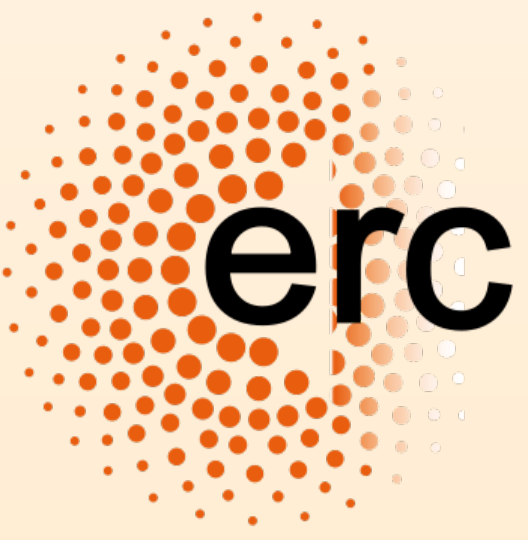


Search for a 4th Neutrino with CeSOX



T. Lasserre^{1,2}, on behalf the CeSOX/Borexino Collaboration

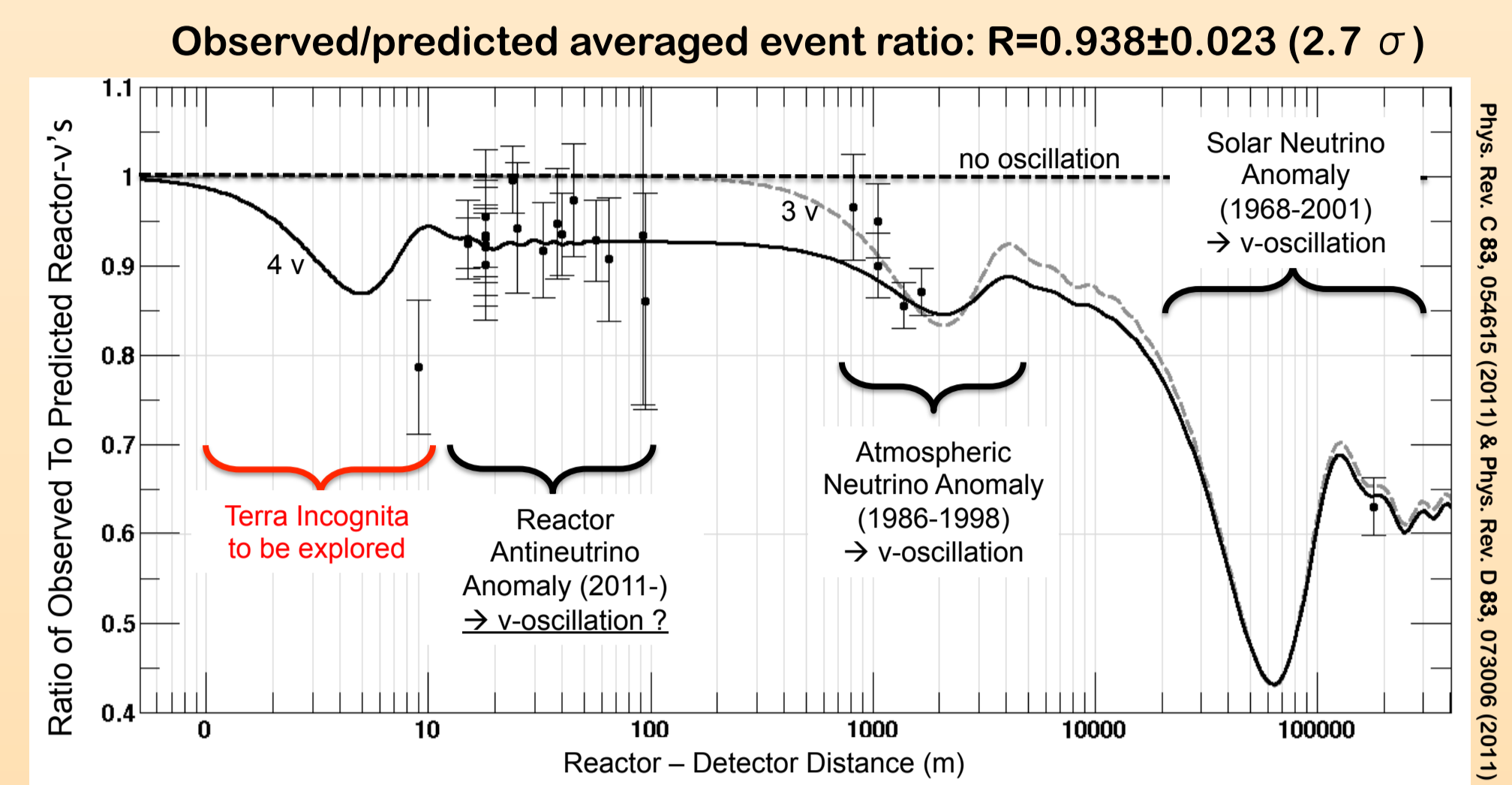
¹ CEA, Centre d'Etudes Nucléaires de Saclay, DSM/Irfu, 91191 Gif-sur-Yvette Cedex, France
² Laboratoire APC, Paris, France



Short Baseline Neutrino Anomalies

Anomaly	Source	Type	Sensitivity to Oscillation	Channel	Significance
LSND	Decay-at-Rest	$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$	Total Rate, Energy	CC	3.8 σ
MiniBoone	Short baseline	$\nu_\mu \rightarrow \nu_e$	Total Rate, Energy	CC	3.8 σ
Gallium	Electron Capture	ν_e dis.	Total Rate	CC	2.7 σ
Reactor	Beta-decay	$\bar{\nu}_e$ dis.	Total Rate, Energy	CC	2.7 σ
Cosmology	Big-Bang	All	Number of ν (N_{eff})	CC	possible

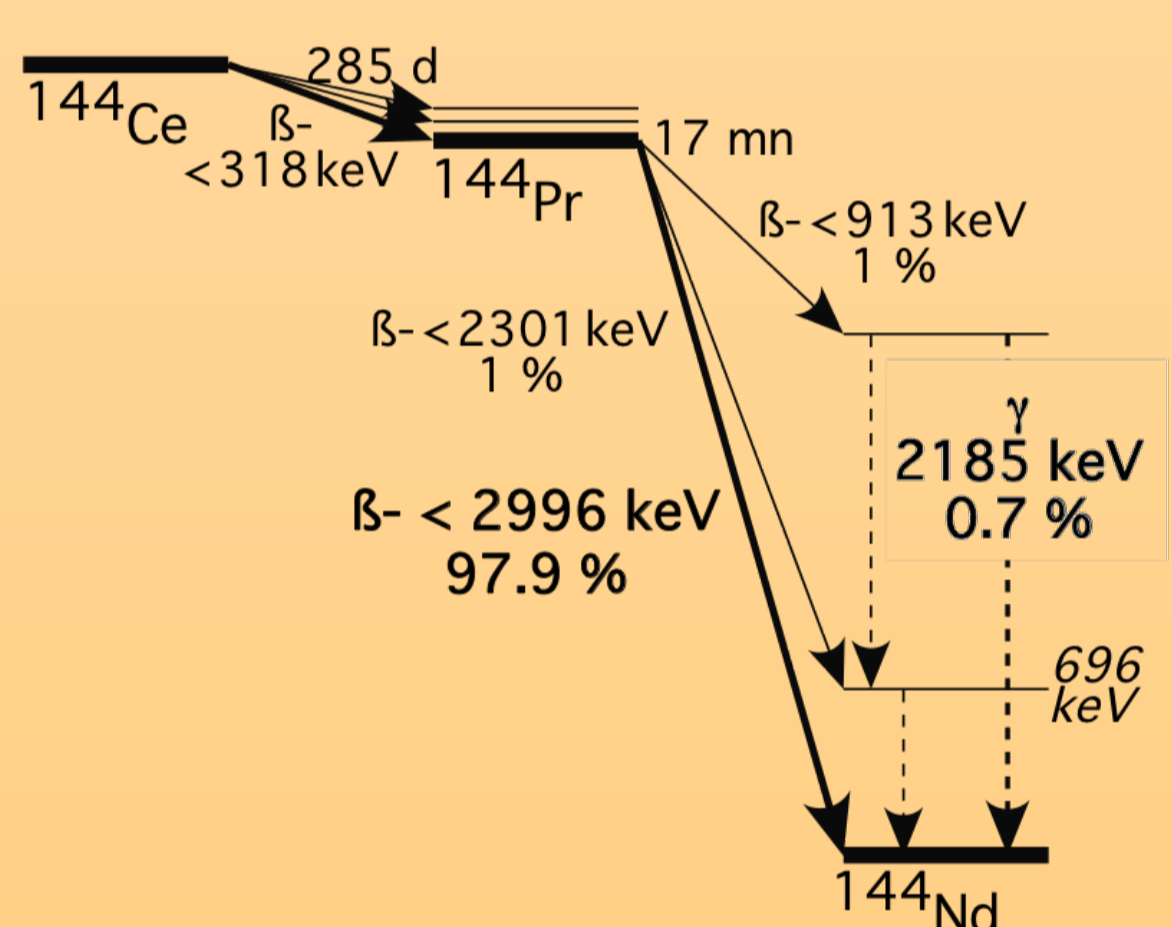
→ could accommodate a light eV 4th neutrino state...



¹⁴⁴Ce-¹⁴⁴Pr

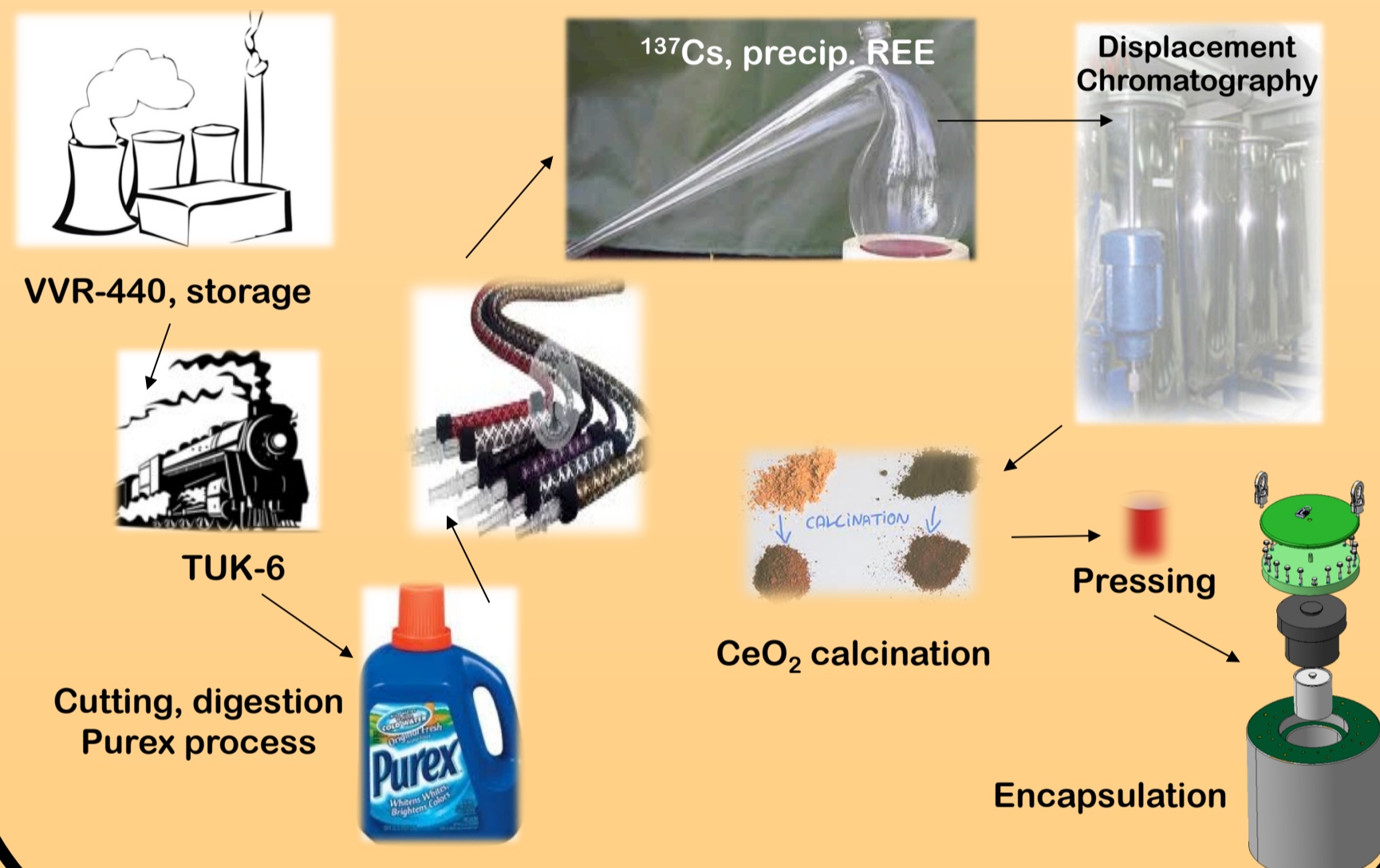
(ITEP N°90 1994, PRL 107, 201801, 2011)

- $\bar{\nu}_e$ detected via $\bar{\nu}_e + p \rightarrow e^+ + n$ (Q=1.8 MeV)
 - High cross section → need >3 PBq
 - (e⁺,n) detected in coincidence → low background
- ¹⁴⁴Ce-¹⁴⁴Pr antineutrino generator
 - Abundant fission product (5%)
 - ¹⁴⁴Ce: long-lived ($t_{1/2}=411$ d)
 - ¹⁴⁴Pr: short-lived & $Q_\beta=3$ MeV



¹⁴⁴Ce Production

- Production at PA Mayak (Russia, Rosatom)
- Activity: >3.7 PBq
 - 10 kg of CeO₂ (4-5 g/cm³)
 - 1.8 l in a double stainless steel cylinders (SFRM)
- Cylindrical W-alloy shield (18.5 g/cm³)
 - 50 cm ϕ x 50 cm H, 19 cm thick, 2.2 tons
- Dose rate : <90 μ Sv/h at contact of the shield



¹⁴⁴Pr ν -spectrum

- ¹⁴⁴Pr: 8 allowed or 1st forbidden transitions

$$\frac{dN}{dW} = K p(W) (W - W_0)^2 \times F(Z, W) \times C(Z, W)$$

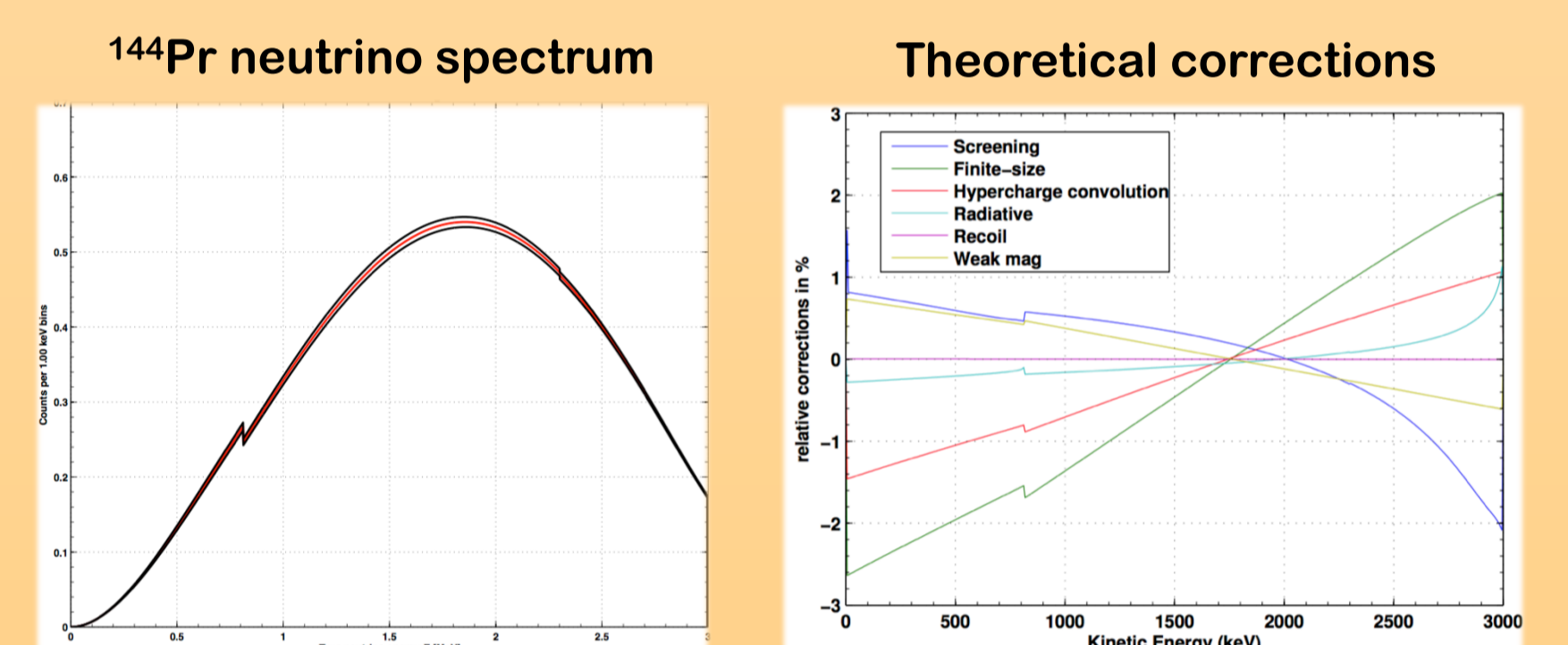
Reduced beta particle energy: $W = E/m_e$

Endpoint energy: $W = Q_\beta/m_e + 1$

Phase space factor

Fermi function: influence of the Coulomb field of a point-like nucleus

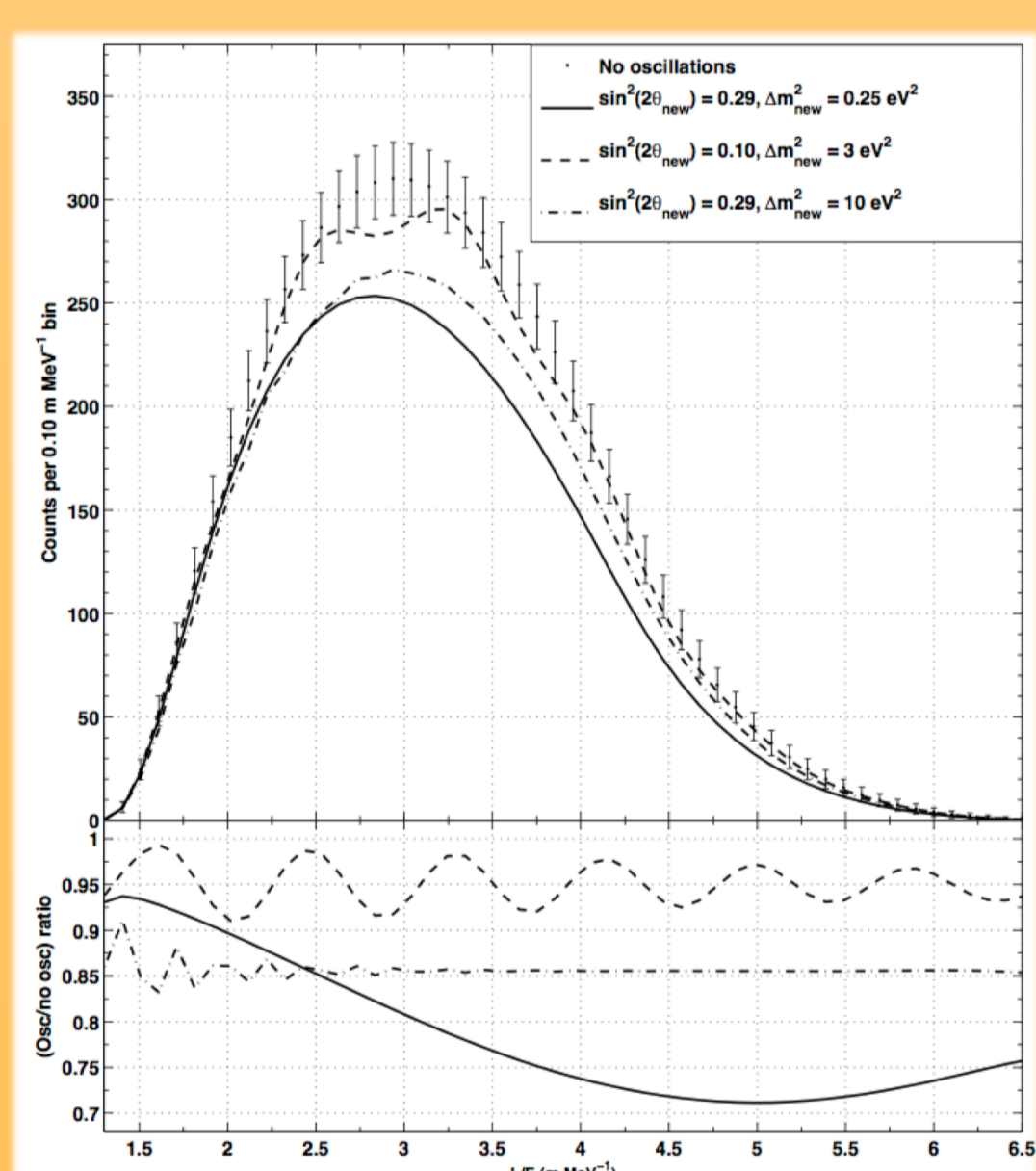
Shape factor (depends on the nature of the transition) + corrective terms



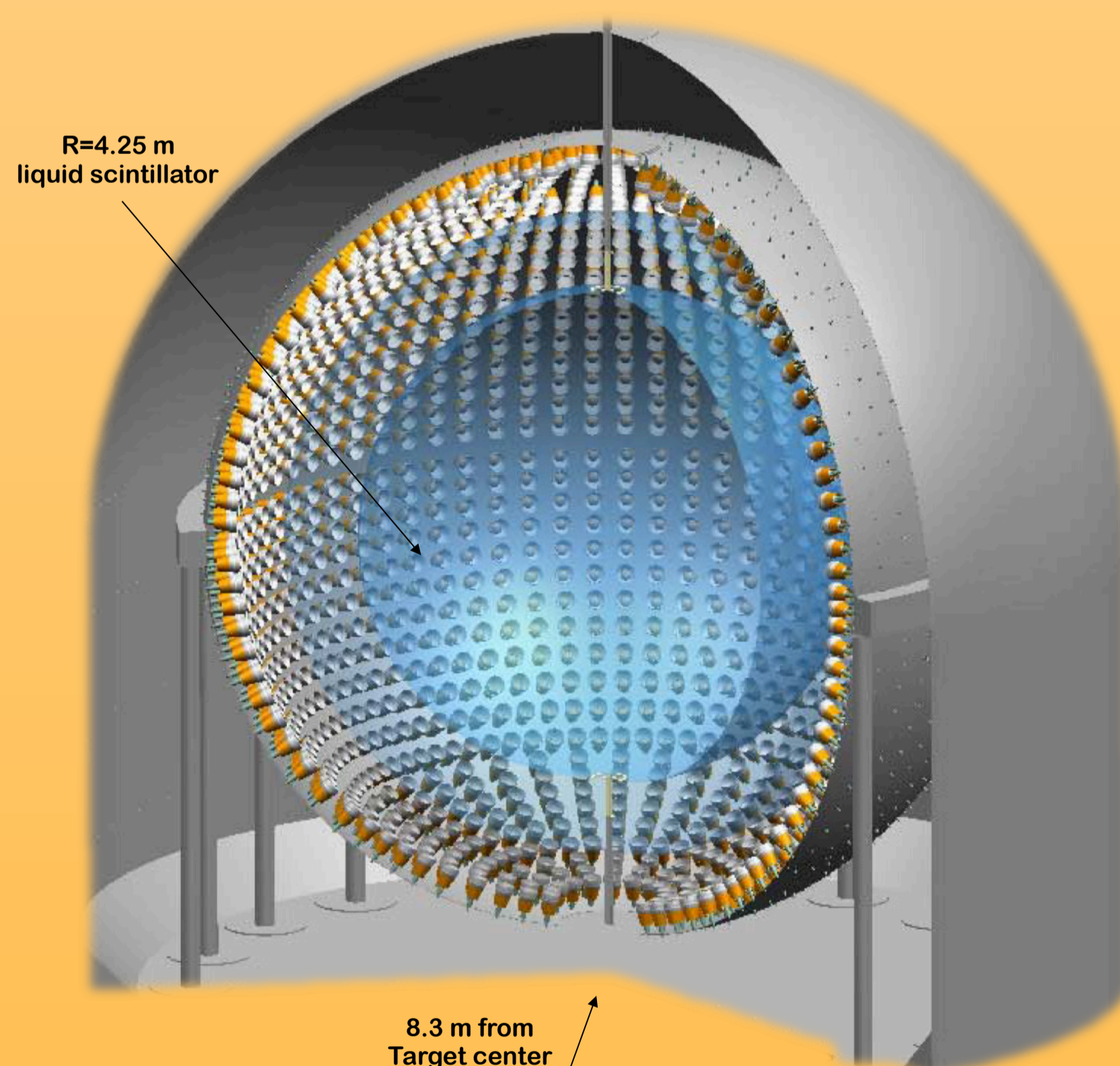
- Measurement of β -spectrum (100 kBq ¹⁴⁴Ce sample) + conversion to ν -spectrum
- Precision on interaction rate: 1%

¹⁴⁴Pr ν -signal

$\bar{\nu}_e + p \rightarrow e^+ + n$: 10 000 interactions / 1.5 y / 3.7 PBq

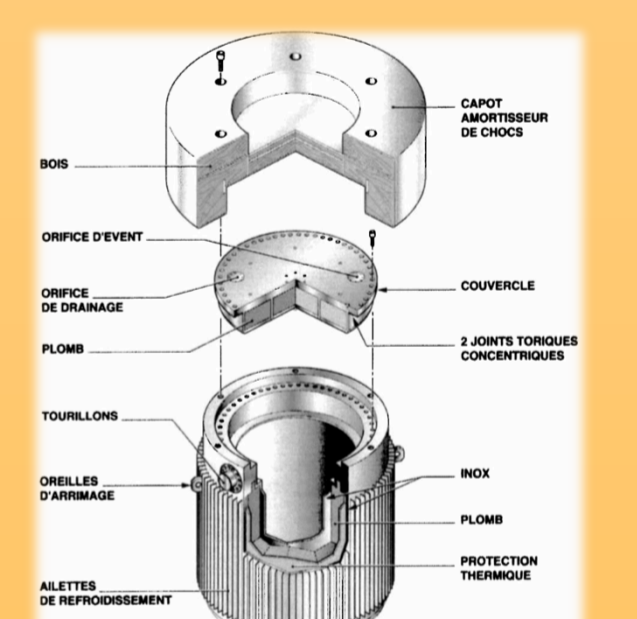


Borexino detector



Logistic

- AREVA TN-TMR cask
 - Type B(U) certified by IAEA
 - Extension of licensing for ¹⁴⁴Ce + W-shield ongoing
 - Cask booked for 11/2015

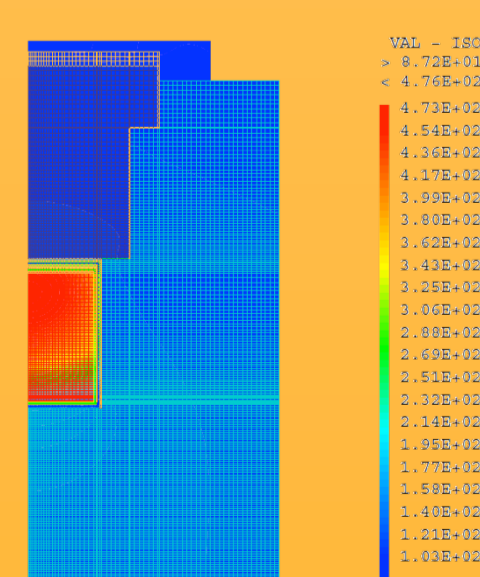


- Route (AREVA TNI)
 - Train to Saint Petersburg
 - Boat to Le Havre
 - Truck to LNGS

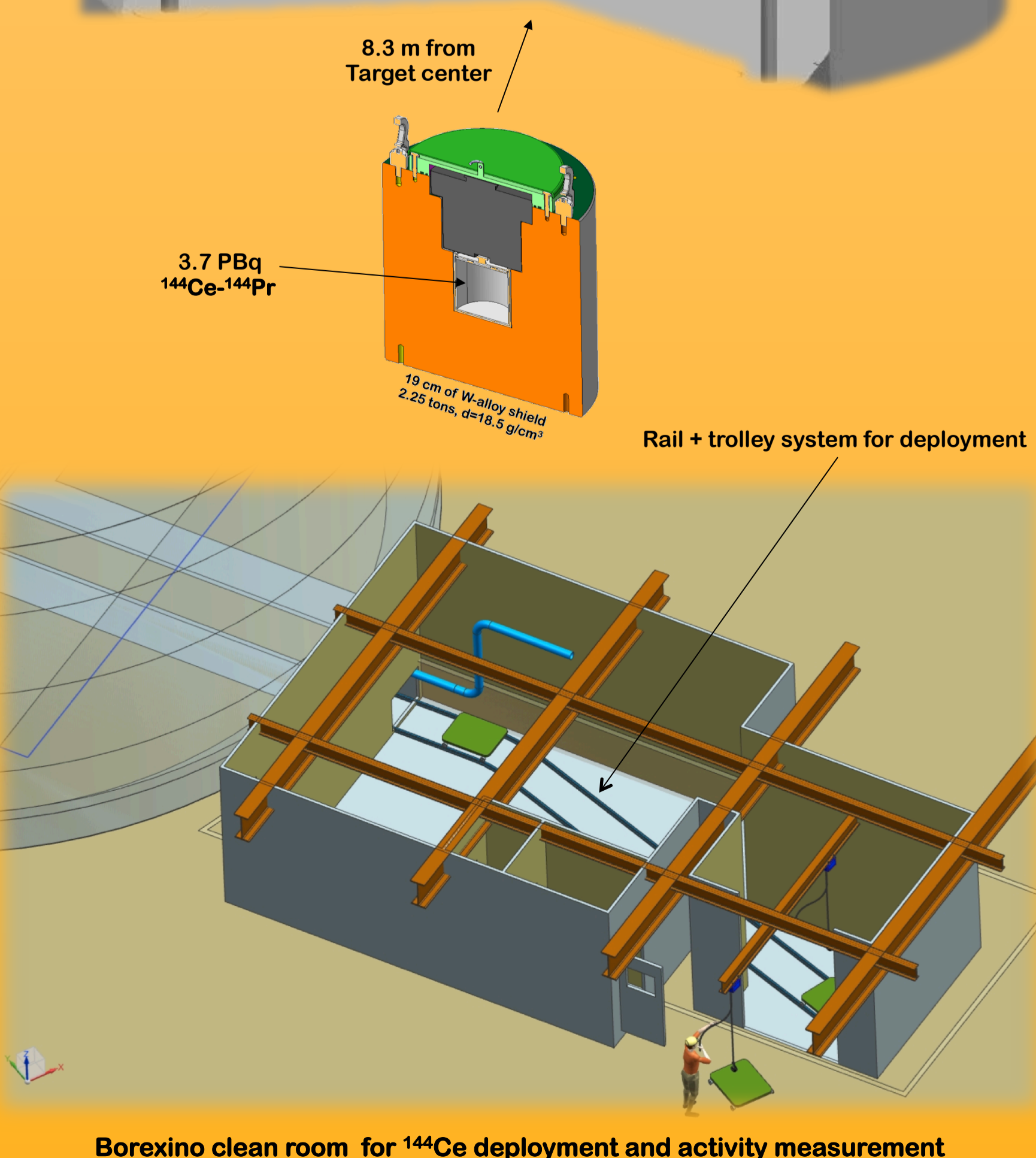
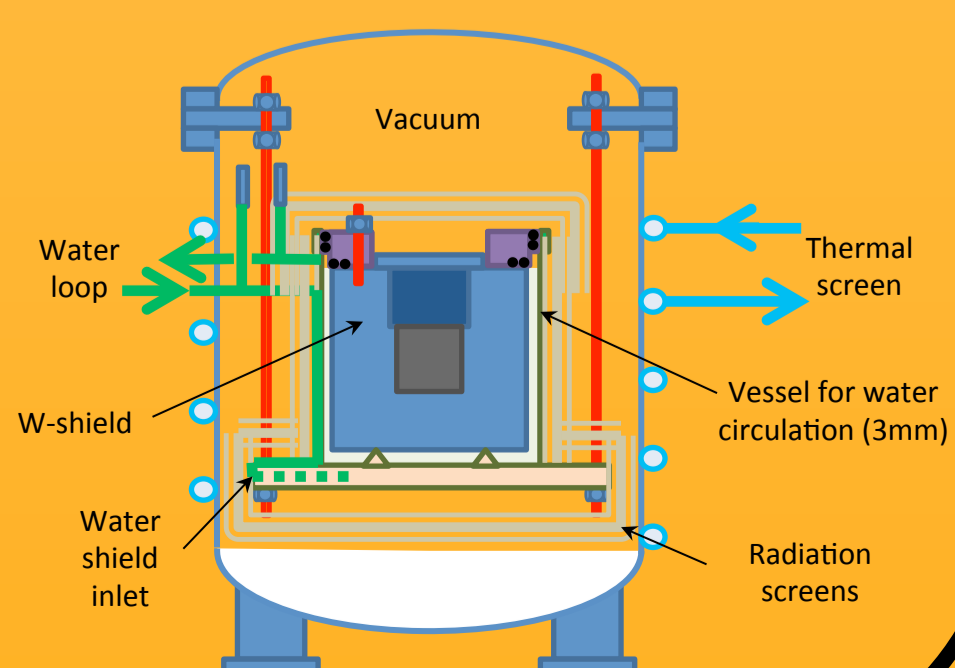


¹⁴⁴Ce Activity

- W-Shield in air at LNGS
 - 1000 Watt – 4.7 PBq
 - CeO₂: $T_{max} = 450^\circ\text{C}$
 - Capsule: $T_{max} = 380^\circ\text{C}$
 - Shield surface: $T_{max} = 85^\circ\text{C}$



- Dedicated calorimeter
 - $H_{144\text{Ce}} = m \cdot C_p \cdot (T_o - T_i) - H_{\text{loss}}$
 - Heat loss: $H_{\text{loss}} < 1$ Watt
 - Measure (<1% error)
 - Water T° in/out
 - Water mass flow



Borexino clean room for ¹⁴⁴Ce deployment and activity measurement

Sensitivity

- >3.7 PBq ¹⁴⁴Ce production: 2014/15
- Deployment at LNGS (11/2015)

