A high-energy axion detector for CAST

(J.I. Collar, D. Miller, J. Vieira, EFI UoCh)

•**Goal:** extend sensitivity of CAST to axion-induced gammas from few tens of keV to ~150 MeV

•**Motivation**: If new boson couples to nucleons, it can substitute for a γ in plasma and nuclear processes [1]. Solar luminosity via axion emission can be as high as few % of total. Search with helioscope has not been performed before.

→ Weak experimental limits already exist from observed solar γ flux below 5.5 MeV
($a \rightarrow \gamma\gamma$ following $p + d \rightarrow He + a$) [2].

→ Other reactions of interest exist
(e.g., 2.2 MeV from $p + n \rightarrow d + a$, 511 keV from $e^+ + e^- \rightarrow a + \gamma$, 477 keV from $^7Be+e^- \rightarrow ^7Li^* + \nu_e$ [3], etc.)

→ A generic search should not be limited to M1 transitions [4]. Should surpass sensitivity of searches for anomalous production of single γ's in accelerators [5]. May surpass sensitivity to small branching ratios ($\sim<10^{-5}$-10^{-6}) in laboratory searches [6]. (calculation of expected sensitivity in progress)

•**Must be compact and non-intrusive**, yet reach the lowest possible sea-level background and highest efficiency

→ Careful design and selection of detector and shielding materials

→ Use of Pulse-shape background discrimination in lieu of additional shielding

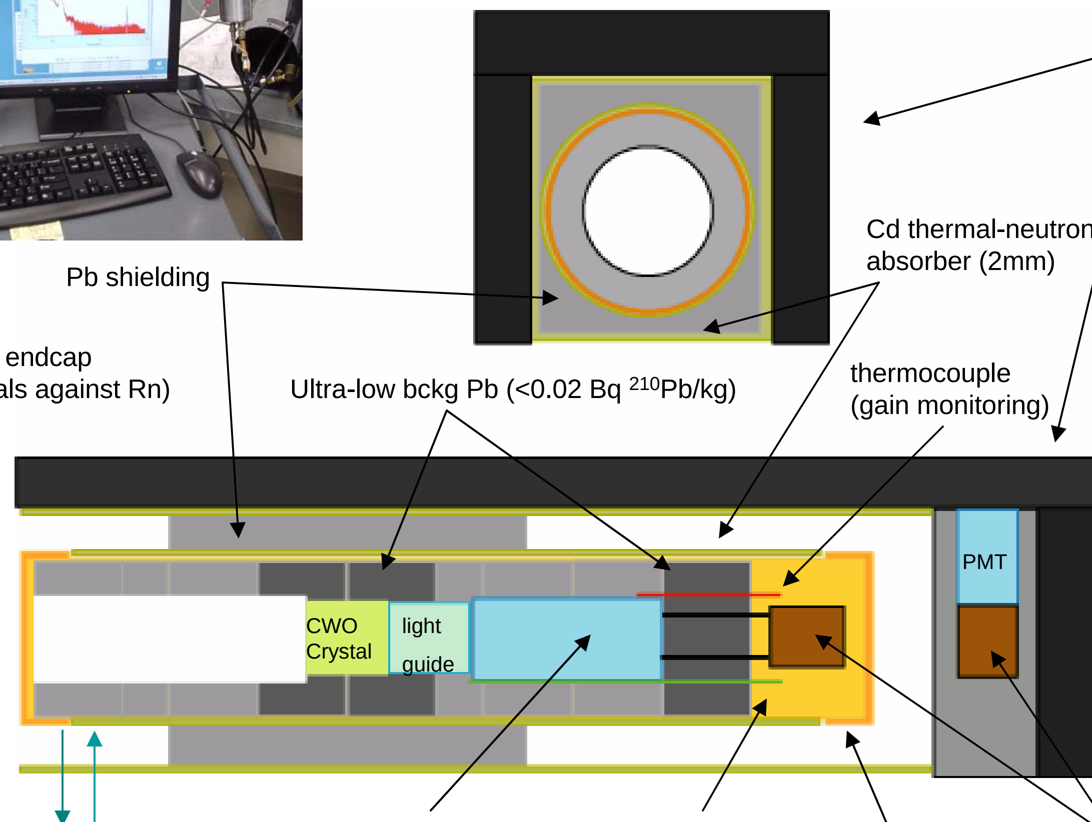
[1] G. Raffelt, "Stars as laboratories for fundamental physics", University of Chicago Press, Chicago and London (1996).
[2] G. Raffelt and L. Stodolsky, Phys. Lett. B119, 323 (1982).
[3] M. Krcmar et al., Phys. Rev. Lett. (hep-ex/0104035)
[4] G. Raffelt, Priv. Comm..
[5] C. Hearty et al., Phys. Rev. D 39(1989)3207.
[6] A. V. Derbin et al., Phys. At. Nucl. 65 (2002)1335; M. Minowa Phys. Rev. Lett. 71(1993)4120.

Minimalistic detector and DAQ

(space between μMs and CCD very limited, also must not add to platform burden)

DAQ: XIA Polaris DSPEC digital spectrometer (shoebox-sized package offers event-by-event waveform capture for pulse-shape analysis (PSD), muon veto input and all power supplies)

Front View

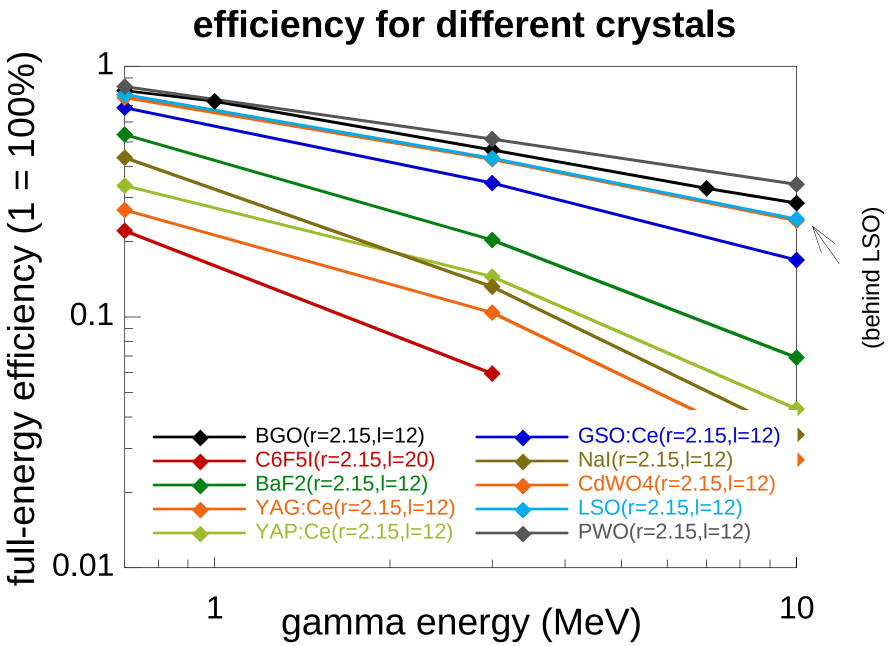


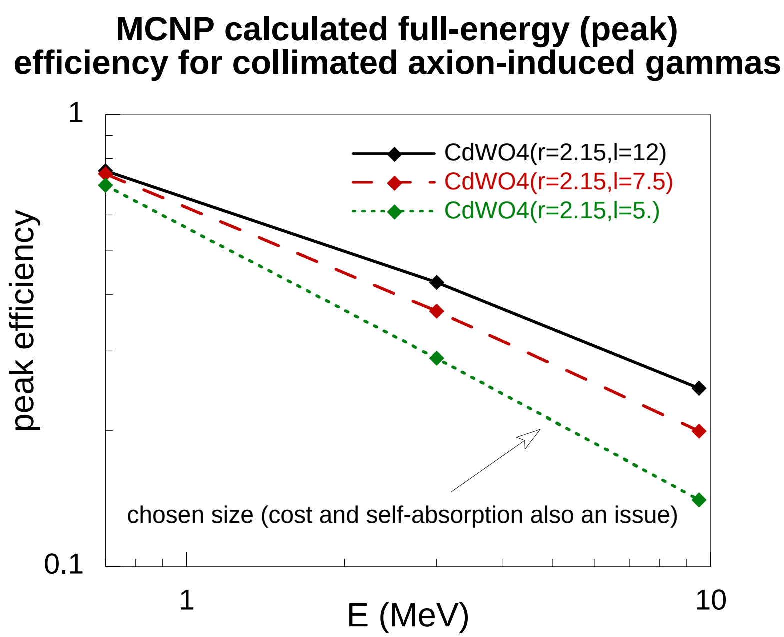
Side View (total length 60 cm, weight ~ 25 kg)

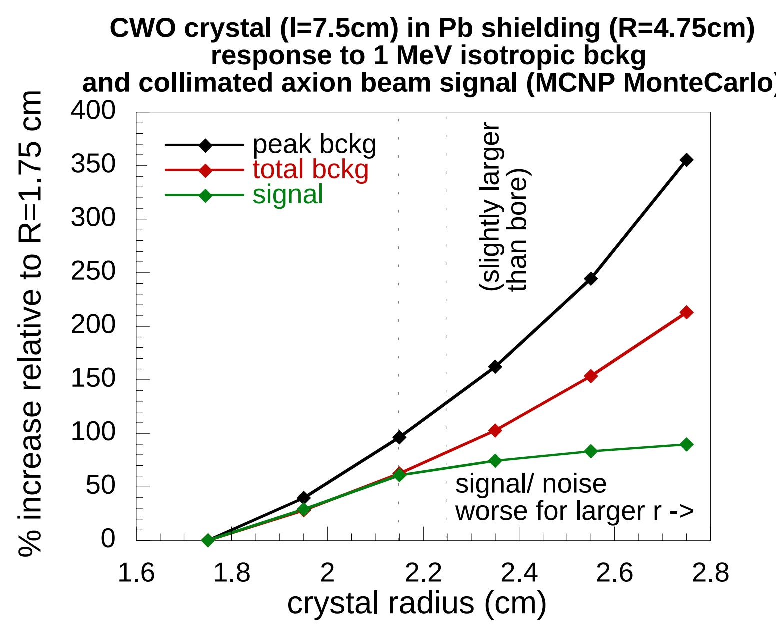
Decisions, decisions:

Monte Carlo of inorganic crystal response reduced best choices to BGO or CWO (PWO has too low a light yield)

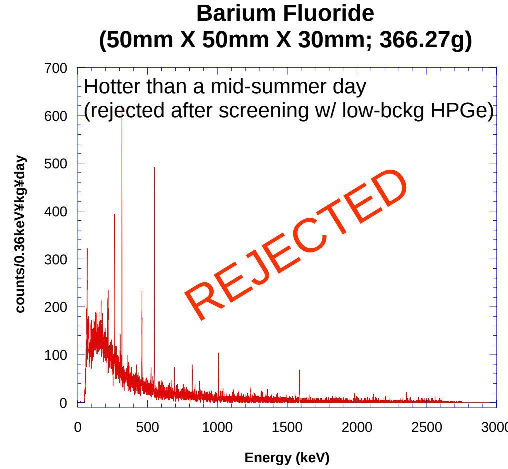
Choice of optimal crystal length and radius via Monte Carlo of collimated signal and isotropic backgrounds. Crystal must be well-aligned with magnet bore (only slightly larger than it).

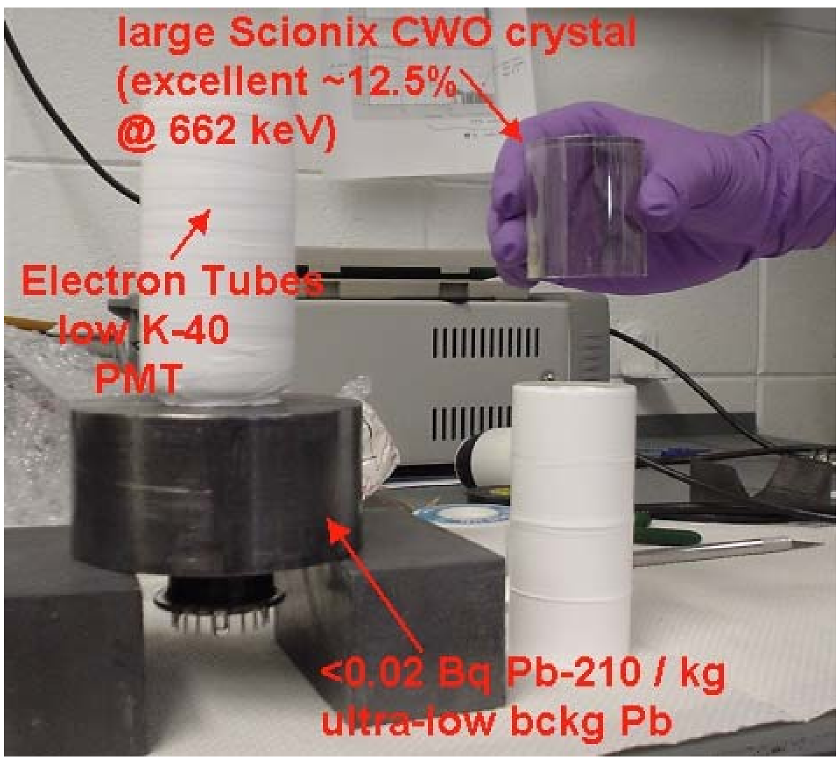




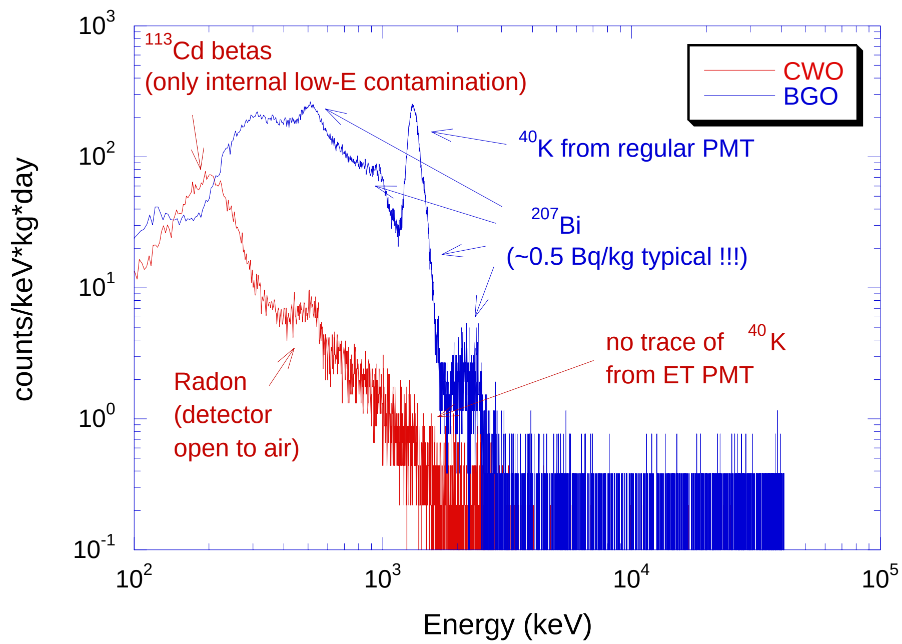


Crystal selection in EFI low-background lab (6-60 m.w.e)

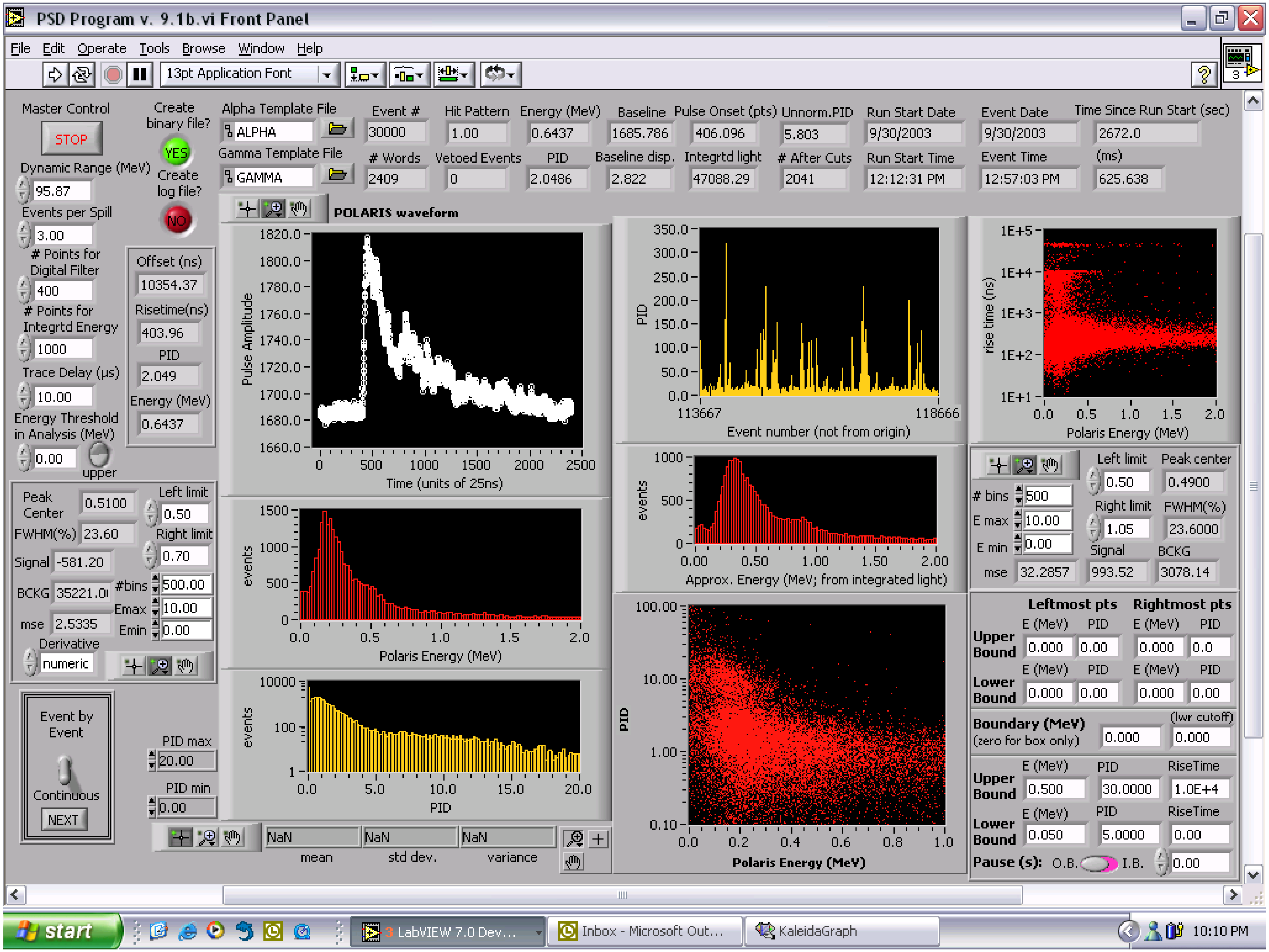




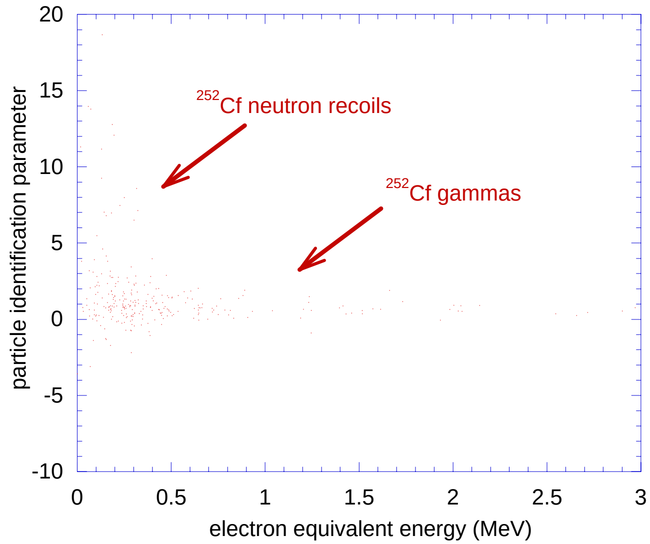
Comparison of standard BGO and CAST CWO
(muon veto, low Pb-210 shielding, 6 m.w.e. depth)

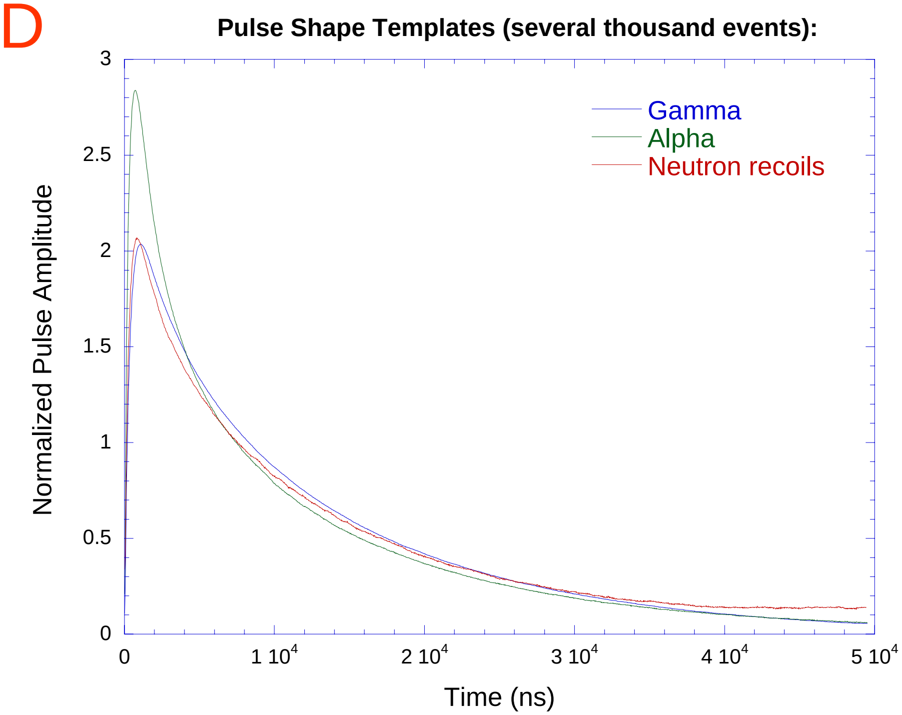


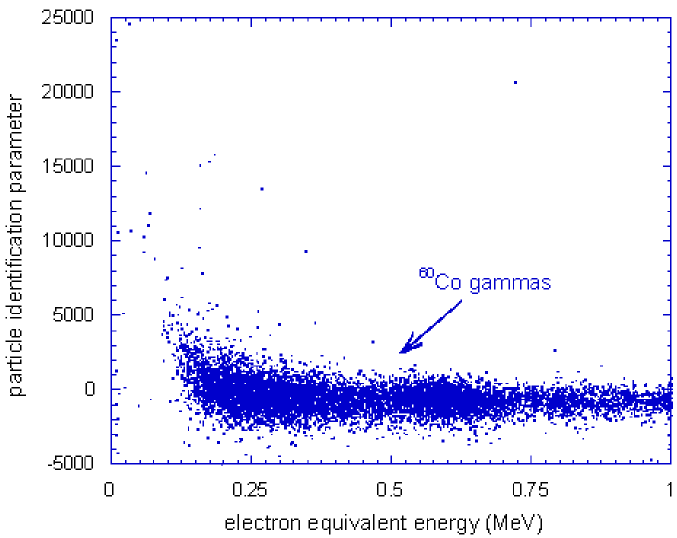
XIA Polaris DSPEC allows event-by-event analysis

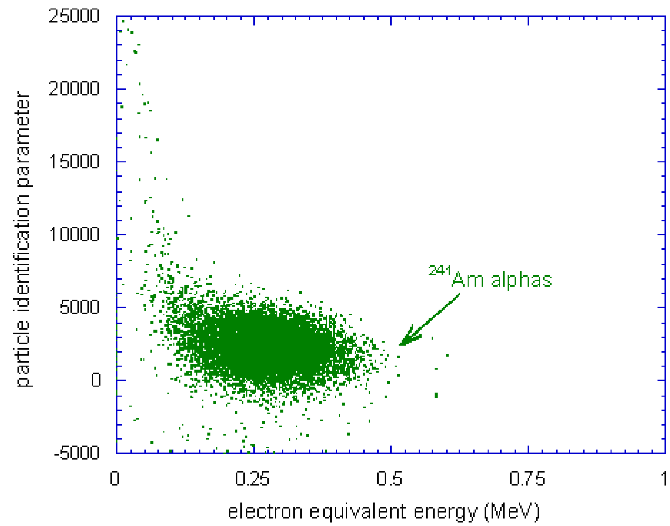


CWO is also excellent for PSD

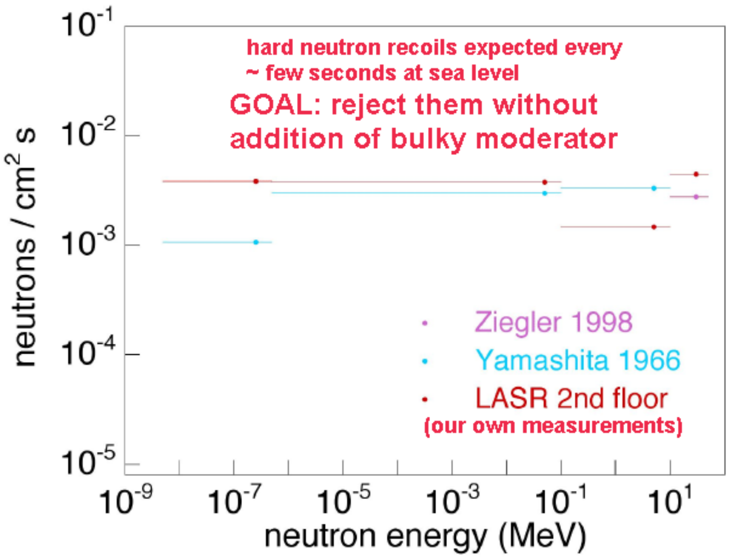








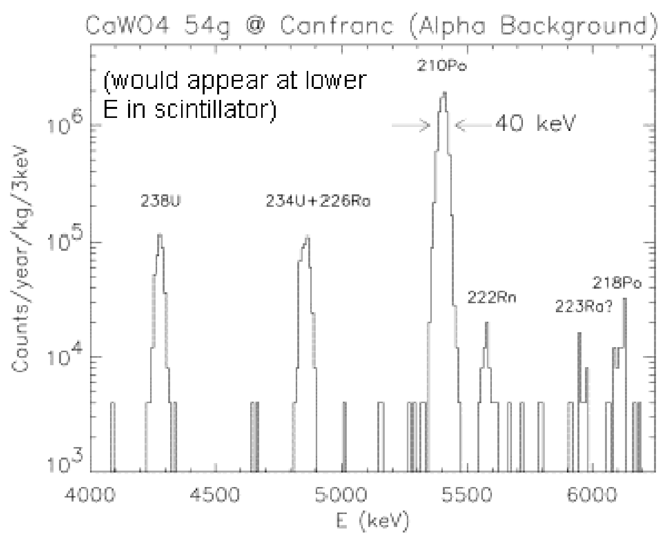
PSD can reject non gamma-like backgrounds while keeping shielding to a minimum



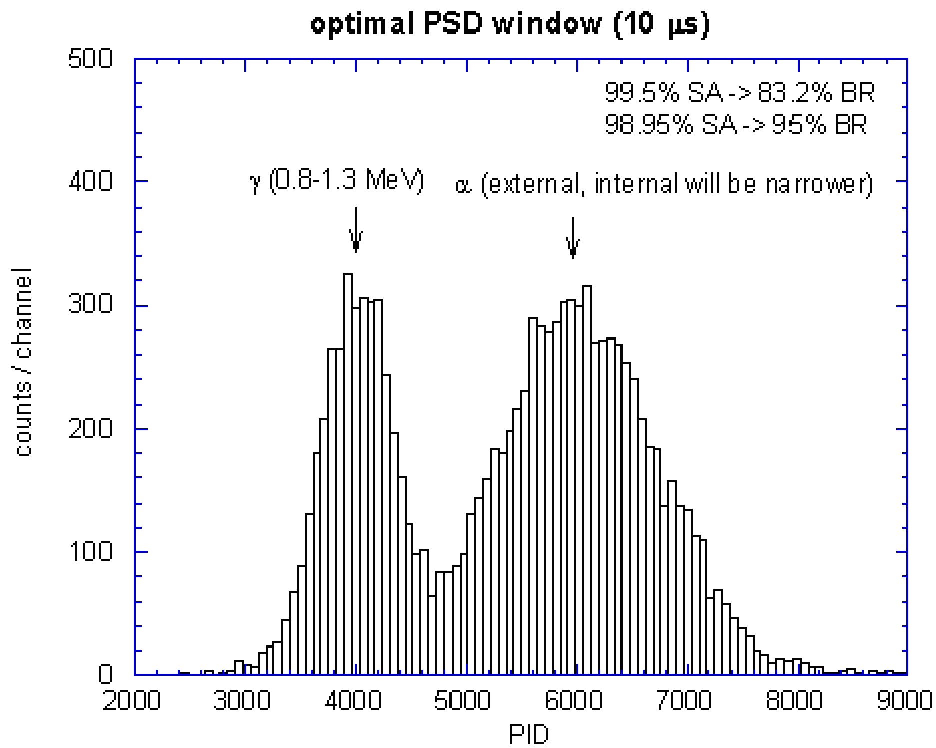
Achieved PSD surpasses that of CWOs used in ββ-decay

(T. Fazzini et al. NIM 410(98)213;
F.A. Danevich et al. PLB 344(95)72;
F.A. Danevich et al. nucl-ex/0003001)

Possible internal alpha contamination can be rejected

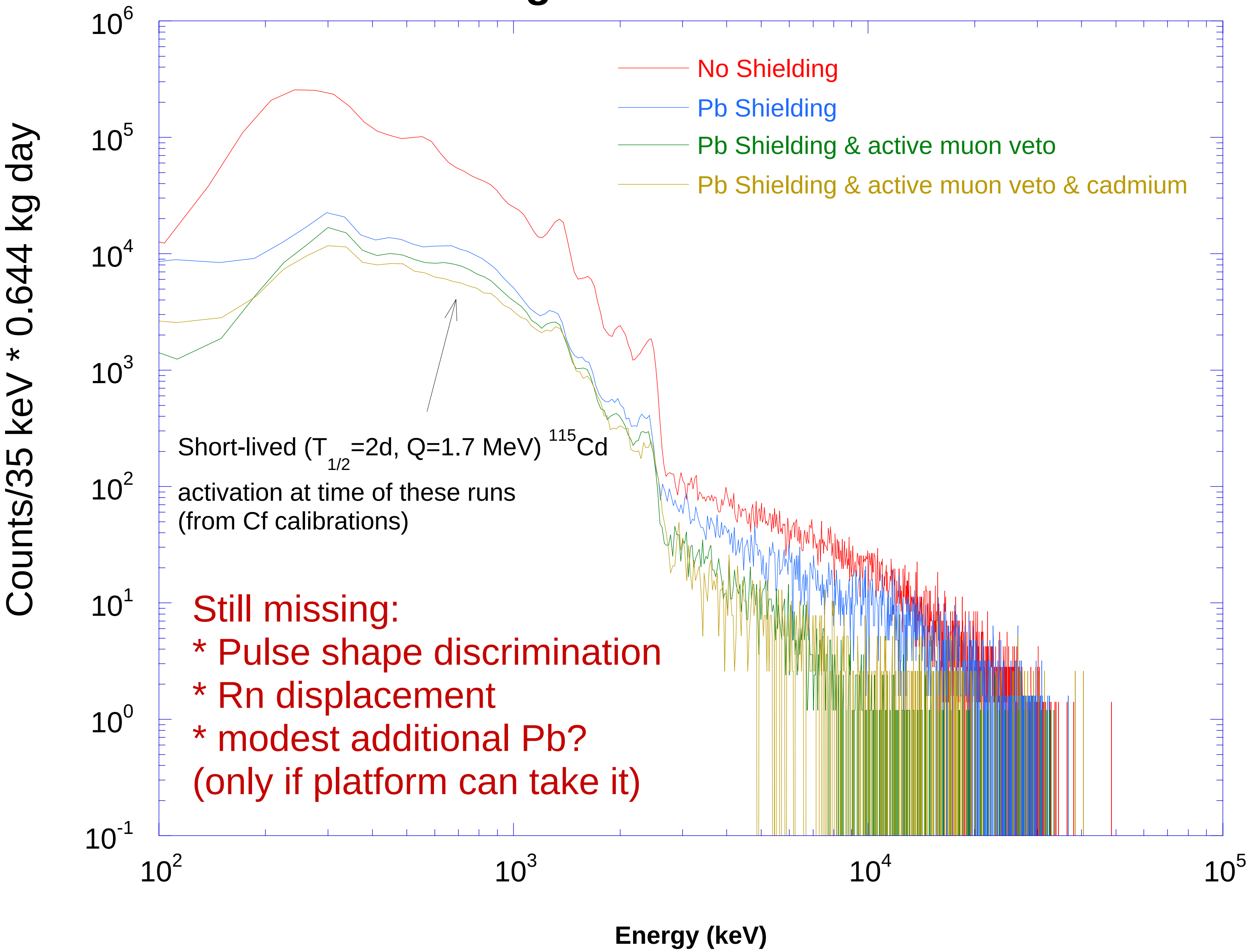


Bolometer data from S. Cebrian et al.
(U. Zaragoza)



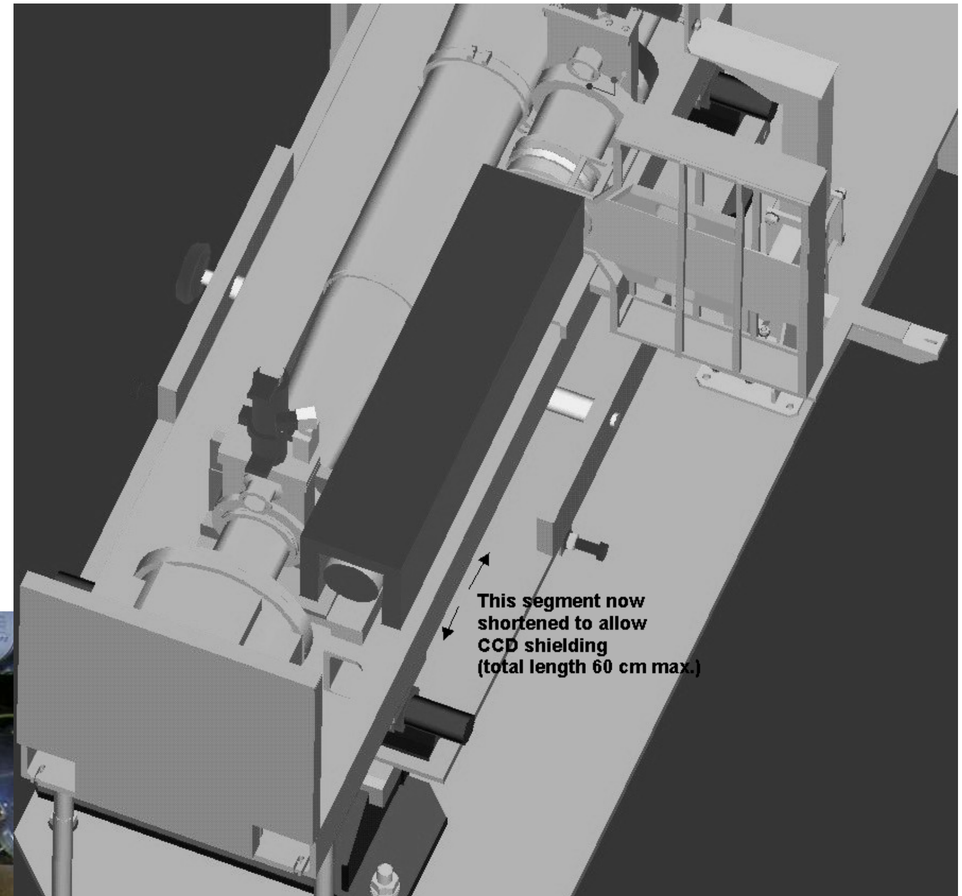
98.8% Signal acceptance for
95% α-background rejection

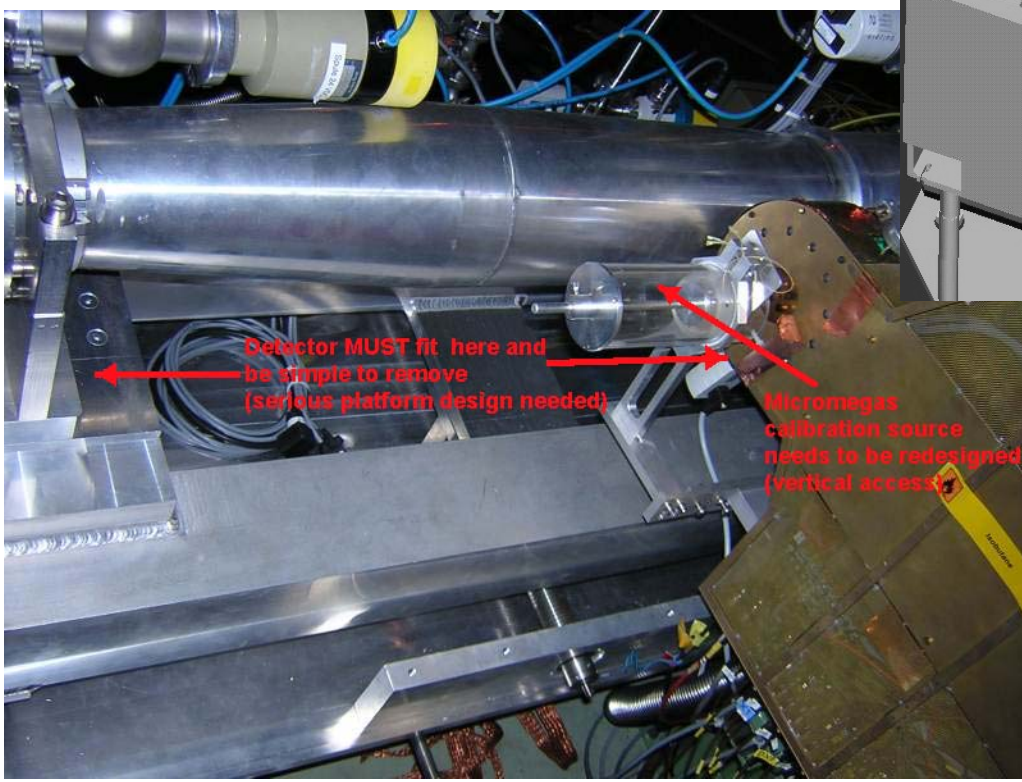
PRELIMINARY:
Background Reduction data



Detector essentially ready for placement as early as this December

(but platform design must be carefully prepared to avoid interference and allow fast removal if needed)





Need exact Micromegas cross-section to determine low-E threshold

(~200-300 keV expected)