

SEARCHING FOR THE X17 USING MAGNETIC SEPARATION



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Australian
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CRICOS PROVIDER #00120C

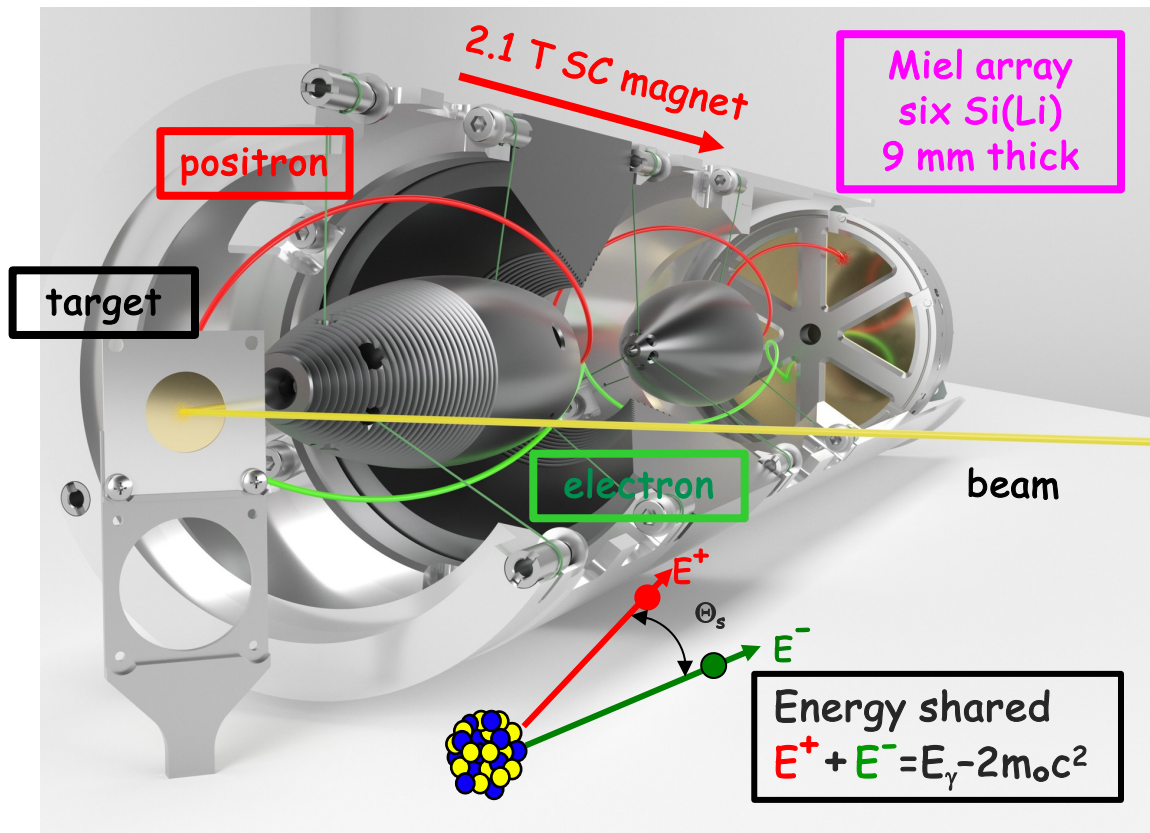
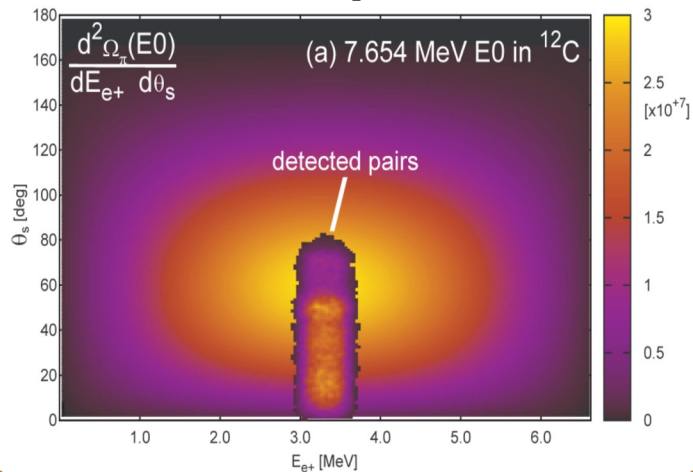
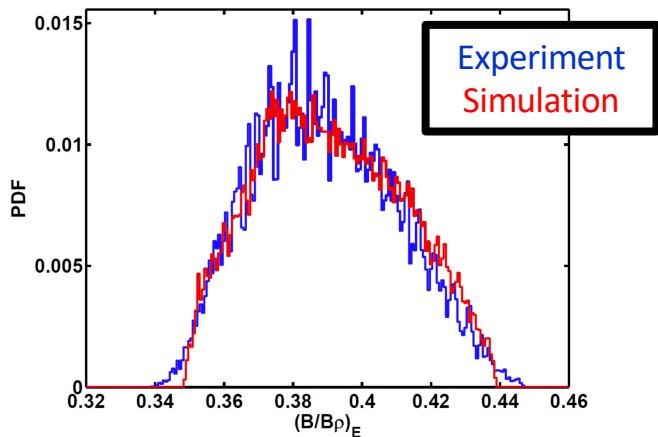
Outline

- ANU Super-e e^+e^- pair spectrometer
- ${}^7\text{Li}(p,\gamma\pi){}^8\text{Be}^*$ with Super-X & 14 MV tandem (ANU, proposal)
- ${}^7\text{Li}(p,\gamma\pi){}^8\text{Be}^*$ with TPC & 5 MV tandem (Univ. Melbourne, proposal, Martin Seviior)



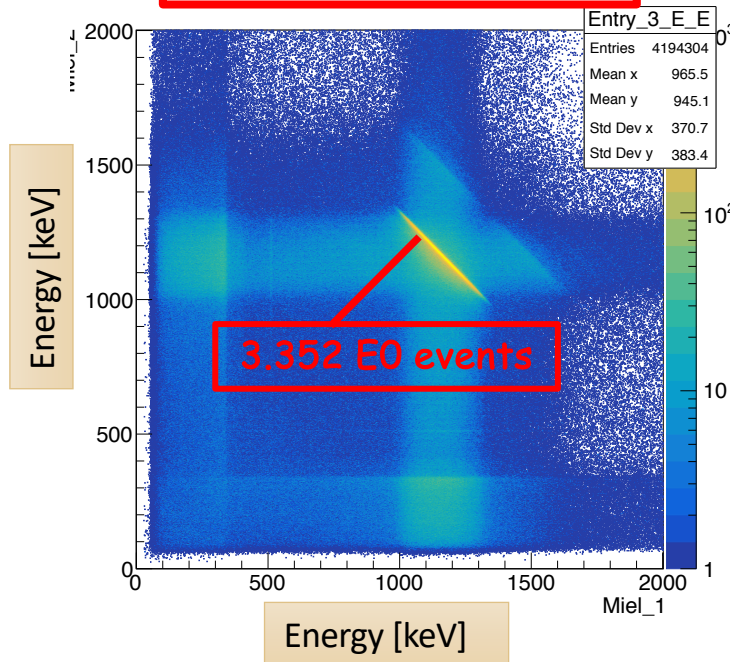
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ANU Super-e pair spectrometer

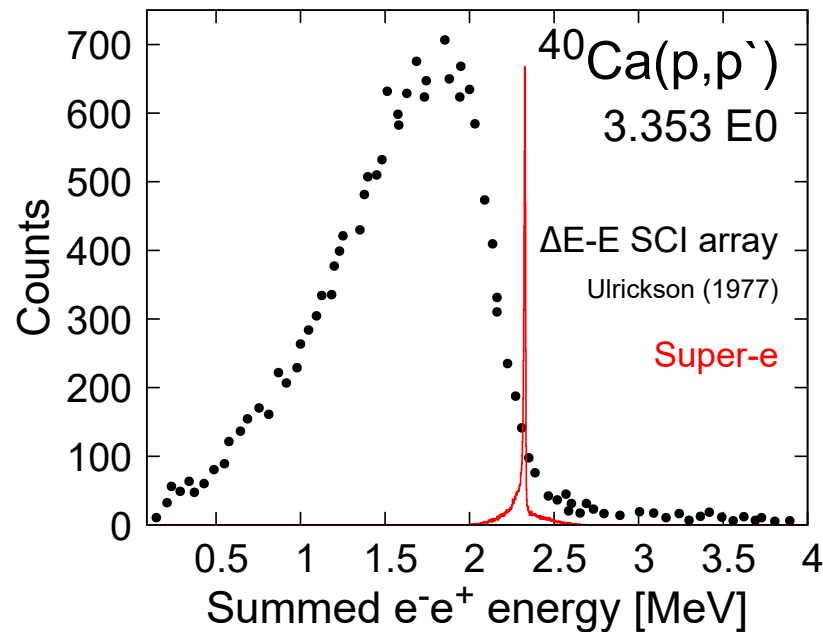


3.353 MeV E0 in ^{40}Ca

Energy vs. Energy matrix
NO gating



Super-e: $E^+ \sim E^-$



M. Ulrickson, et al., PRC15
(1977) 186
2 $\Delta E-E$ scintillator telescopes



5.212 MeV SD to GS EO in ^{40}Ca

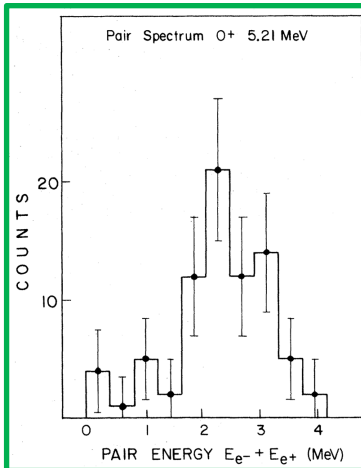
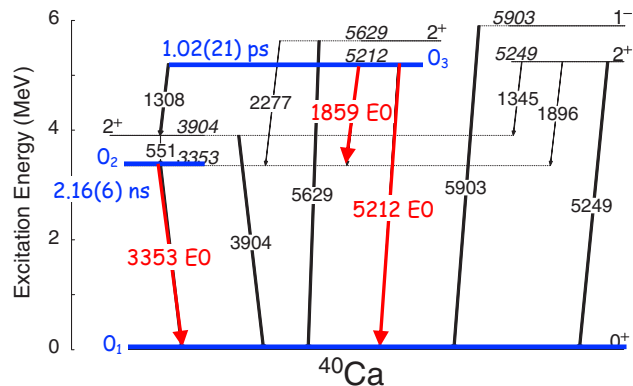
with E. Ideguchi (Osaka)

PHYSICAL REVIEW LETTERS 128, 252501 (2022)

Electric Monopole Transition from the Superdeformed Band in ^{40}Ca

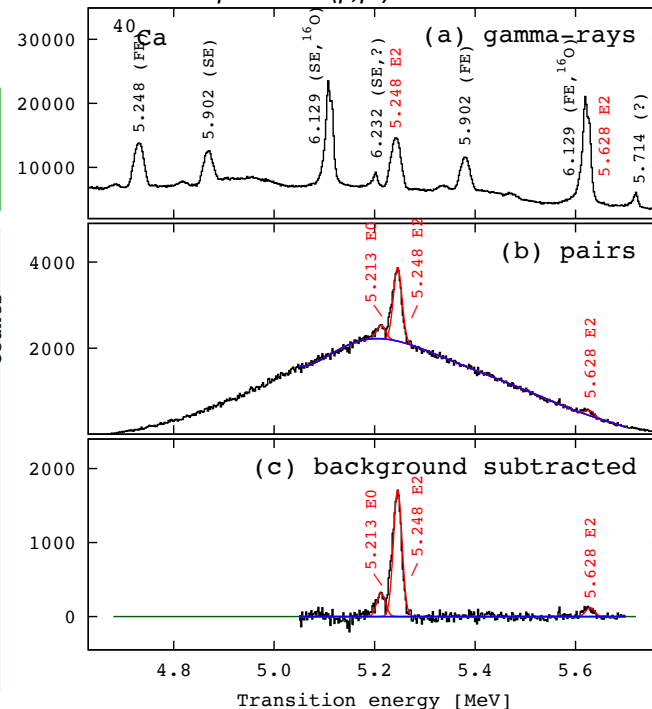
E. Ideguchi (井手口 栄治)^{1,*}, T. Kibédi², J. T. H. Dowie,² T. H. Hoang¹, M. Kumar Raju^{1,3}, N. Aoi (青井 考)¹, A. J. Mitchell², A. E. Stuchbery², N. Shimizu (清水 則孝)^{4,1}, Y. Utsuno (宇都野 穰)^{5,4}, A. Akber², L. J. Bignell², B. J. Coombes², T. K. Eriksen², T. J. Gray², G. J. Lane² and B. P. McCormick²

M. Ulrickson, et al., PRC15 (1977) 186
2 ΔE -E scintillator telescopes



$$10^3 \rho^2(\text{EO}) < 60$$

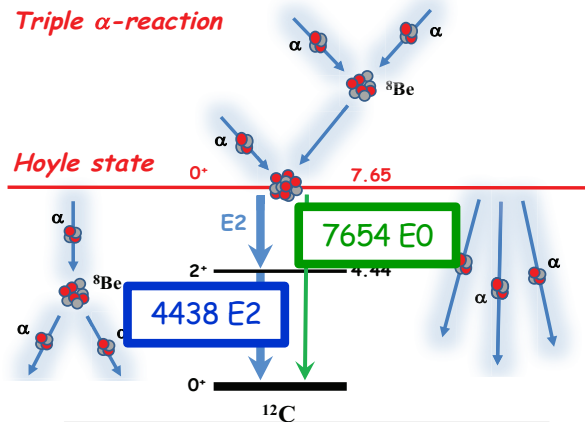
ANU Super-e $^{40}\text{Ca}(p,p')$ at 8.6 MeV



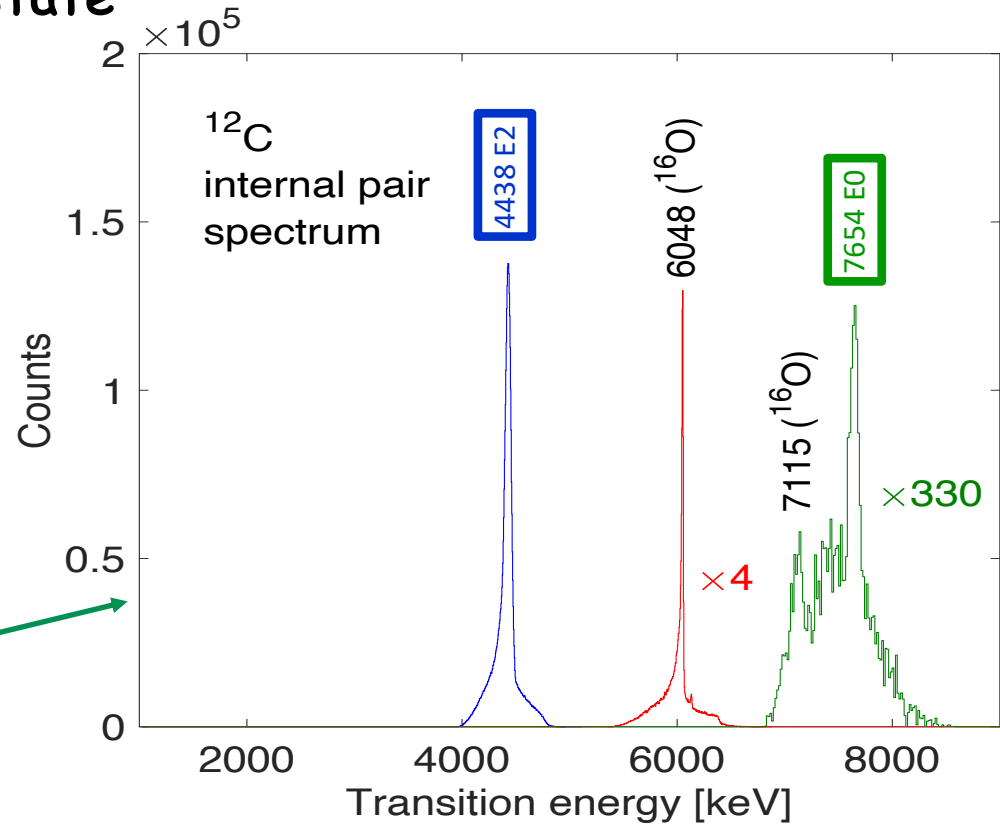
$$10^3 \rho^2(\text{EO}, \text{O}_3 \rightarrow \text{O}_1) = 2.3(5)$$



7.654 MeV E0 from the Hoyle state



3 α rate up by 35%



PHYSICAL REVIEW C **102**, 024320 (2020)

Improved precision on the experimental E0 decay branching ratio of the Hoyle state

T. K. Eriksen,^{1,*} T. Kibédi,^{1,†} M. W. Reed,¹ A. E. Stuchbery,¹ K. J. Cook,^{1,2} A. Akber,¹ B. Alshahrani,^{1,3} A. A. Avaa,^{3,4} K. Banerjee,^{1,3} A. C. Berriman,¹ L. T. Bezzina,¹ L. Bignell,¹ J. Buete,¹ I. P. Carter,¹ B. J. Coombes,¹ J. T. H. Dowie,¹ M. Dasgupta,¹ L. J. Eviatts,^{6,7,8} A. B. Garnsworthy,⁶ M. S. M. Gerathy,¹ T. J. Gray,¹ D. J. Hinde,¹ T. H. Hoang,⁸ S. S. Hota,¹

PHYSICAL REVIEW LETTERS **125**, 182701 (2020)

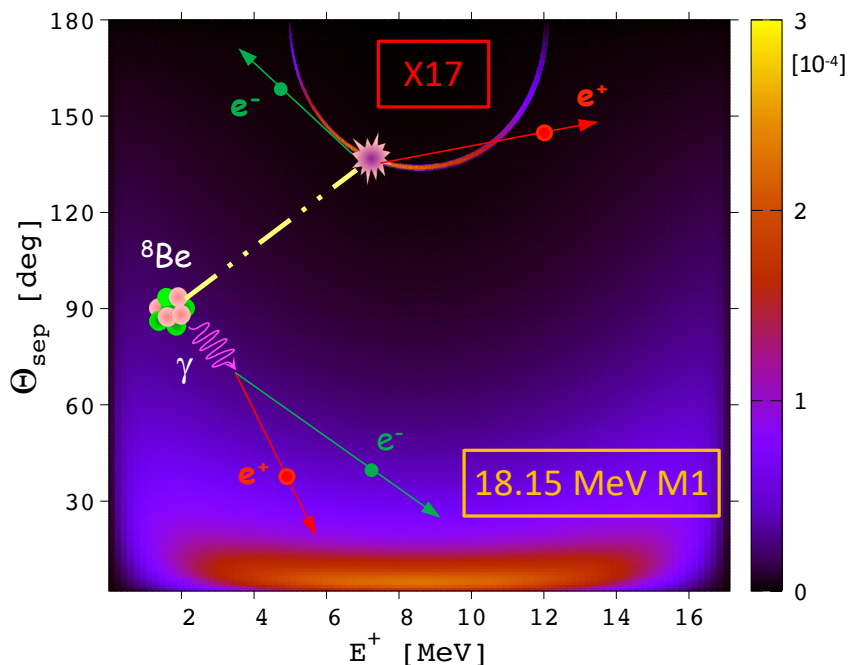
Radiative Width of the Hoyle State from γ -Ray Spectroscopy

T. Kibédi,^{1,†} B. Alshahrani,^{1,2,*} A. E. Stuchbery,¹ A. C. Larsen,³ A. Görgen,³ S. Siem,³ M. Guttormsen,³ F. Giacompo,^{3,†} A. I. Morales,^{4,8} E. Sahin,³ G. M. Tveten,³ F. L. Bello Garrote,³ L. Crespo Campo,³ T. K. Eriksen,³ M. Klintejord,³ S. Maharramova,³ H.-T. Nyhus,³ T. G. Tornyi,^{3,5,†} T. Renström,³ and W. Paulsen³

$$\Gamma_{\text{IPF}}(7.65 \text{ E0})/\Gamma = 7.6(4) \times 10^{-6}$$



Searching for X17 in ${}^7\text{Li}(p,\gamma\pi){}^8\text{Be}^*$



Double differential IPF cross sections
M1: Tim Grey & Jackson Dowie, ANU
X17: Lászlò Sarkadi, ATOMKI

18.15 MeV 1^+ state

- Resonant excitation at $E_p=1.03$ MeV
- $\Gamma=138(6)$ keV

18.15 MeV M1 EM transition

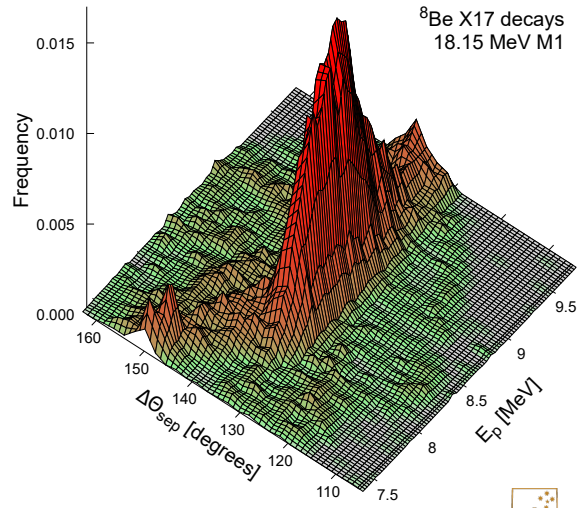
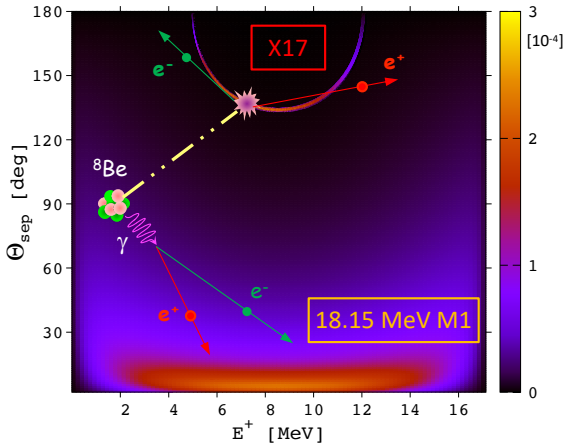
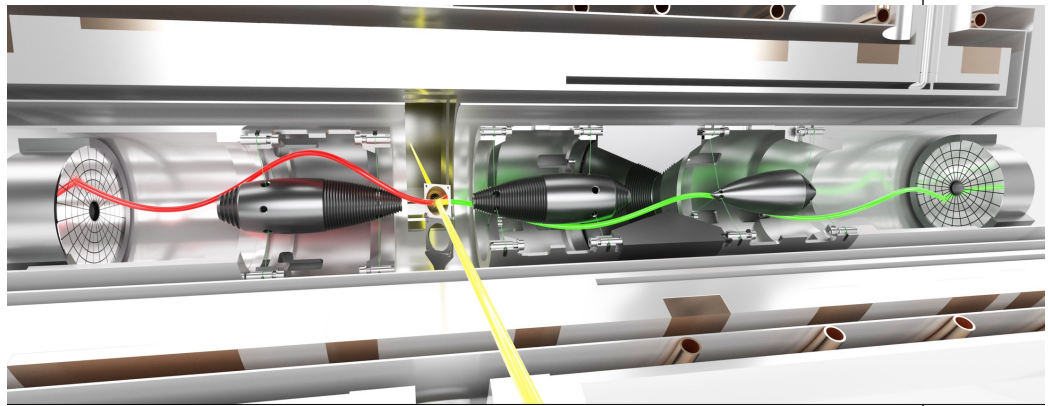
- $\Gamma_\gamma=1.9(4)$ eV, $\Gamma_\gamma/\Gamma=1.5\times 10^{-5}$
- $\Gamma_{\text{IPF}}(\text{M1})/\Gamma_\gamma=3.2\times 10^{-3}$

18.15 MeV M1 X17 decay

- $\Gamma_{\text{IPF}}(\text{X17})/\Gamma_\gamma=5.8\times 10^{-6}$ Krasznahorkay PRL 2016
- Most intensity for $E^+ \sim E^-$ pairs at $\theta_{\text{sep}} \sim 140^\circ$
- 50% of the intensity:
 $E^+ [6.7:10.7]$ MeV; $\pm 23\%$
 $\theta_{\text{sep}} [134^\circ : 140^\circ]$



Searching for X17 in ${}^7\text{Li}(p,\gamma\pi){}^8\text{Be}^*$ - Super-X (ANU)

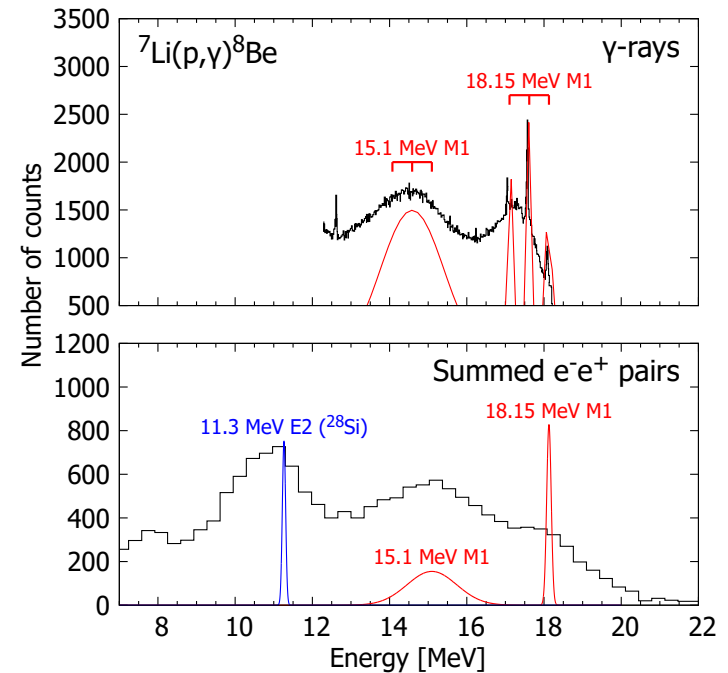
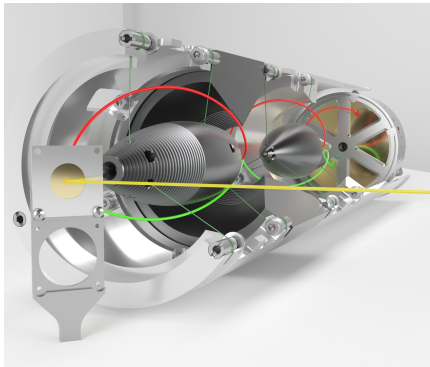


- Twin lens system to accept e^+e^- $110^\circ < \Theta_{sep} < 180^\circ$
- Three double sided DSSD to reconstruct trajectories; $\Delta\Theta_{sep} \sim 6^\circ$
- NaI energy detectors; Si(Li) or hpGe bremsstrahlung?
- 14 UD & energy degrader foil to run at 1.03 MeV resonance energy



${}^7\text{Li}(p,\gamma\pi){}^8\text{Be}^*$ - High resolution pair spectroscopy Super-e (ANU)

- ❑ $E_p=1.03$ MeV, energy degrader foil just before analysing magnet of the 14 UD
- ❑ Super-e pair spectrometer, looking for normal conversion of the 15.1 & 18.15 MeV M1
- ❑ Quantify the contribution of the 21.6 MeV E1 ($\Gamma \approx 4$ MeV)

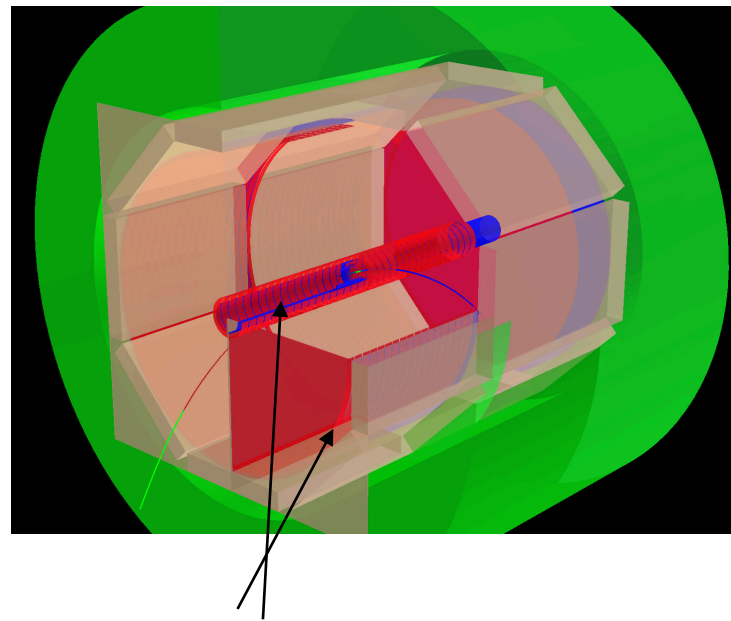
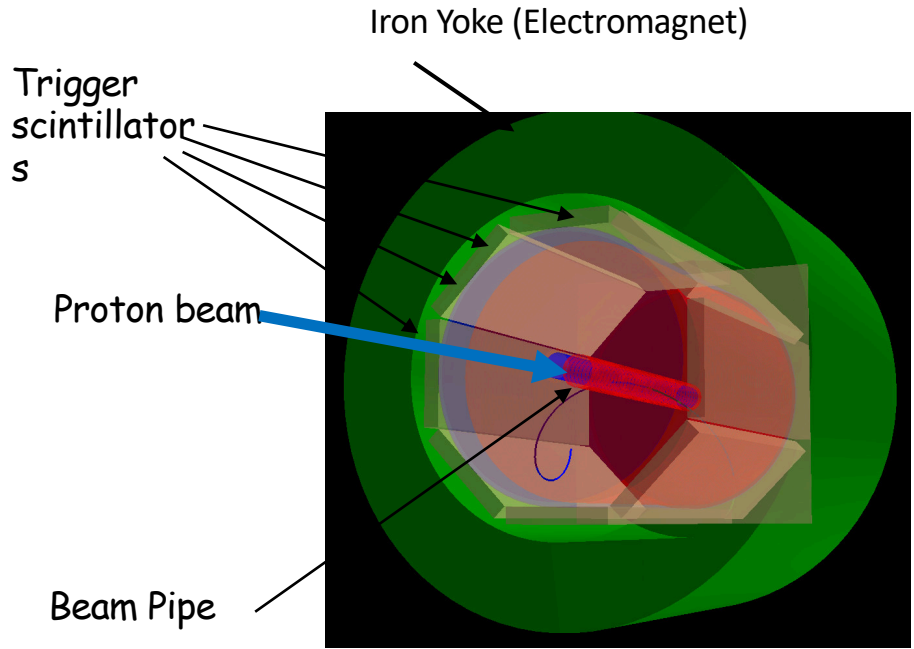


- ❑ Black: Krasznahorkay et al., EPJ Web of Conferences 142, 01019 (2017)
- ❑ red & blue: Simulated gamma and pair spectrum



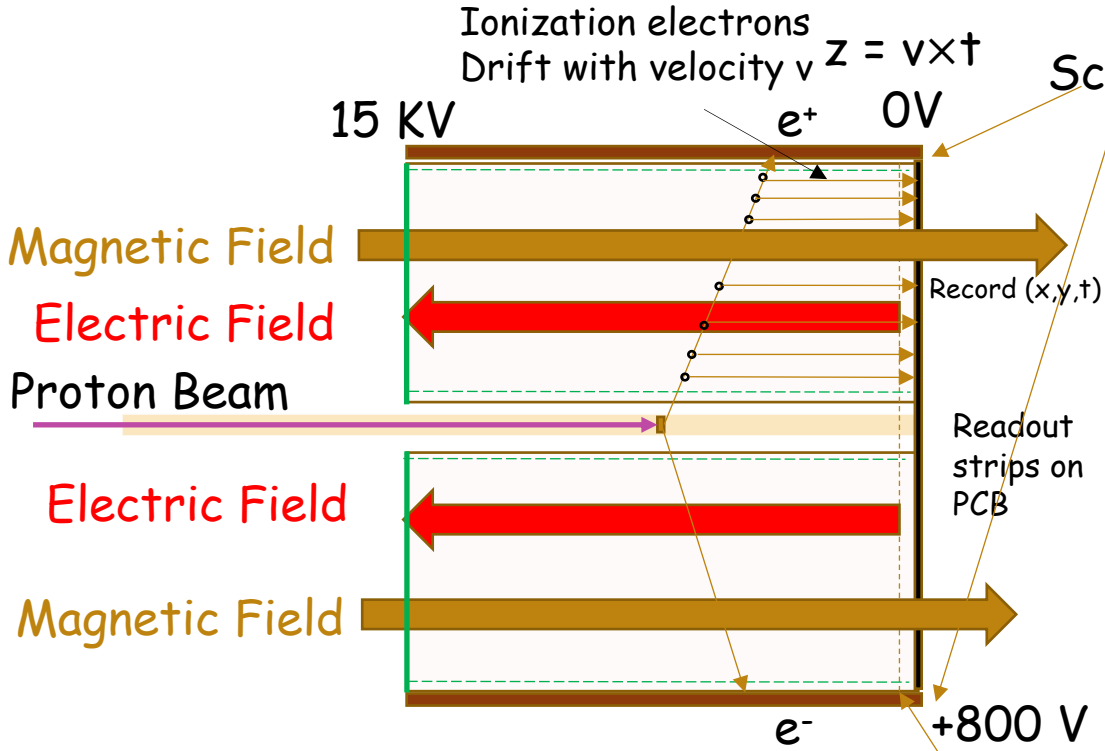
Time Projection Chamber to be installed on 5 MV Pelletron

Univ. Melbourne, details available at Sevir et al. [arXiv:2302.13281](https://arxiv.org/abs/2302.13281))

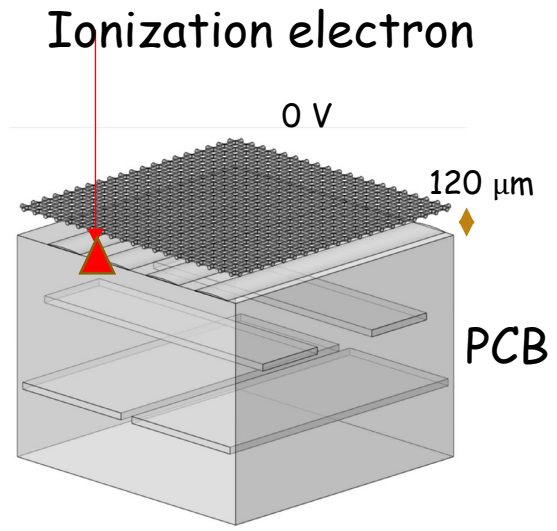


- ❑ 34 cm diam solenoid, up to 0.4 Tesla
 - ❑ 35 cm long active volume He (90%) / CO₂ (10%)
- Electric Field Cage

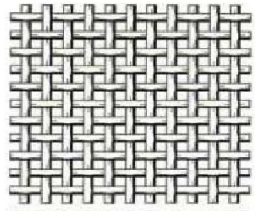




Scintillators



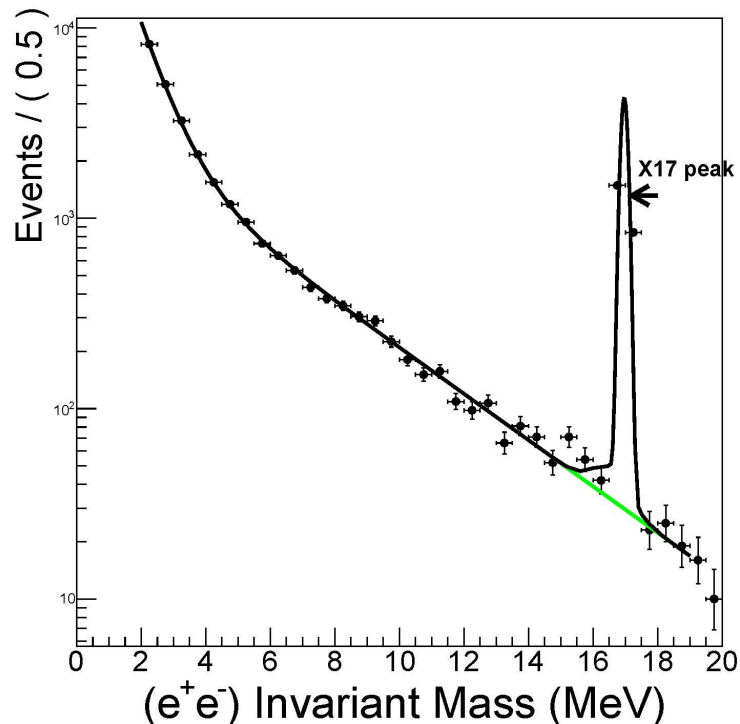
Micromegas wire mesh



Expected performance of the TPC

- ❑ Design based on extensive simulations (*Geant4*, *COMSOL*, *GARFIELD*, *ROOT*, *GenFit*)
- ❑ Full simulation and reconstruction of IPC+X17 with 50 μm Mylar vacuum wall
- ❑ 4 Day run on Pelletron. $2\mu\text{A}$ proton beam, $2 \times 10^{19} / \text{cm}^2$ ${}^7\text{Li}$ target
- ❑ Quantify sensitivity as a function of BR relative to $p + {}^7\text{Li} \rightarrow {}^8\text{Be} + \gamma$
- ❑ ATOMKI found X17 with BR $\sim 6 \times 10^{-6}$ ${}^7\text{Li}(p, \gamma)$ at 6σ

IPC + X17 Log plot



X17 BR= 6×10^{-6} ${}^7\text{Li}(p, \gamma)$
2300(48) events
50 σ significance







HEAVY ION ACCELERATOR FACILITY

