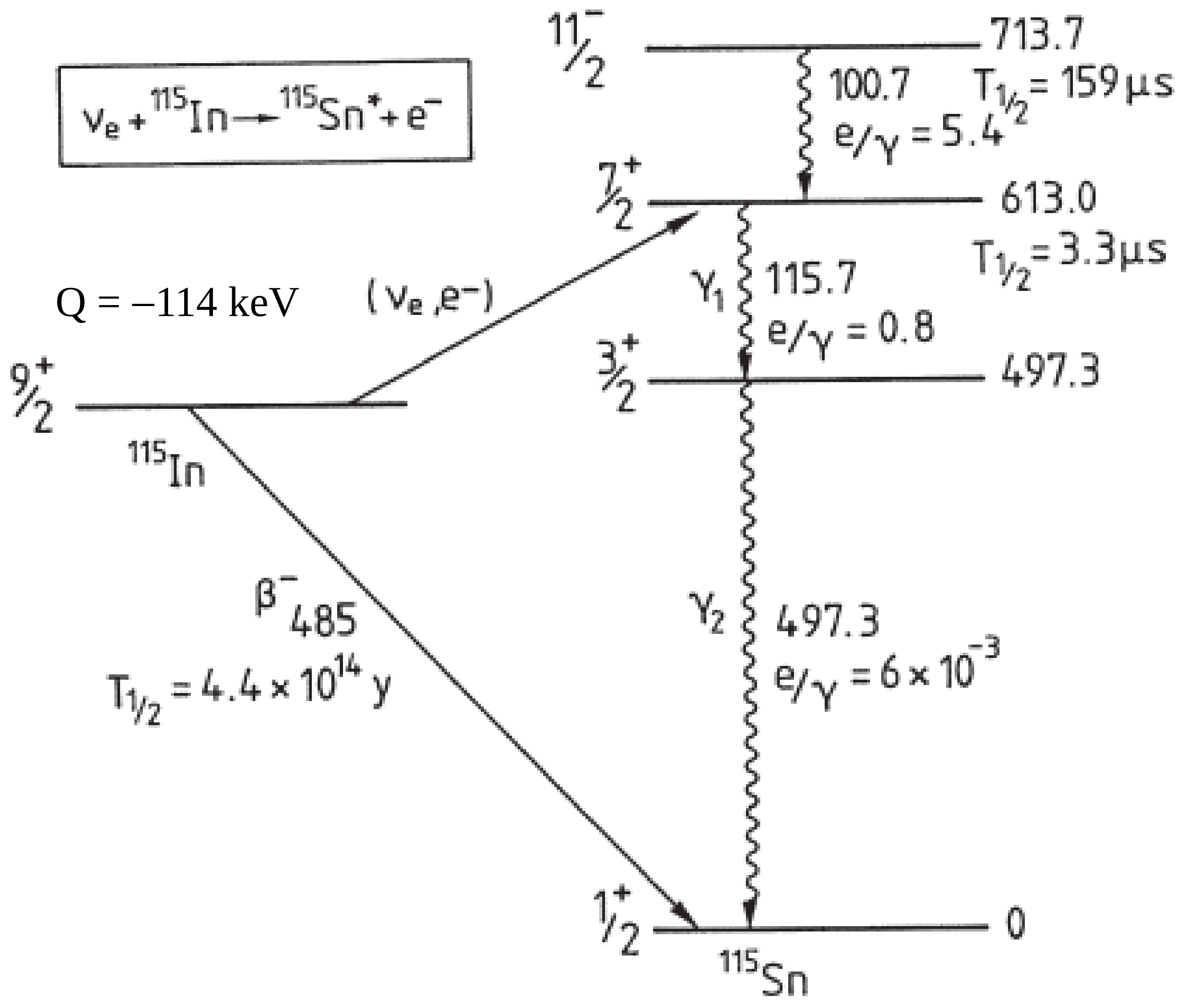
An Indium detector for solar neutrinos

- Raghavan proposed a real-time Indium detector for solar neutrinos – PRL **37**, 259 (1976).
- LENS - segmented 8% In-loaded 125 ton LS detector – "photon lattice" with LS divided into 3" sized cubical units
- Segmentation needed to reduce huge random coincident background from natural β decay of ^{115}In (95% abundance) –3 in. resol. in X,Y, Z
- Booth (1987) explored possibility of measuring q-p in superconducting In
- How about a cryogenic bolometer of In metal (or a suitable compound)?

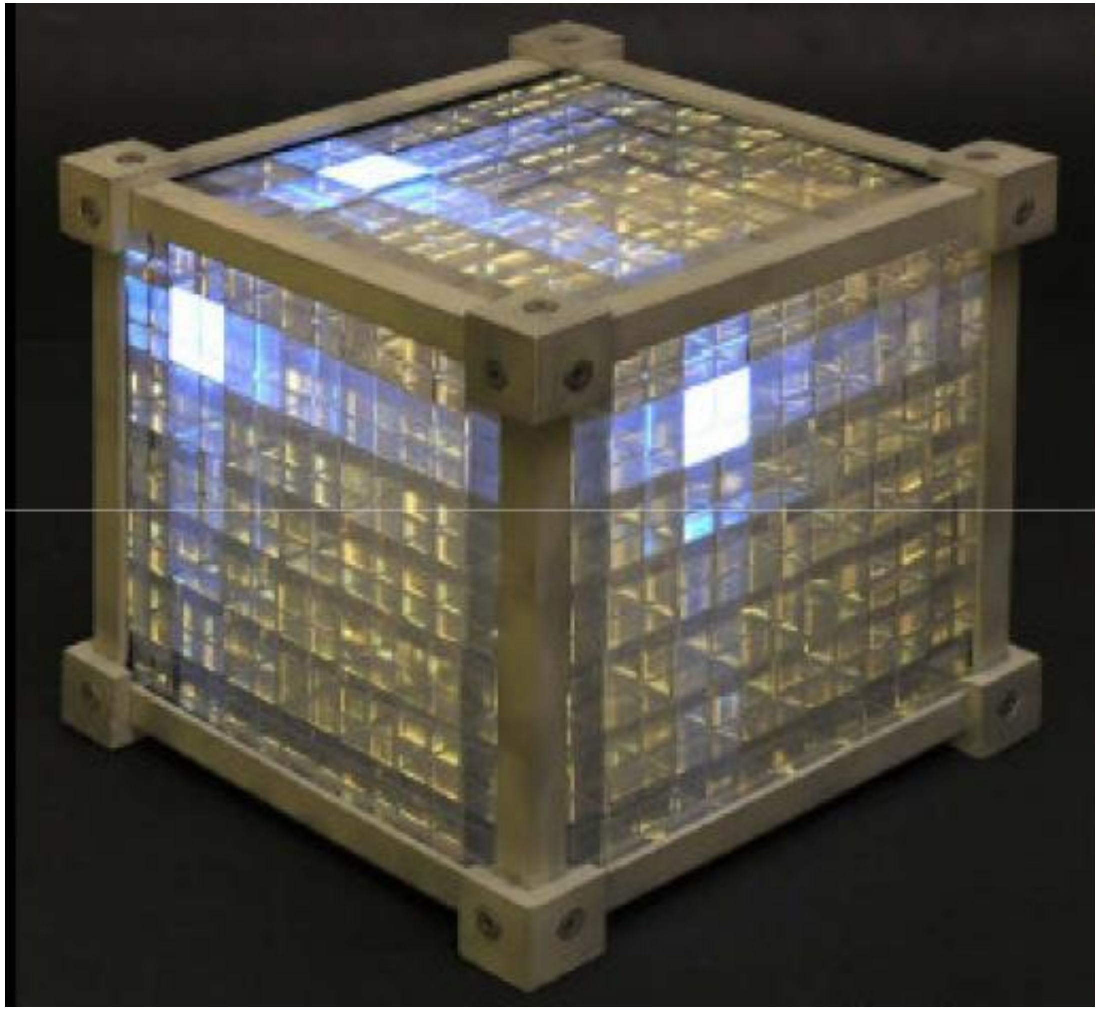
Levels excited in low energy ν_e CC interaction with ^{115}In

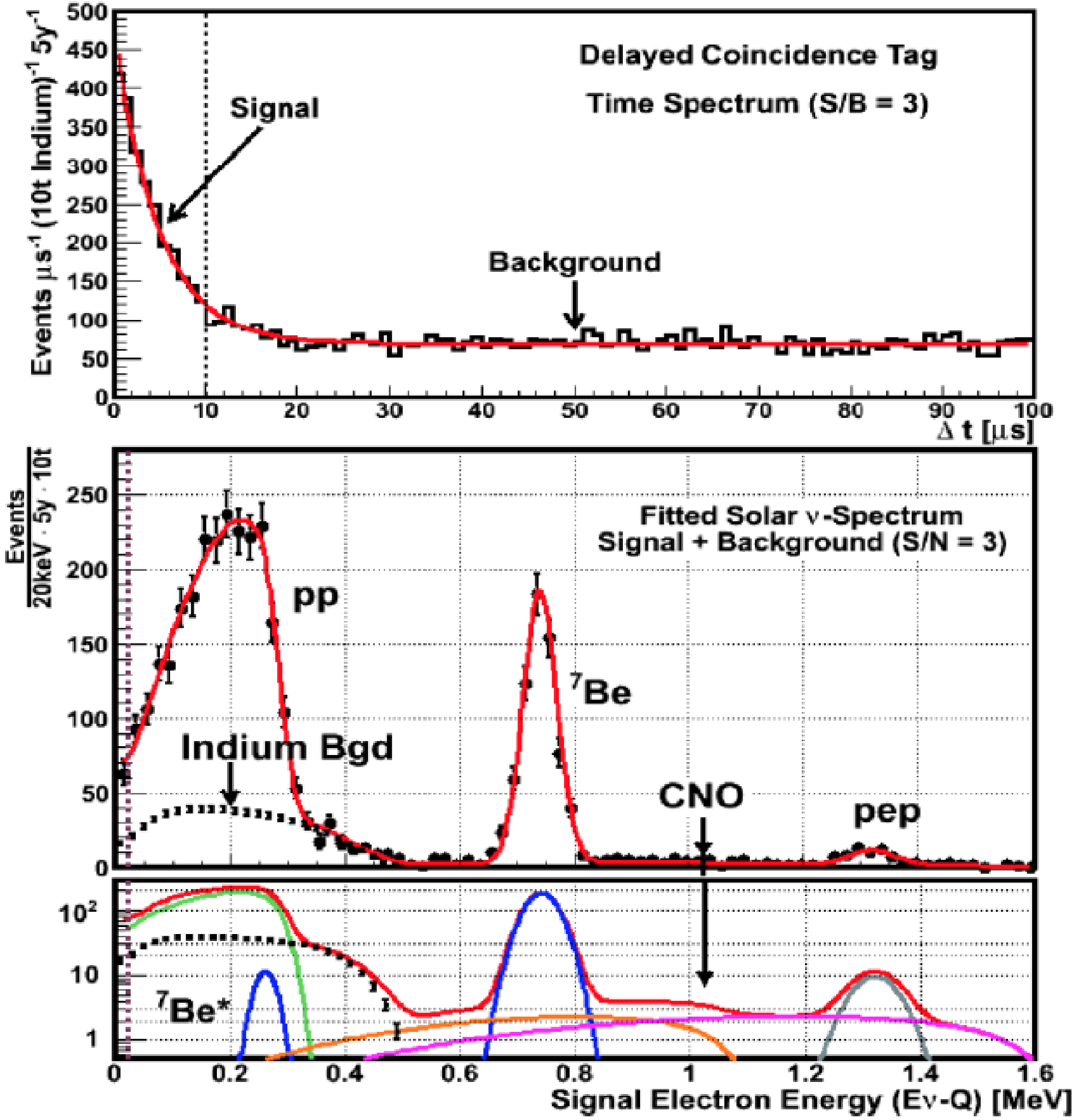


Signal:

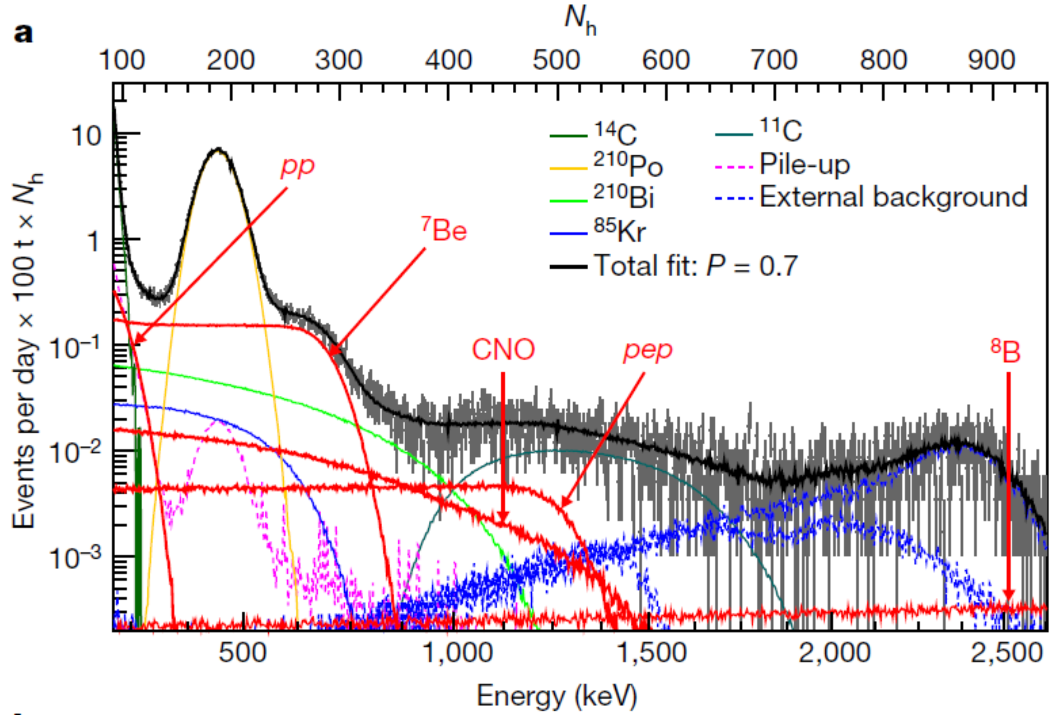
IBD e⁻ - delayed γ_{116} - prompt γ_{497}

Prototype In-doped LS detector at Kimbalton Mine

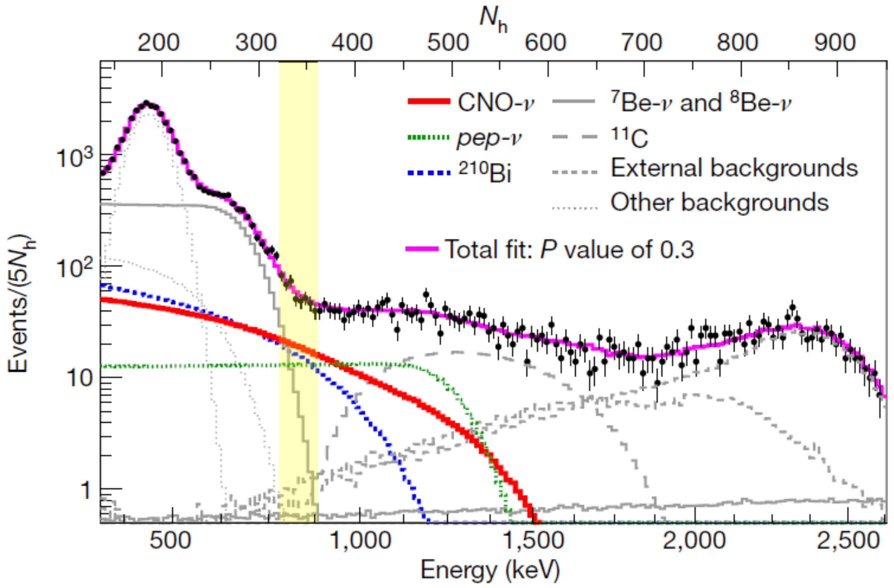




Ref. Raghavan's Physics Colloquium at BARC (26 Oct 2010)



pp, *^{7}Be* neutrinos measured: Nature **512**, 383 (2014)



CNO vs ~1% Φ_ν (tot): Nature **587,** 577 (2020)

Simulation of 125-ton 8% Indium-loaded Liquid Scintillator (LENS collaboration)

Count rates\signal, Bkgd	*pp* events/(yr.Ton Indium)	Bkgd events/(yr.Ton Indium)
Raw rate	62.5	8×10^{12}
Spatial-time cuts	50	2.8×10^{5}
+ $\geq$ 3 hits	46	3×10^{4}
+ E_{sum}=614 keV	44	306
Topology	40	13 ± 0.6

Science goals of a In-loaded LS

- Measure E spectrum of *pp*, ^{7}*Be*, *pep* neutrinos (~50–1500 keV) in real time
- Measure core temperature of sun *directly* via Doppler broadening of ^{7}Be neutrinos [Bahcall] as well as the *p-p* neutrinos [Grieb, Raghavan].
- Search for a possible sterile neutrino-electron neutrino mixing using a radioactive ν_e source or one made online using a high current p/d beam on a suitable target [6].
- Search for neutrino-antineutrino oscillations using strong anti-ν_e source or one made online using a high current p/d beam on a suitable target.
- Search for dark matter (2-body) decay and/or annihilation through unidentified peak in neutrino spectrum.

C. Grieb, R. Raghavan, PRL **98**, 141102 (2007)

TABLE I. Neutrino energies and thermal shifts.

	q(lab) keV	$+\Delta\langle E\rangle$ keV	$+\delta\langle E\rangle$ keV	$+\Delta E$ keV	$+\delta E$ keV
pp	420.2[a]	3.41[b]	1.6	5.2[c]	1.7
pep	1442.2	6.65[b]	4.54		
^{7}Be	861.8	1.29[b]	0.81		

[a] Q-value

[b] Mean energy shift (for *pp* in range 110-340 keV)

[c] Shift of max. energy in spectrum

$\delta\langle E\rangle$ Precision attainable in $\Delta\langle E\rangle$

⇐

Thoughts on a cryogenic Indium detector

- Potentially excellent energy resolution of cryogenic detector ($\sim$ few keV) using Indium especially suited for the items 2 and 5.
- Cryogenic detector (10 mK) needs segmentation into units of between 1-3 cm dimension (a full cost-benefit analysis necessary) with total mass $\sim$10 tons (Vol $\sim$ 1m^3)
- 5-10 modules each with its own shielding. In view of the internal ^{115}In radioactivity the shielding could be placed *outside* the cryostat
- Timing < 0.5 μs needed. NTDGe slow ($\tau_{resp} \sim$ 0.1 sec), TES, !
- Measuring quasi-particles (broken e-e pairs) possible (Booth 1987)

Phonon detection using a Series Array of Superconducting Tunnel Junctions

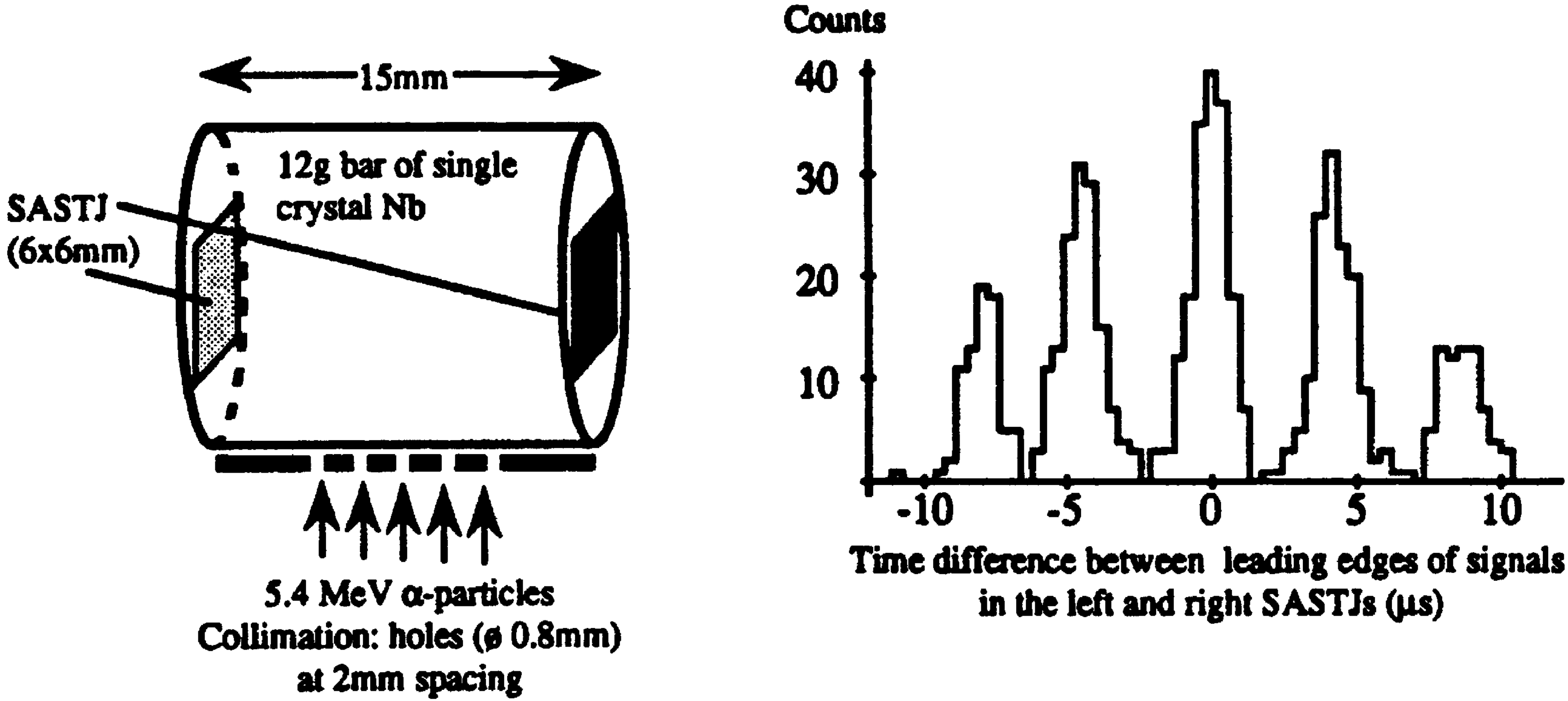


Fig. 14 from N. Booth, B. Cabrera and E. Fiorini, Ann. Rev. Nucl. Part. Sc. **46**, 471 (1996)