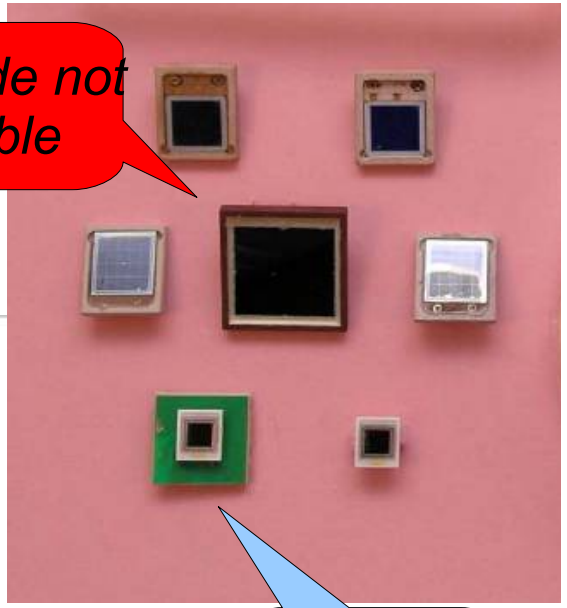
# Technology for CsI(Tl)

**Degrees of freedom:**
- **Surface modification**
- **Wrapping**




*Pin-diode not suitable*

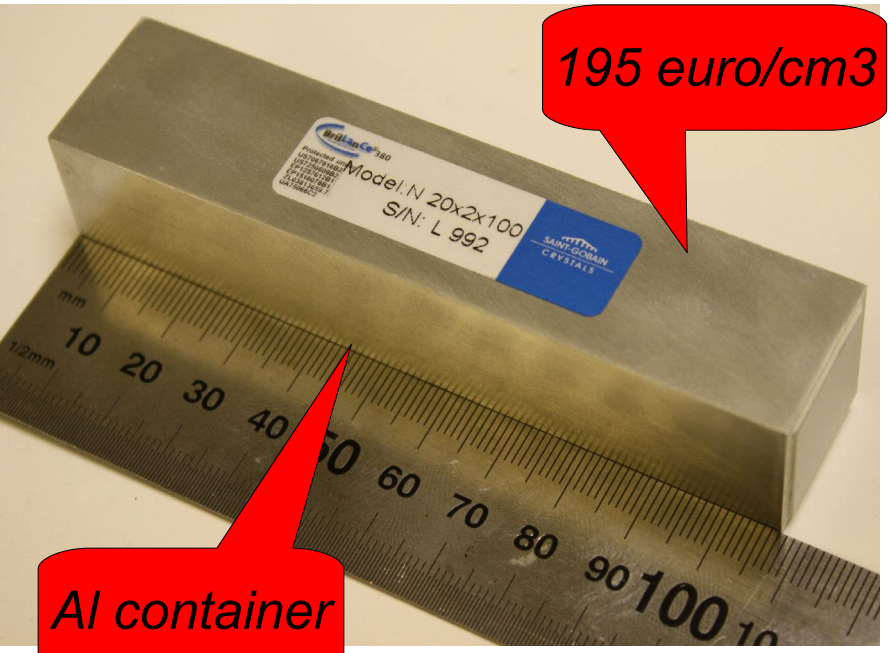


*Avalanche photodiode*

*Candidate from PMT party*

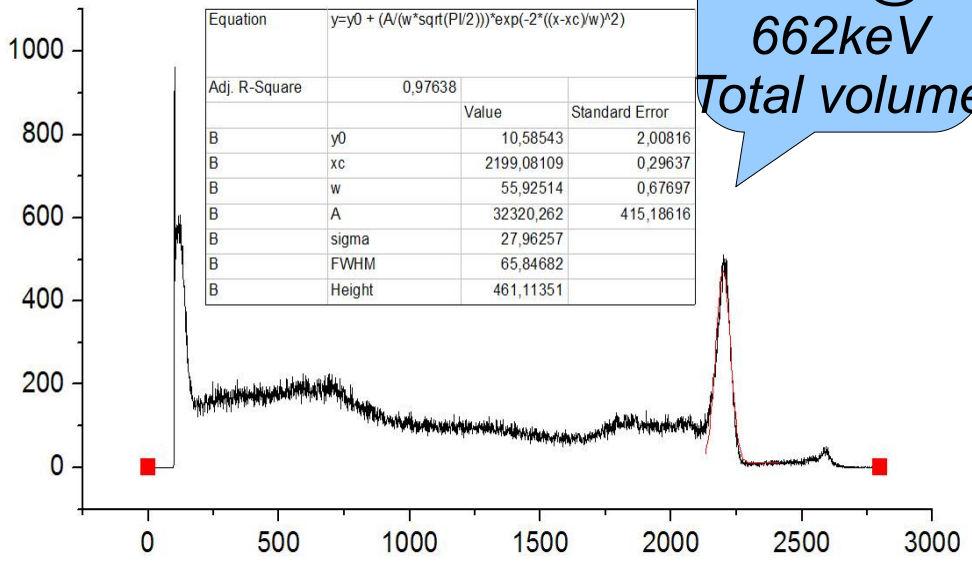

**Parameters to check:**
- **Energy resolution at low energy**
- **Non linearity of lightoutput in reference of position**

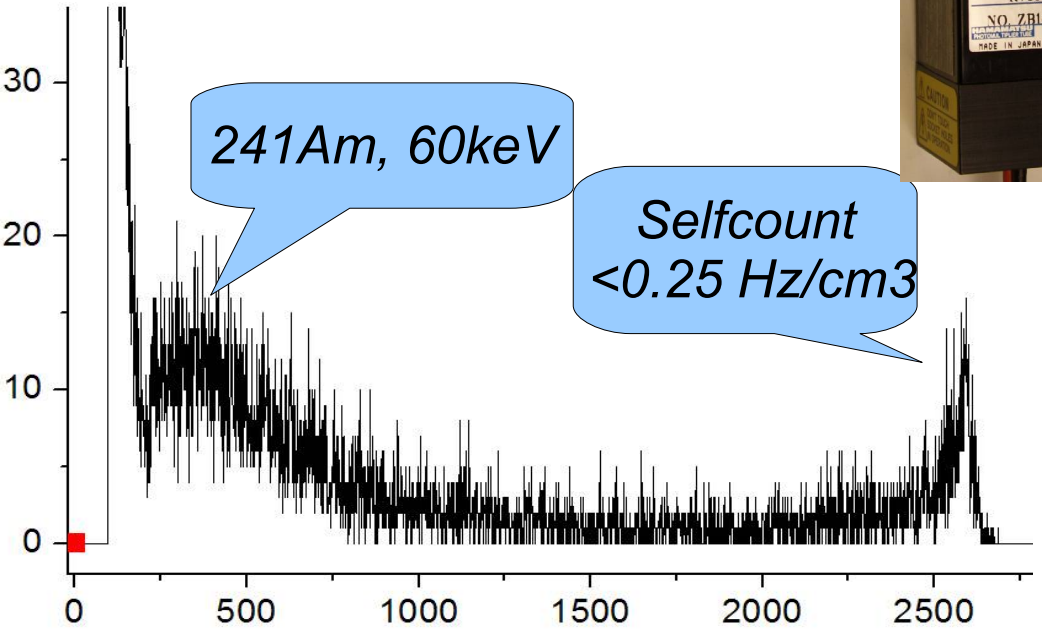
# BriLanCe 380 (LaBr3(Ce 5%)

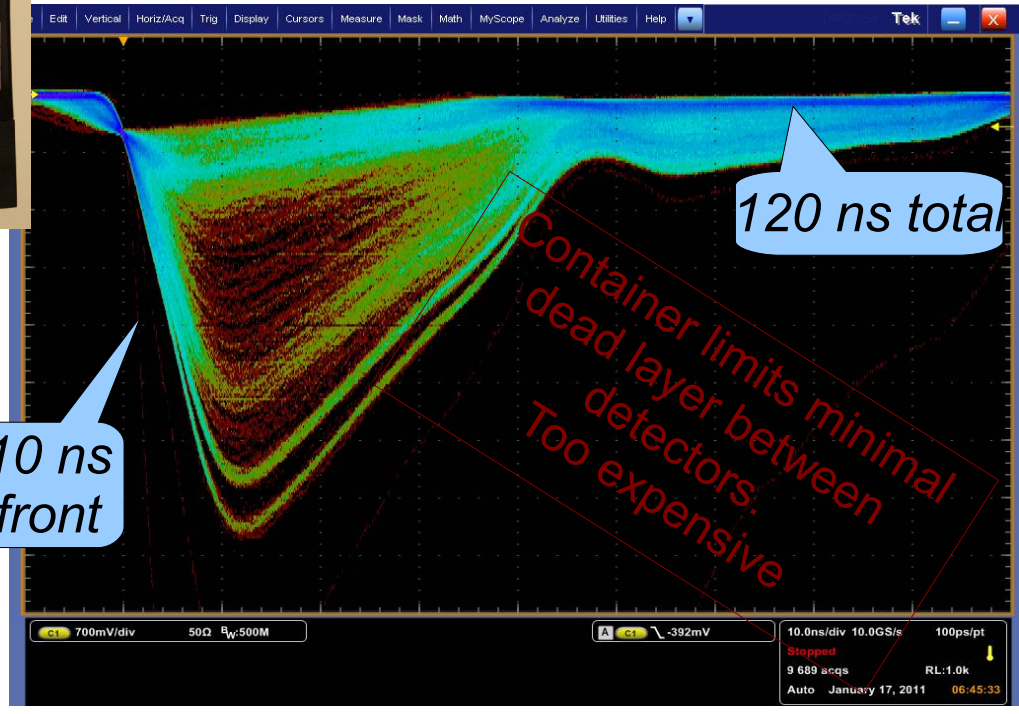




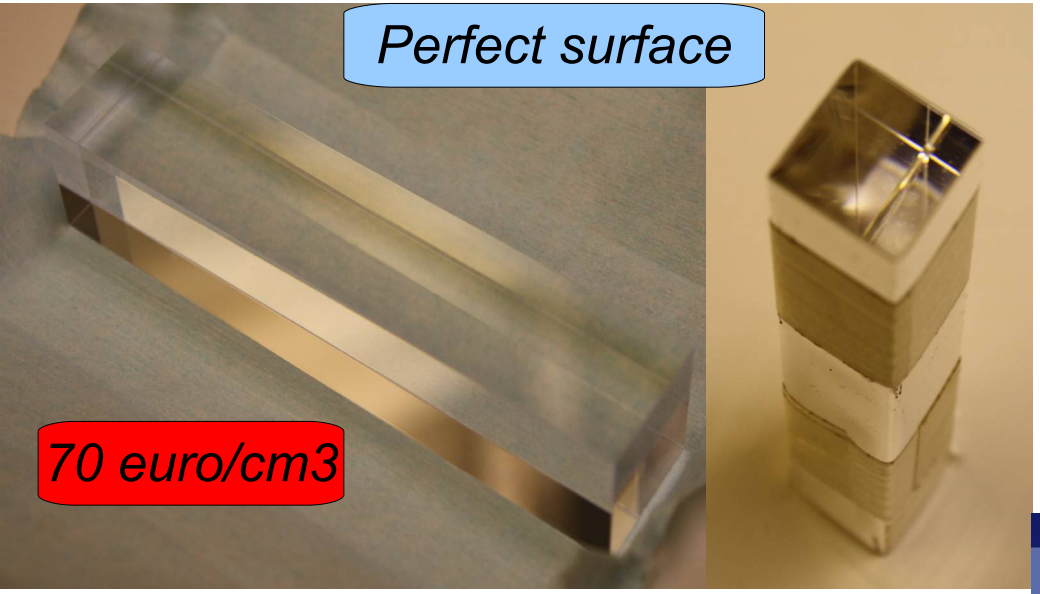
137Cs
<3%@
662keV
Total volume

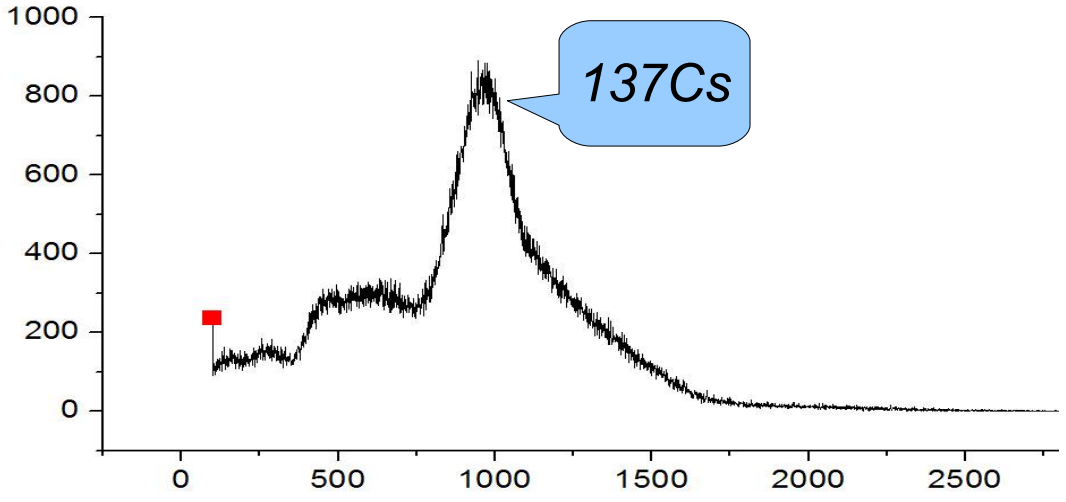


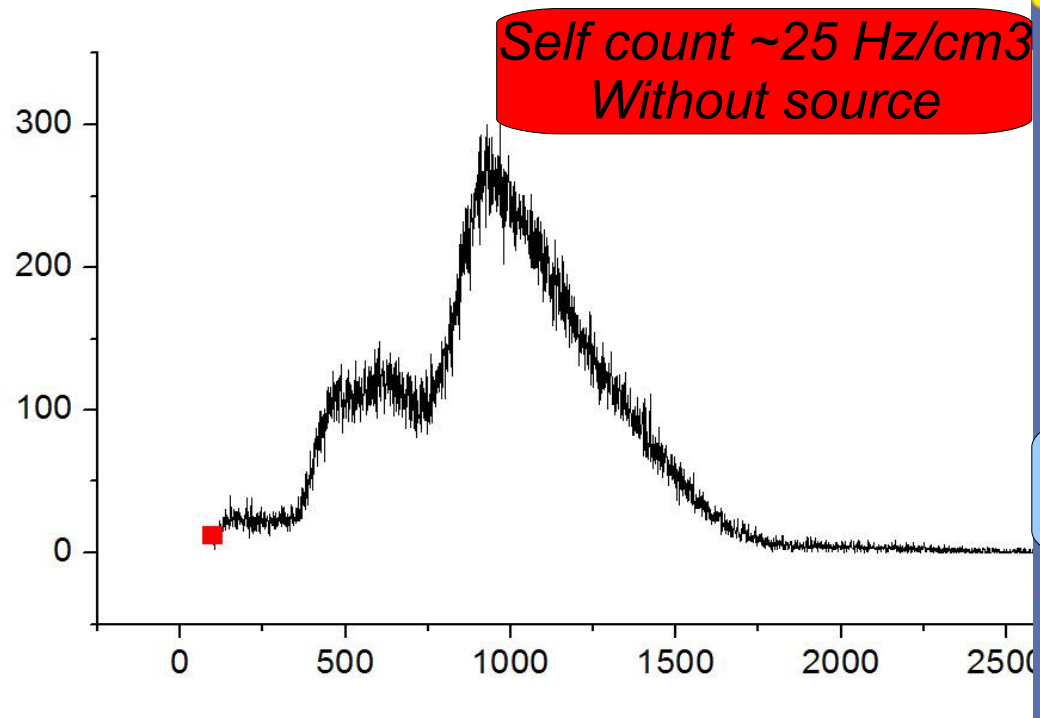



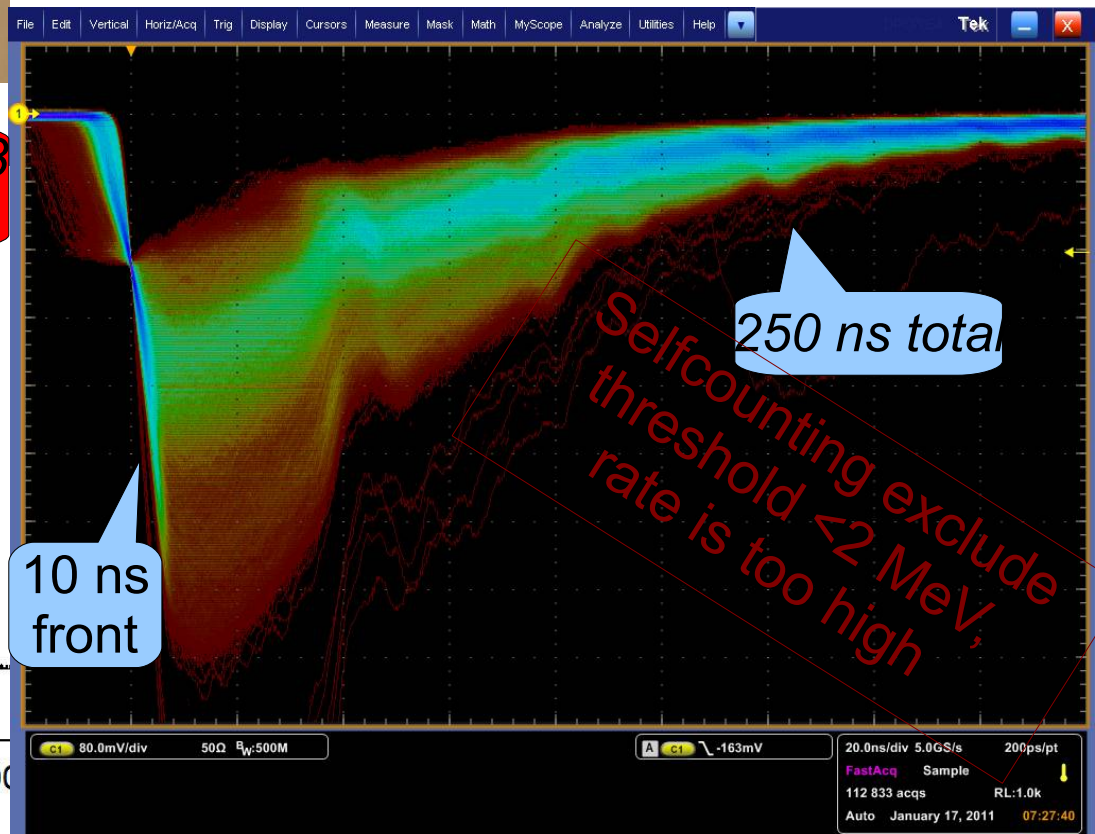



# PreLude 420 ($Lu_{1.8}Y_{.2}SiO_5$:Ce)

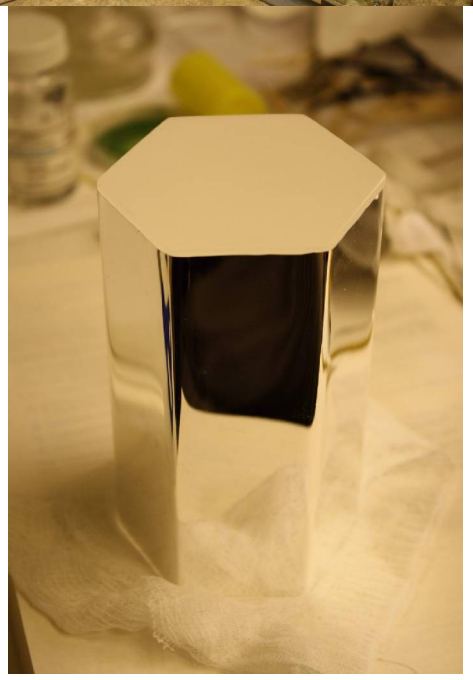


# CsI(pure) (China)



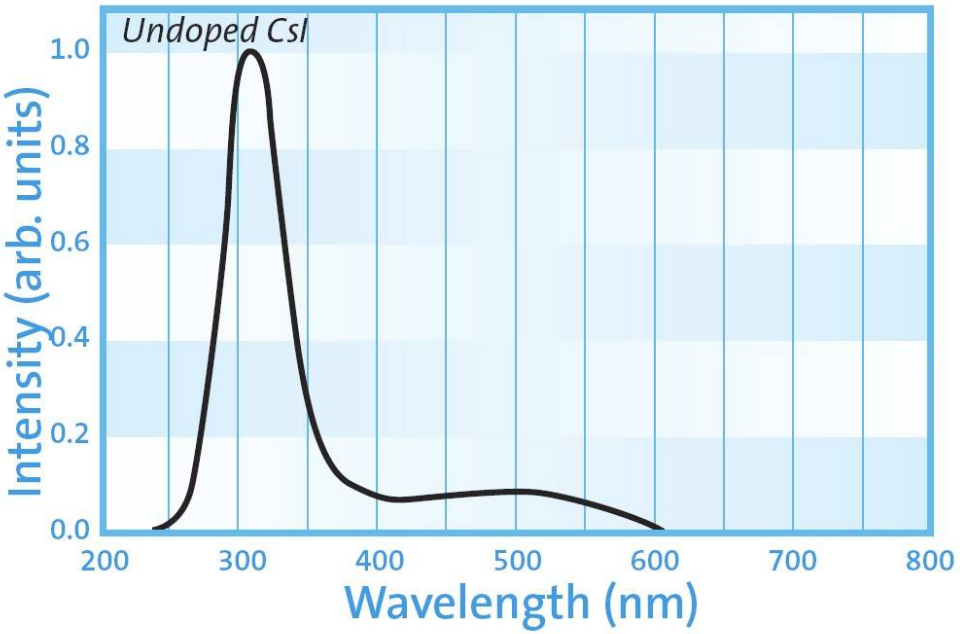



**Figure 1**. Scintillation emission spectrum of CsI(pure)

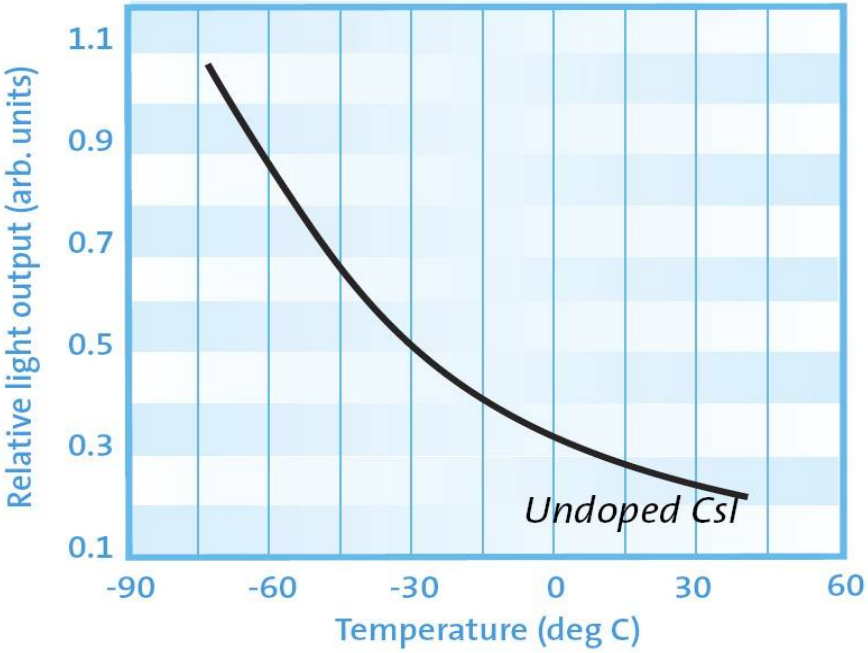
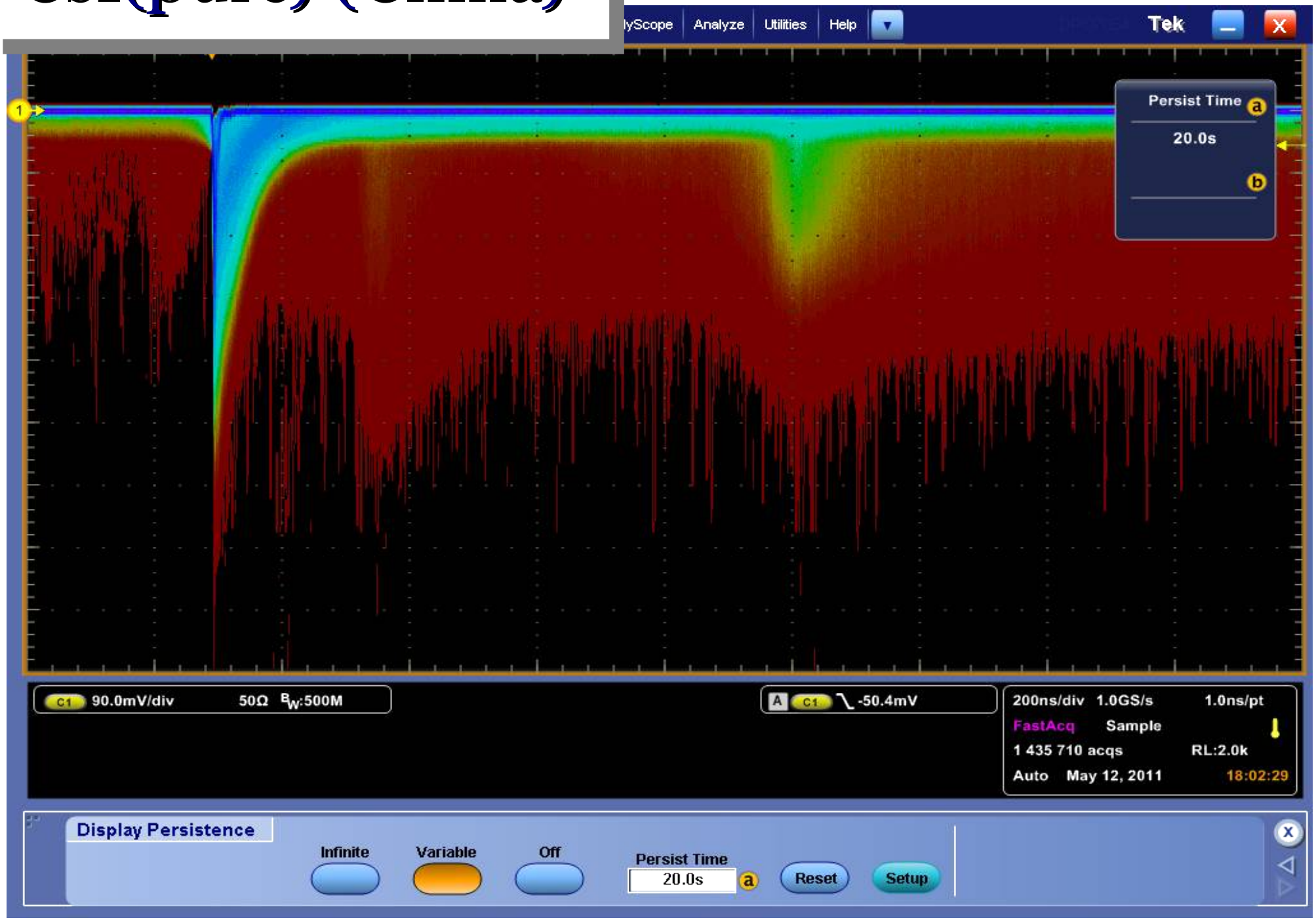



**Figure 2**. Relative light output as a function of temperature for CsI(pure)

# CsI(pure) (China)



# Outlook

| | Resolution 662keV | Threshold, keV | Deadlayers, mkm | Signal duration | Selfcount, Hz/cm3 | Price, euro/cm3 |
|---|---|---|---|---|---|---|
| CsI(Tl) | 7,00% | 200 | 150 | 10 mks | <0,25 | 2 |
| BrilLanCe 380 | 3,00% | 100 | 2000 | 120 ns | <0,25 | 195(155) |
| PreLude 420 | 7,00% | 2000 | 150 | 250 ns | 25 | 70(55) |
| CsI(pure) | n/a | n/a | 150 | 200 ns/mks | | 2 |

No one tested scintillator material has necessary complex of parameters.

- **Candidate scintillator materials are tested.**
- **Optimal conditions for preparing CsI(Tl) is found.**
- **Two solution for light readout is found.**
- **Measuring procedures are defined.**