A dilepton spectrometer for the study of giant resonances in nuclei

Pete Jones, iThemba LABS

African Nuclear Physics Conference, Kruger National Park
1-5 July 2019

A dilepton spectrometer for the study of giant resonances in nuclei

- Electric monopole (E0) transitions can occur whenever there is a change in the mean square value of the nuclear radius **$< r^2 >$**

- They can thus occur as a result of the volume oscillations (the *breathing mode*) as well as of the volume conserving changes in the effective radii (the *shape changing mode*)

- Both modes are of primary interest: the former provides information on the fundamental property of nuclear matter: **the nuclear compressibility**; the latter may shed light both on the **dynamics** of the nucleus-nucleus interaction and on the **spectroscopic properties** of nuclei

- Information is scarce on either of the two modes

- Present low energy (<1 MeV) nuclear structure to high energy resonances (>20 MeV)

0^+ States and E0 transitions

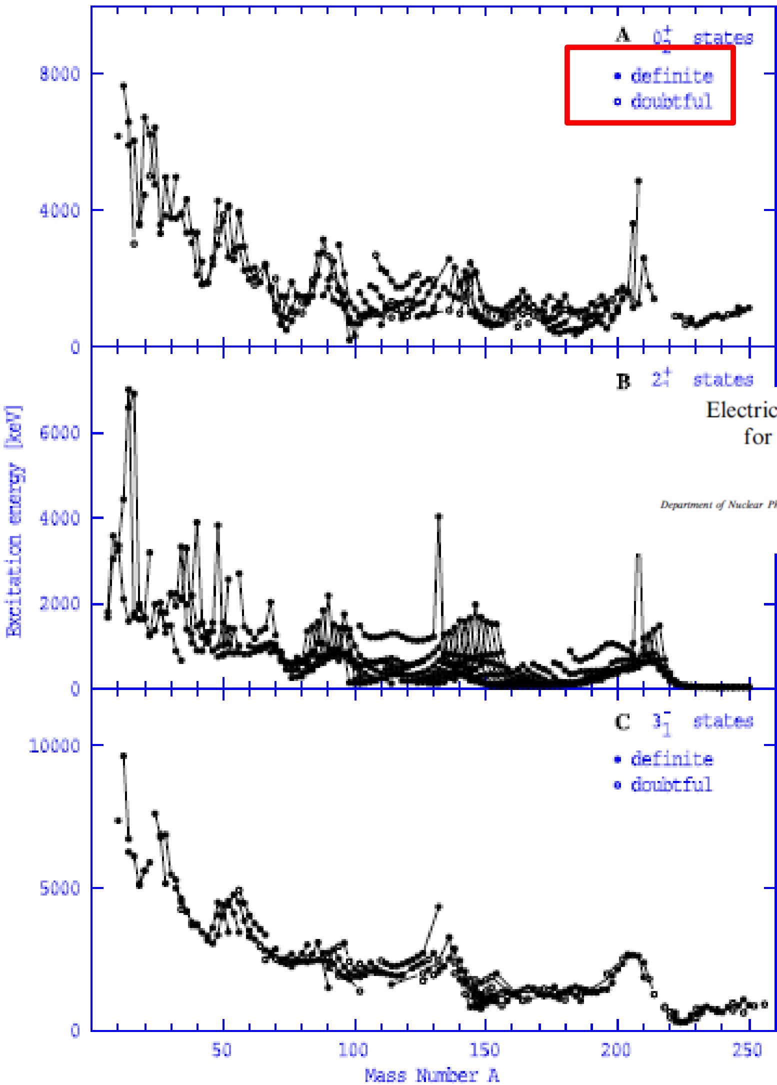

Fig. 1. Excitation energy of the first excited 0^+ (A), 2^+ (B), and 3^- (C) states in even–even nuclides as
isotopes. In order to avoid scale distortion, the 0_2^+ states at 20210 keV in ^{4}He and 20200 keV in ^{8}B

$$X(\mathrm{E0/E2}) \equiv \frac{B(\mathrm{E0})}{B(\mathrm{E2})} = \frac{\rho^2(\mathrm{E0})e^2R^4}{B(\mathrm{E2})}.$$

Electric monopole transitions between 0^+ states
for nuclei throughout the periodic table

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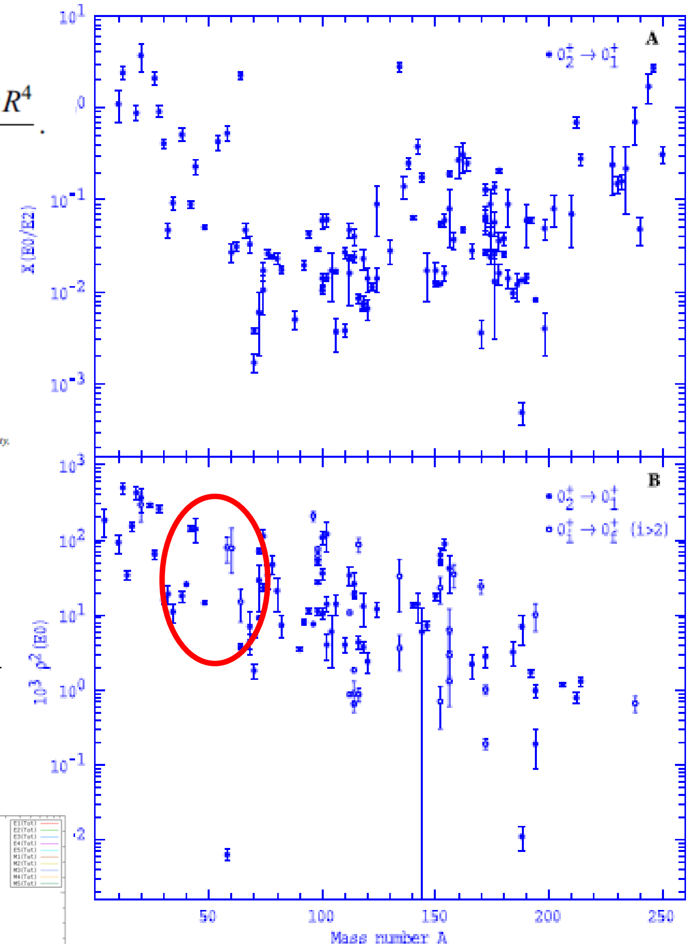
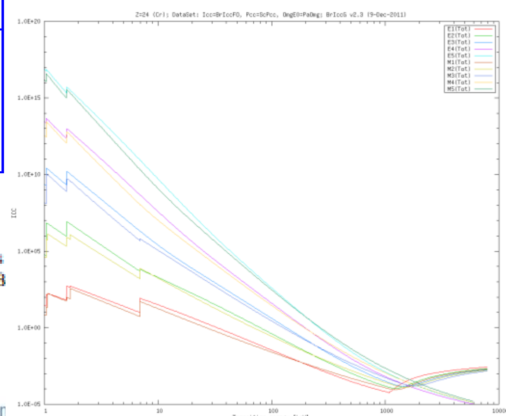
Department of Nuclear Physics, Research School of Physical Sciences and Engineering, The Australian National University, Canberra, ACT 0200, Australia

Available online 5 January 2005

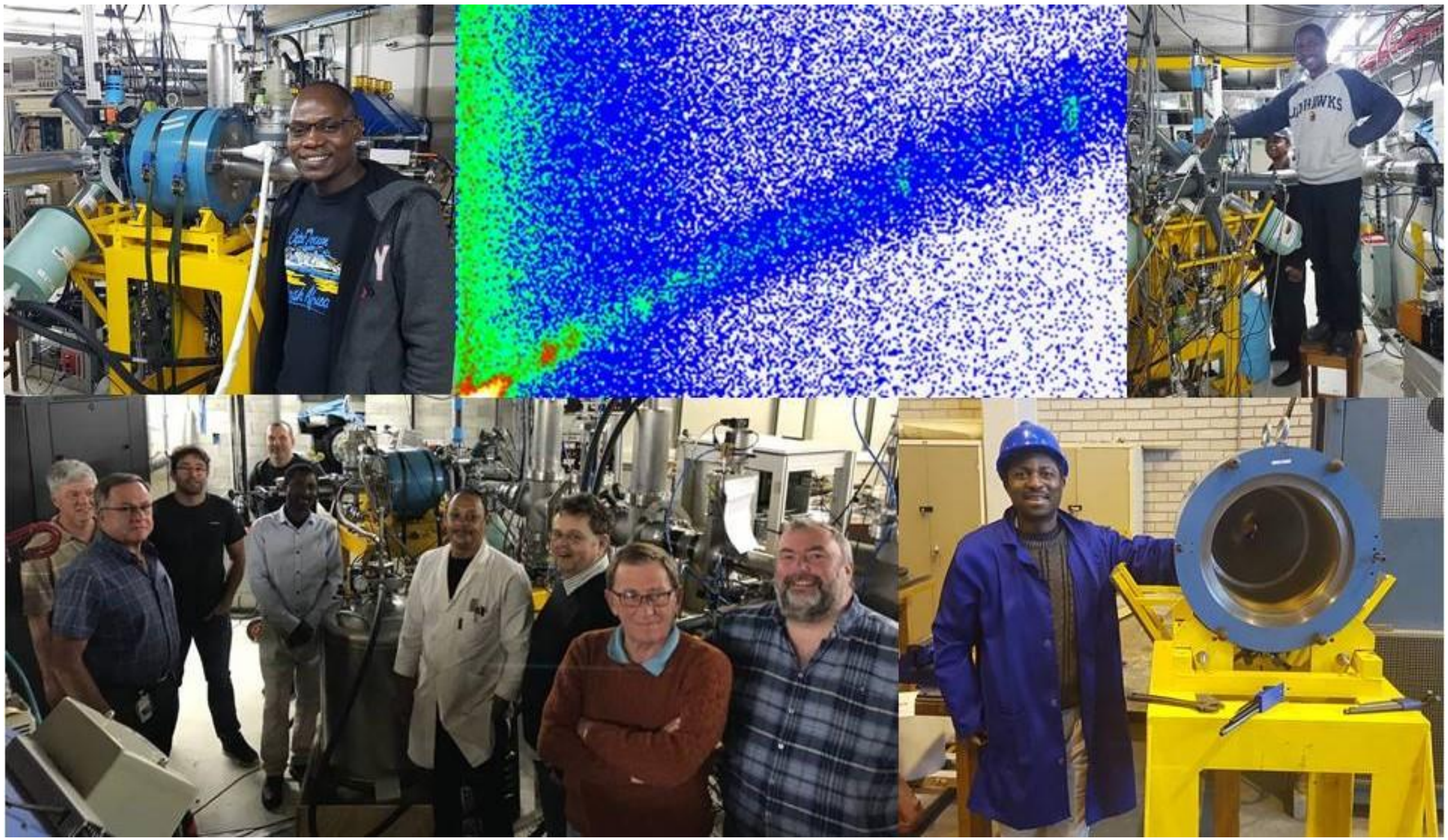
$$\rho(\mathrm{E0}) = \frac{\langle f|M(\mathrm{E0})|i\rangle}{eR^2}$$

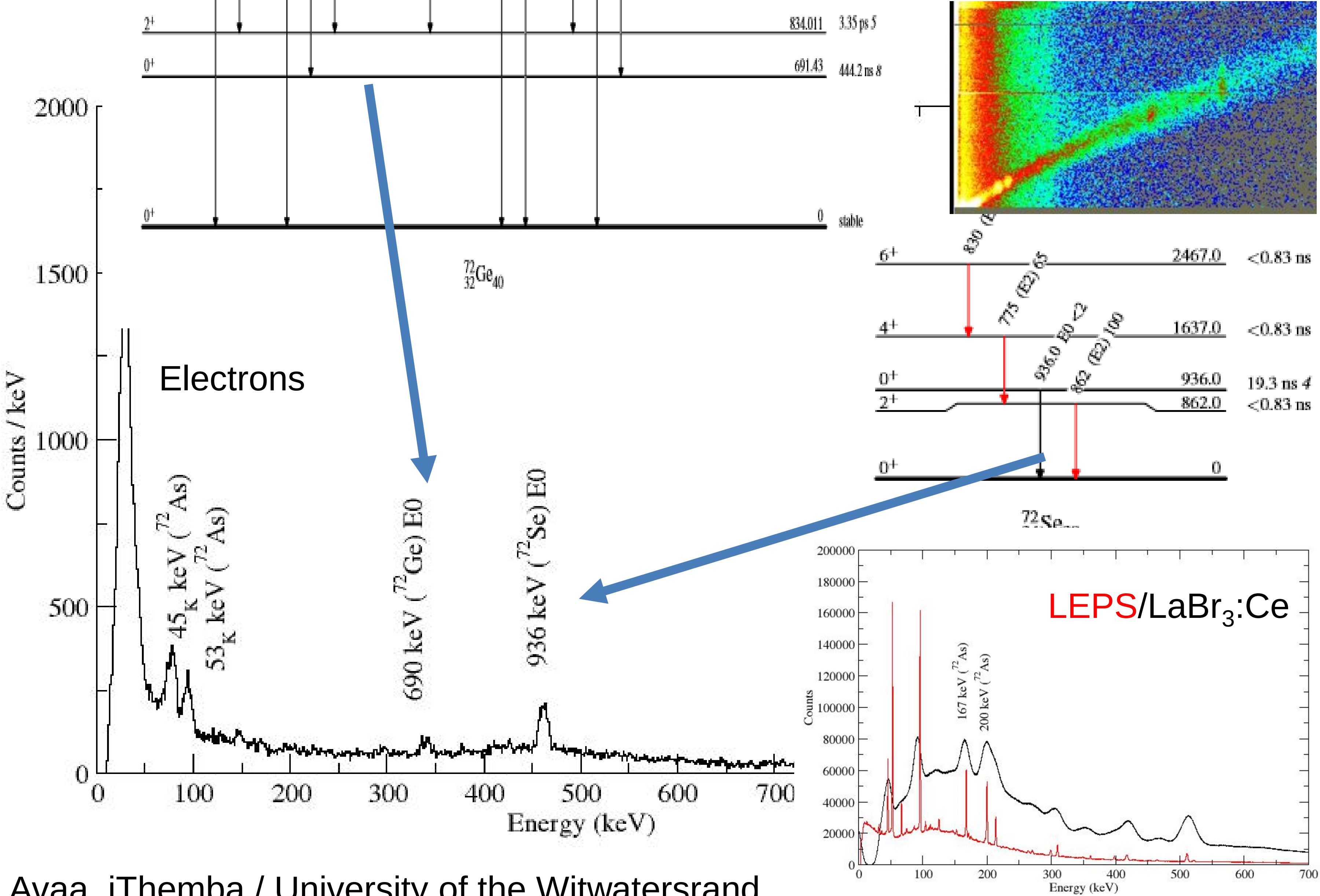


n of mass number A for: (A) X(E0/E2) for $0_2^+ \to 0_1^+$ transitions; and (B) $10^3\rho^2$(E0) for 0
nsitions (open symbols). Transitions for which only limits are known (see Table 1) have
ρ^2(E0) value of 0.66(*16*) $\times 10^{-6}$ in ^{238}U has been omitted.



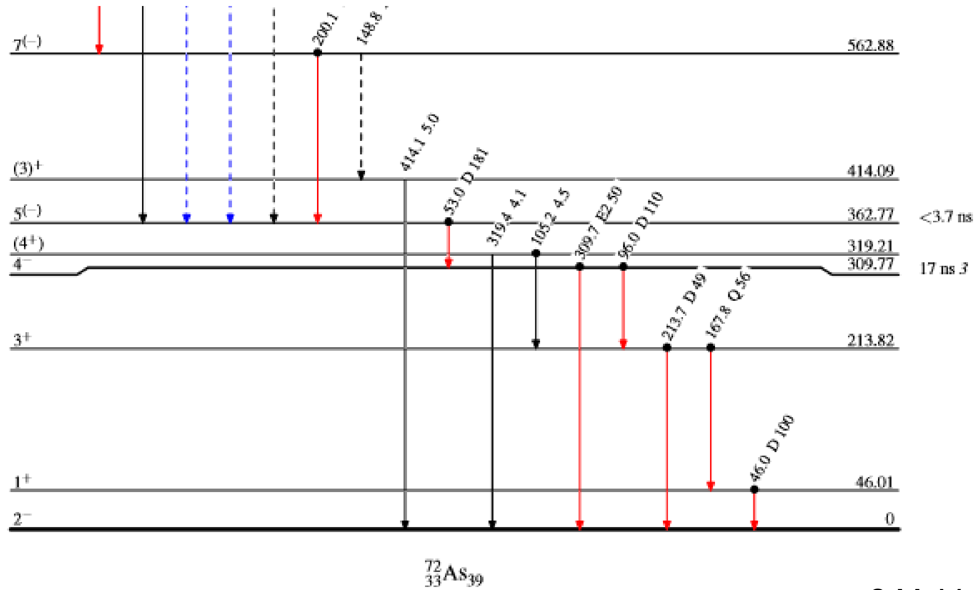
Electric monopole (E0) transitions
^{72}Ge ^{72}Se nuclei - Commissioned October 2018

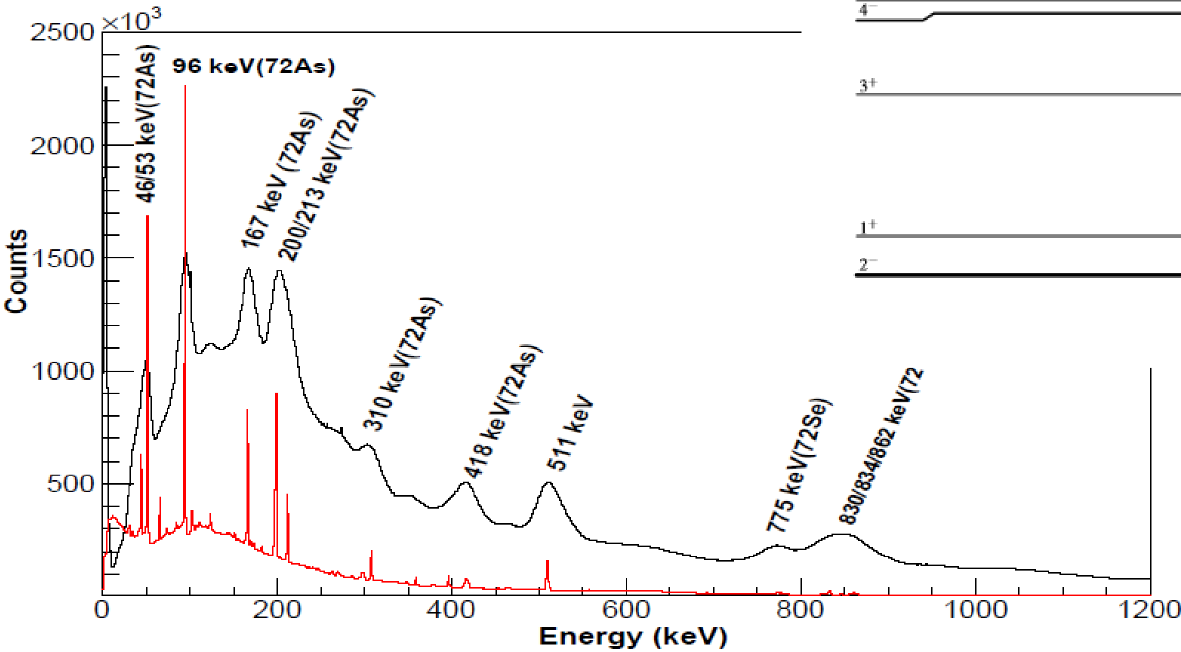


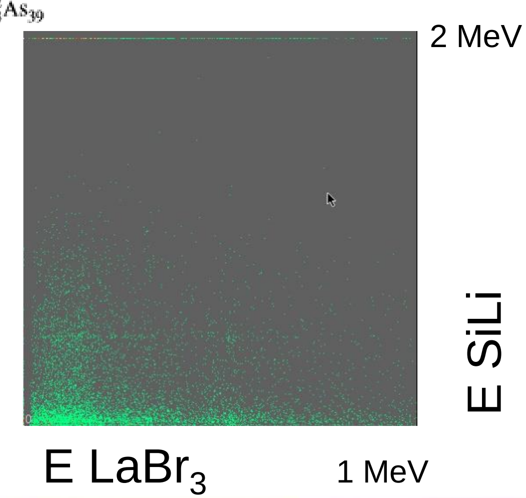


A. Avaa, iThemba / University of the Witwatersrand

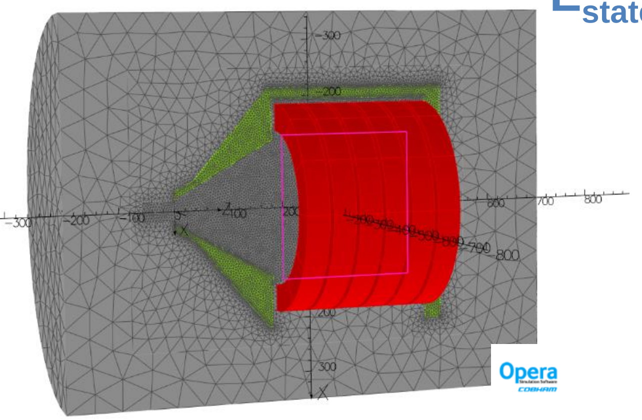
Gamma-rays – or the lack of

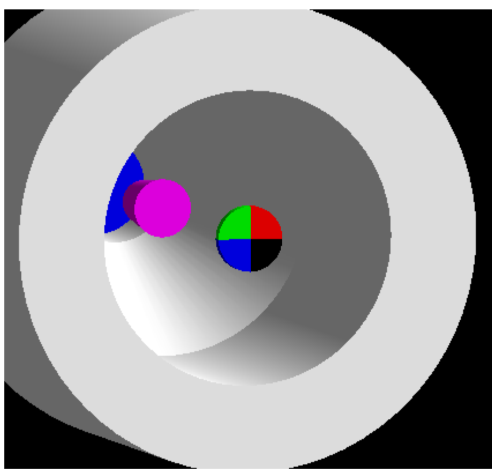


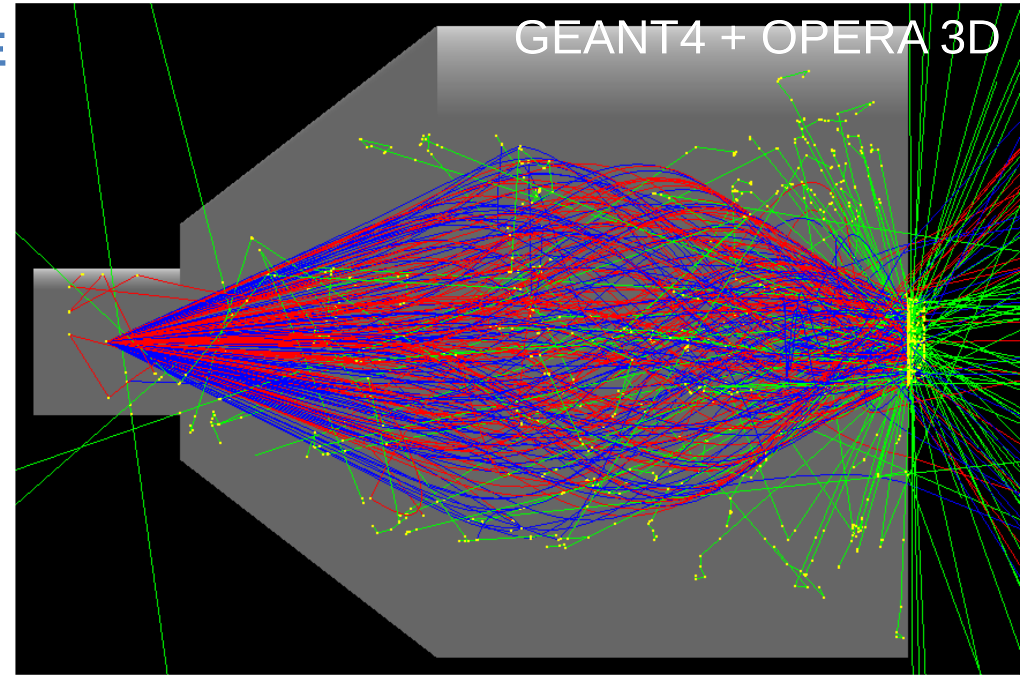


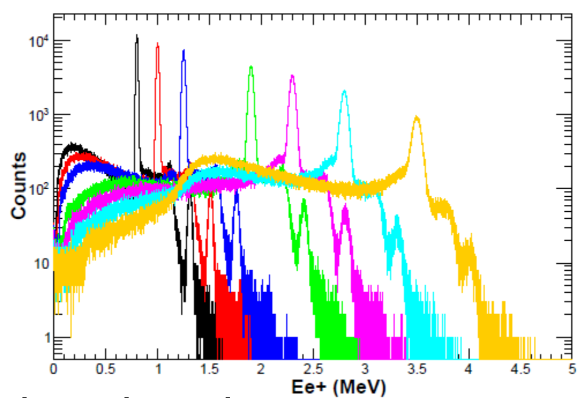


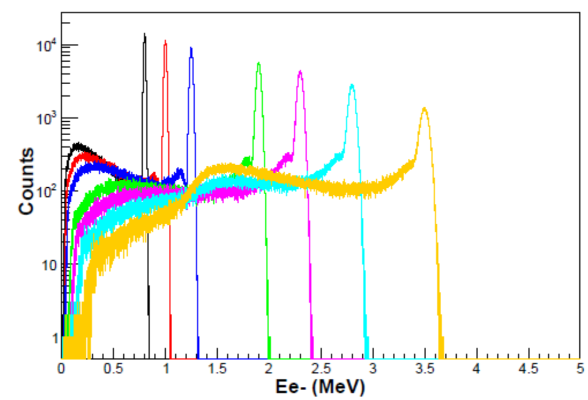
Pair detection, simulation
Low energy E0 – move to higher E
E_{state}<6 MeV







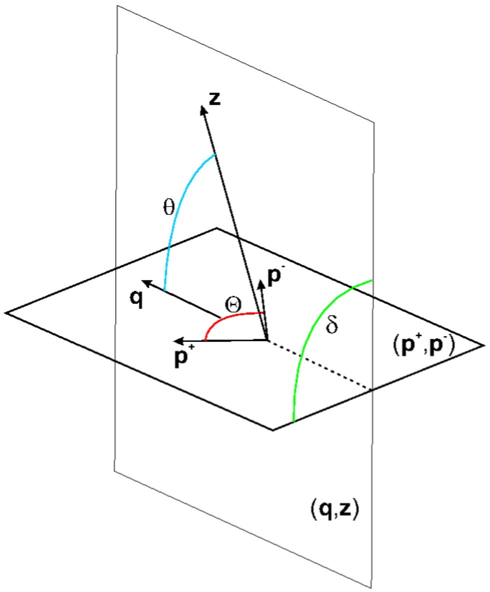




M. Chisapi, iThemba / Stellenbosch University

Internal Pair Formation Basics

Born Approximation



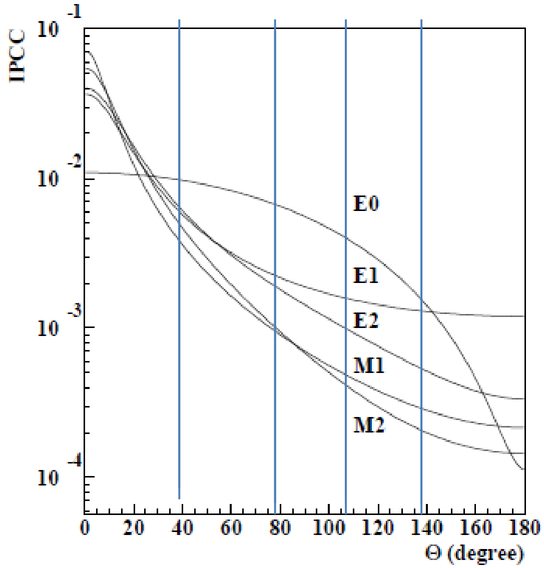
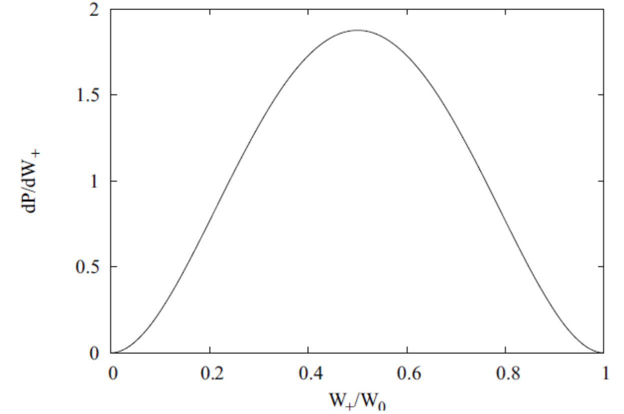
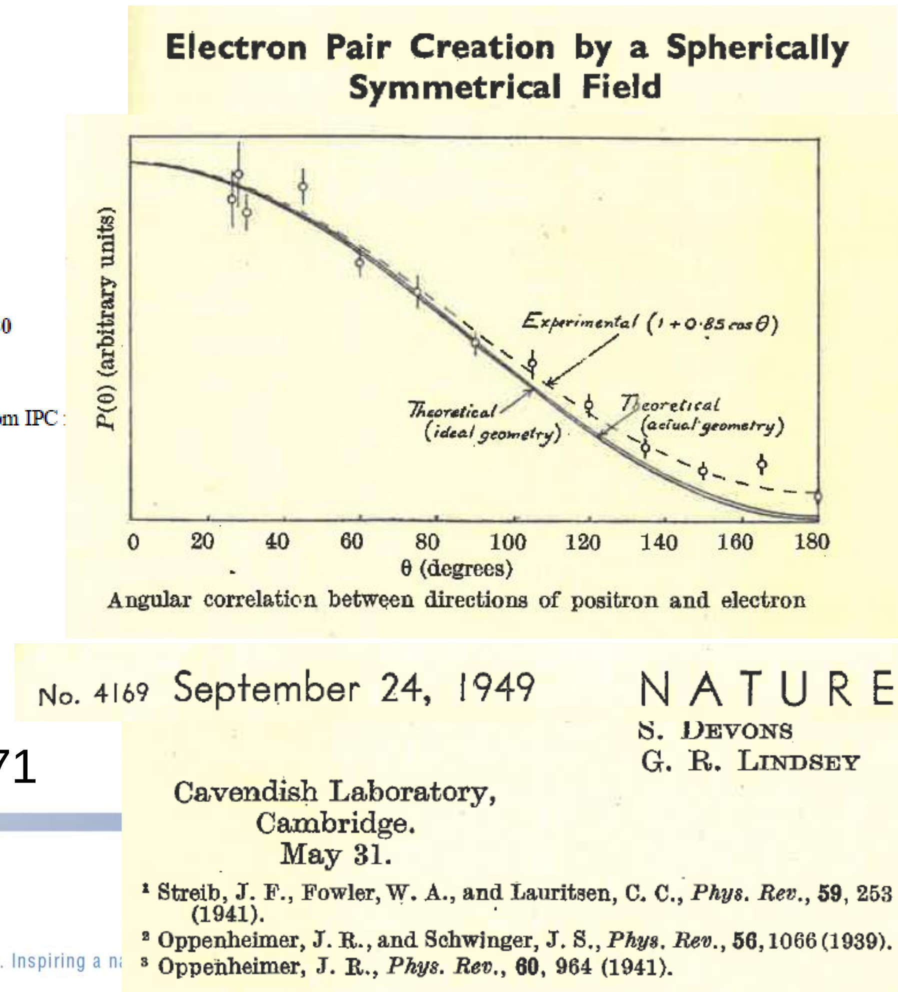


Figure 1: Calculated angular correlations of e^+e^- pairs obtained from IPC : different multipolarities and a transition energy of $E_\gamma = 17$ MeV.




Electron Pair Creation by a Spherically Symmetrical Field

Angular correlation between directions of positron and electron

No. 4169 September 24, 1949 NATURE

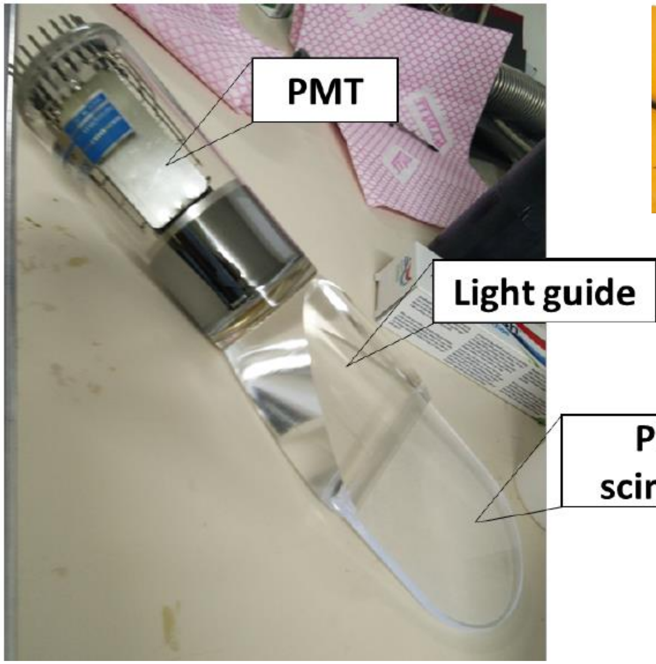
S. Devons
G. R. Lindsey

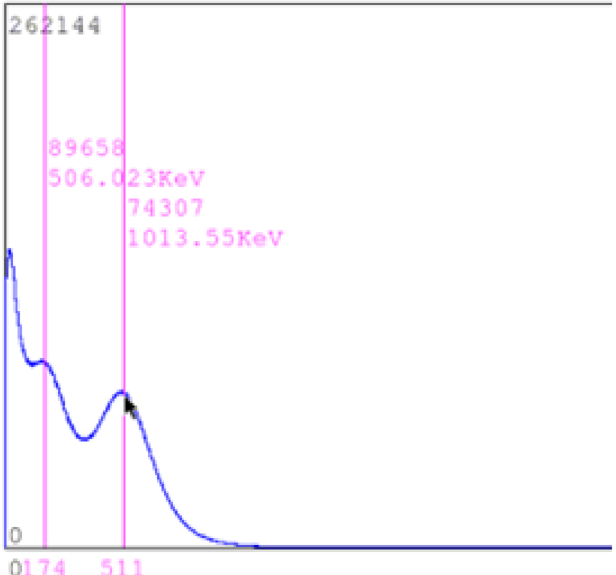
Cavendish Laboratory,
Cambridge.
May 31.

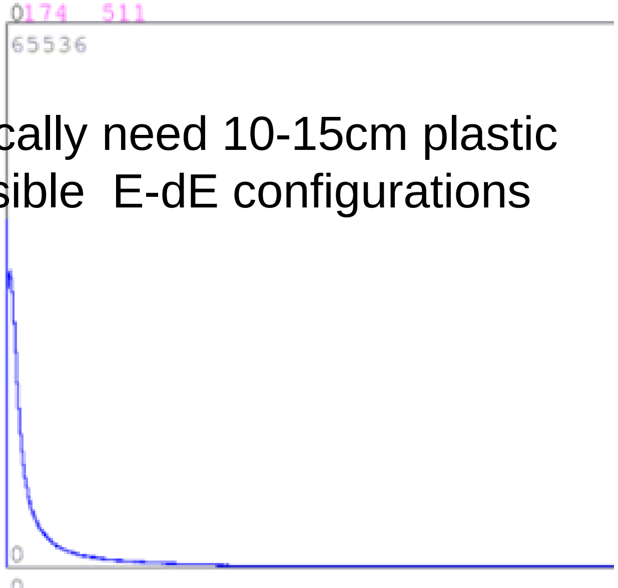
[1] Streib, J. F., Fowler, W. A., and Lauritsen, C. C., *Phys. Rev.*, **59**, 253 (1941).
[2] Oppenheimer, J. R., and Schwinger, J. S., *Phys. Rev.*, **56**, 1066 (1939).
[3] Oppenheimer, J. R., *Phys. Rev.*, **60**, 964 (1941).

L. Guerro et al., Eur. Phys. J. A (2014) **50**: 171

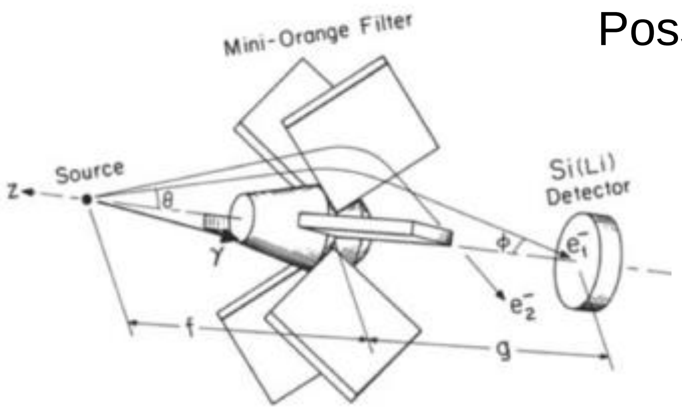
Detector Progress – Magnetic transporter





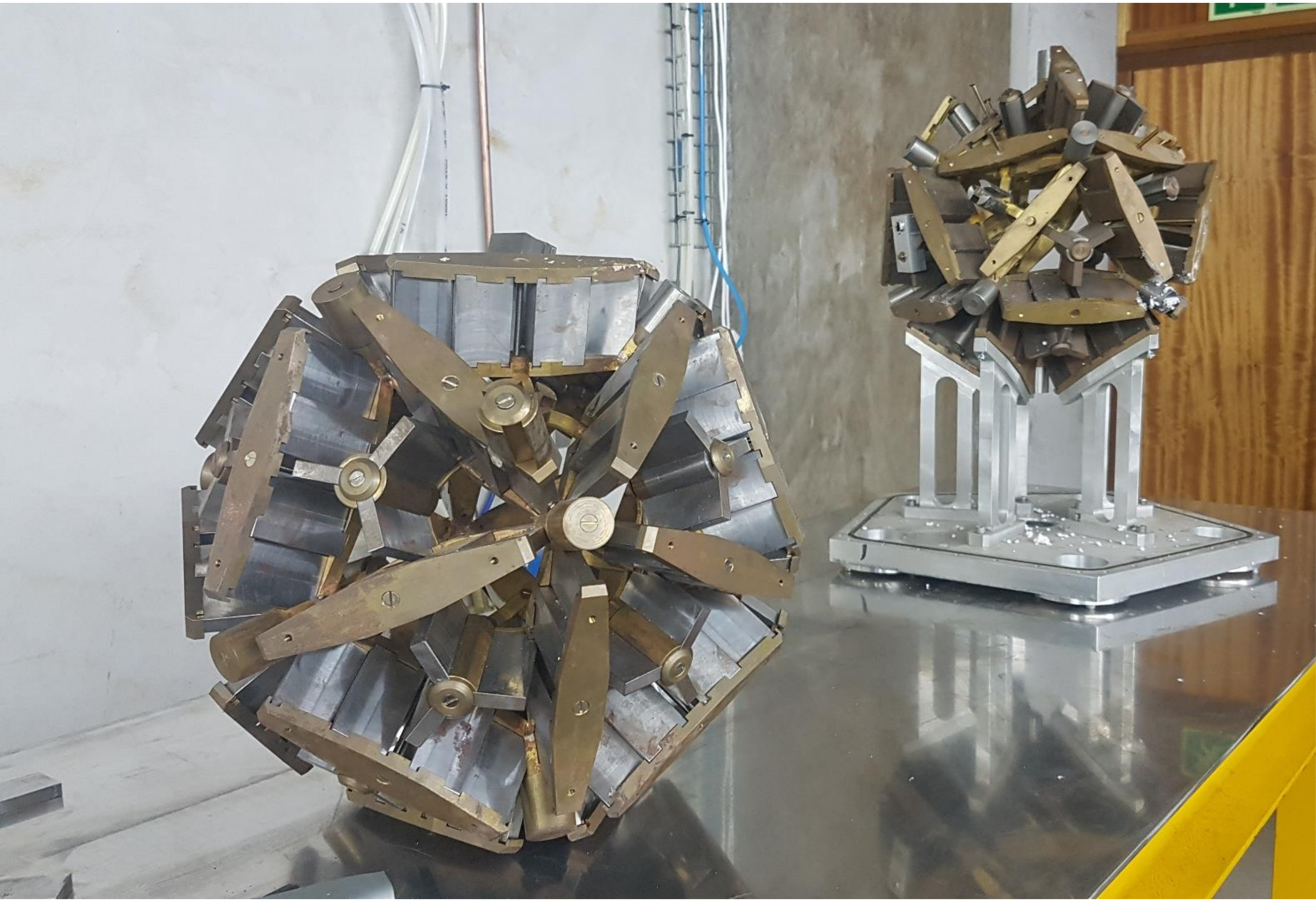


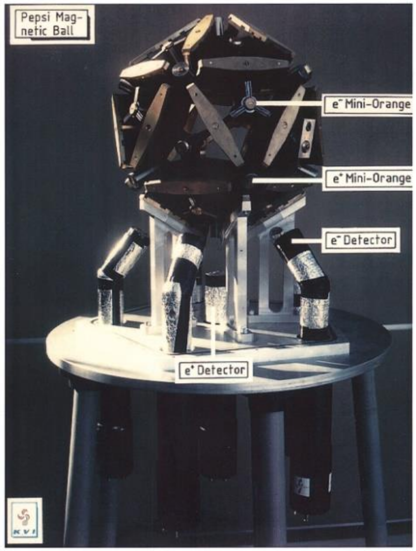
Typically need 10-15cm plastic
Possible E-dE configurations

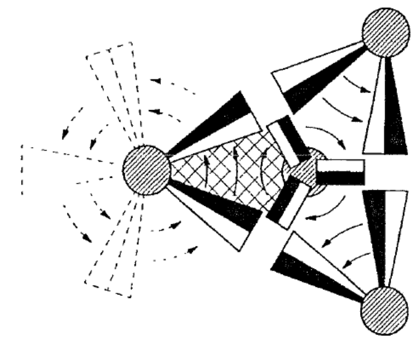


D. Kenfack-Jiotsa, iThemba / Stellenbosch University

PEPSI at iThemba LABS



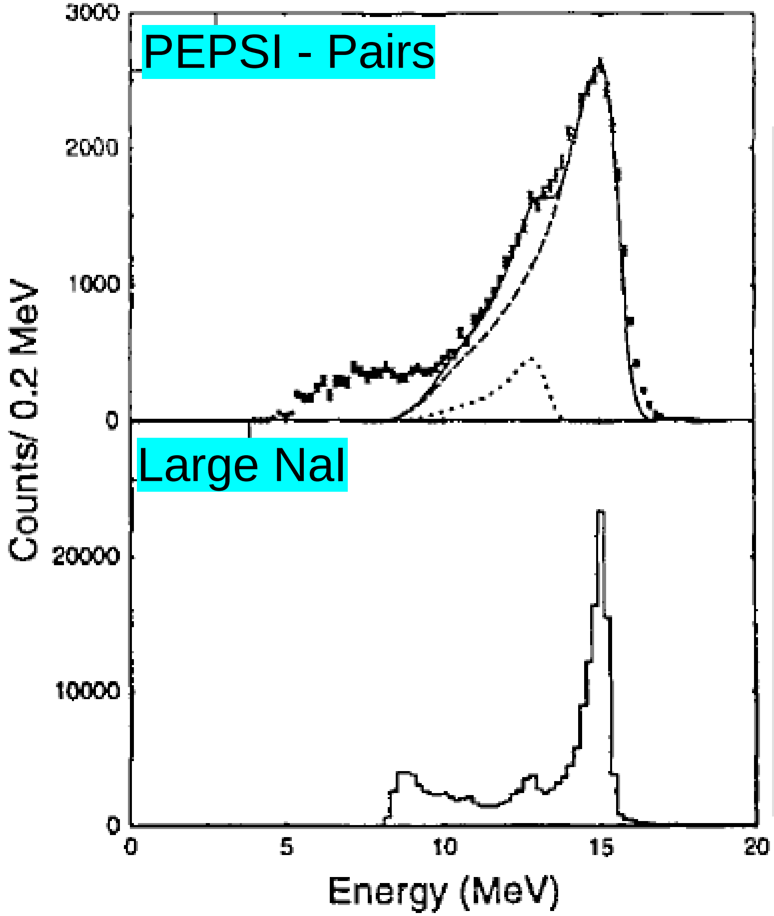




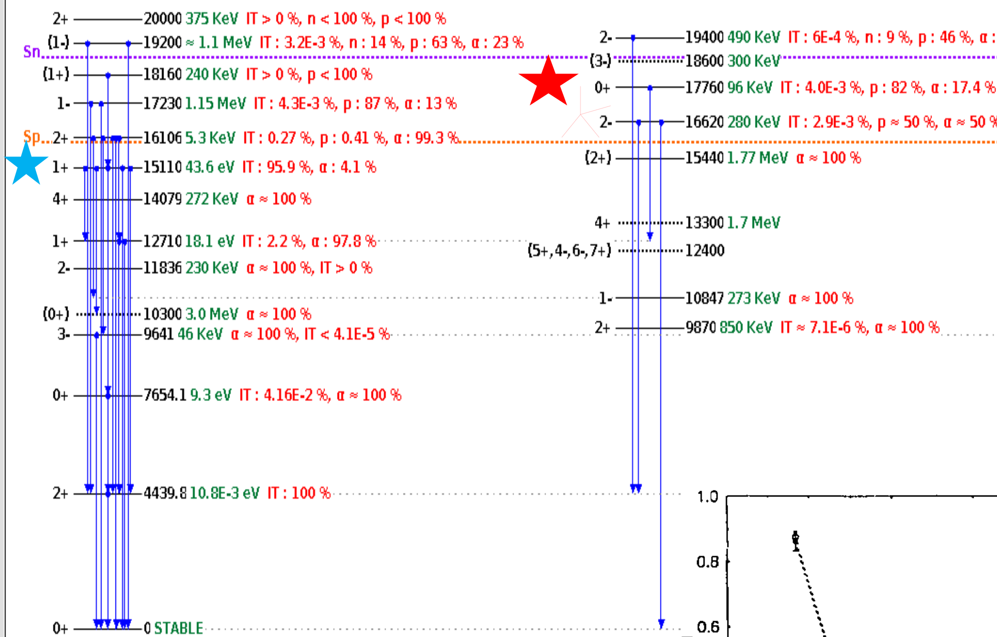
A. Buda, Nucl. Instr. Method. A335 (1993) 479

12 Positron
20 Electron “mini-oranges”

^{12}C Measurements

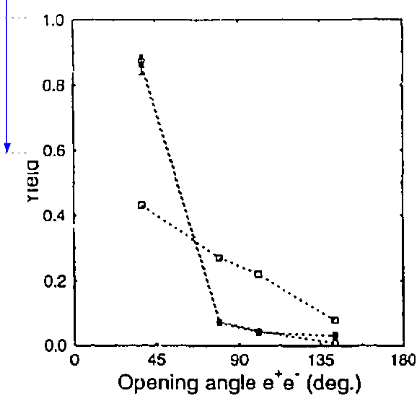


A. Buda, Nucl. Instr. Method. A335 (1993) 479



$\alpha_K = 3.3(5)\times10^{-3}$

$\alpha_K = 3.3\times10^{-3}$ (Born approx.)



- ★ First experiment : ^{12}C via (p,p') reaction to populate 1^+ state at 15.1 MeV
- ★ Also third excited 0^+ at 17.8 MeV achievable (α,α') – measure this at 0º

σ~8.2mb

^{28}Si

^{58}Ni

Dilepton Yields at Low Angles

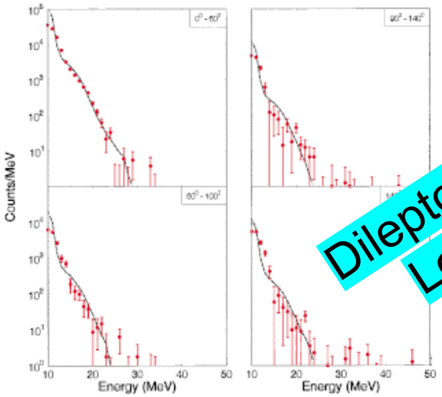


Fig. 2. Dilepton yield measurements for ^{28}Si populated at 50 MeV excitation energy. The four plots correspond to dilepton opening angle ranges of 0°–60°; 60°–100°; 90°–140° and 140°–180°. The dashed line represents the concurrently measured photon yield multiplied by the internal pair conversion coefficient.

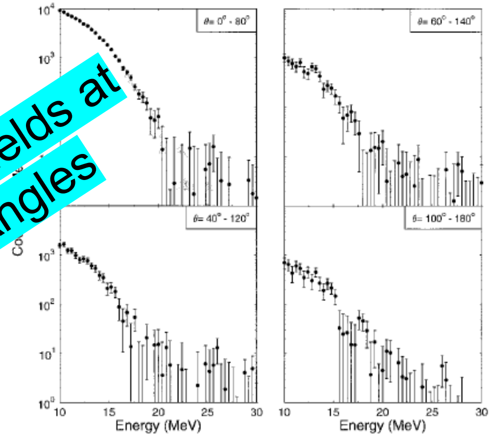
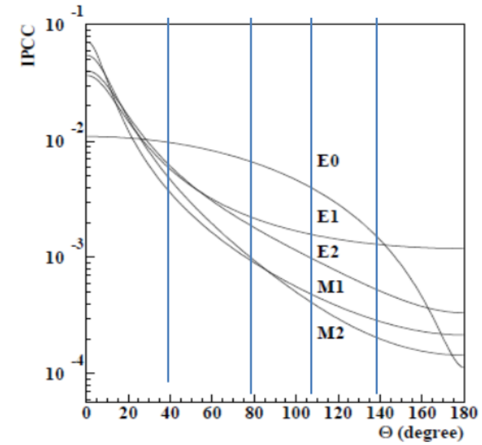


Fig. 4. Dilepton yield measurements for ^{56}Ni populated at 70 MeV excitation energy. The four plots correspond to dilepton opening angles of 0°–80°; 40°–120°; 60°–140° and 100°–180°. The shaded region represents the concurrently measured photon yield multiplied by the internal pair conversion coefficient.



Dilepton Excesses

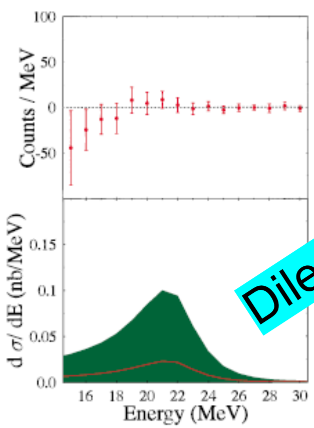


Fig. 3. Top: Dilepton-excess yield measurements for ^{28}Si populated at 50 MeV. Bottom: Cascade analysis of the maximum monopole strength (shaded area) consistent with one standard deviation from the best fit value (solid line).

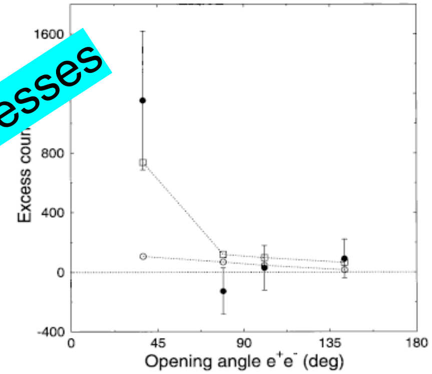
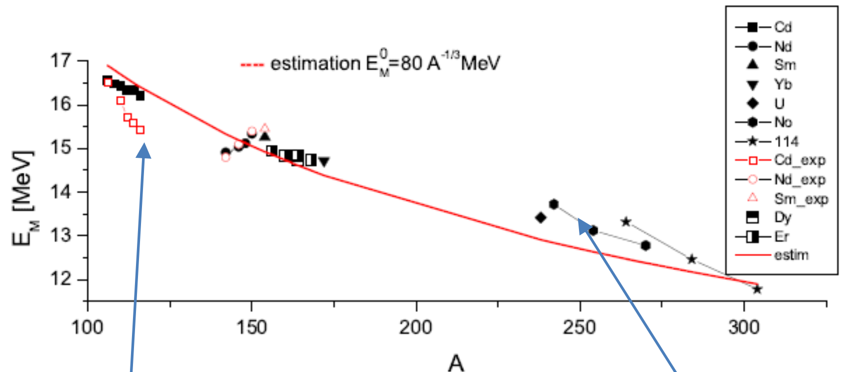


Fig. 5. Dilepton-excess opening angle distribution measurements for ^{56}Ni populated at 70 MeV (filled dots). Open symbols, show the multipole decomposition of the measured yields assuming that both monopole (open dots) and dipole (open squares) components are present.



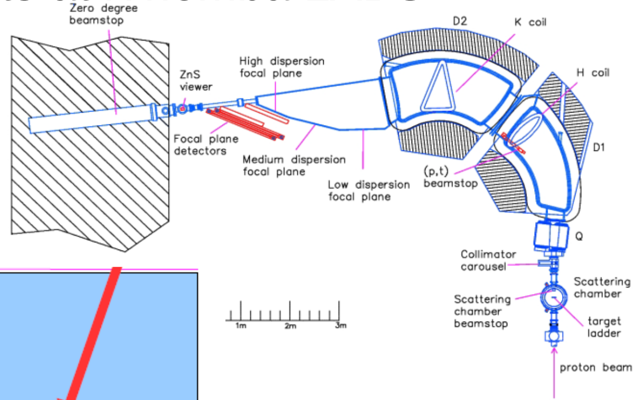
Dependence on calculated ISGMR energies (black filled) experimental (red open)

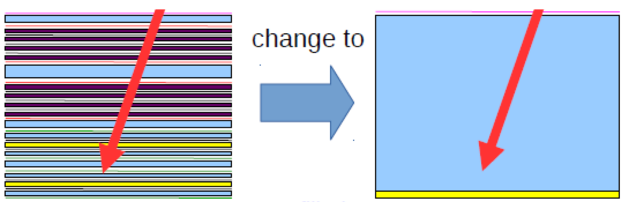
Going forward…

- Simulations
- Magnets
- Detector instrumentation – upgrades

- Measurements ^{58}Ni, ^{40}Ca even ^{16}O

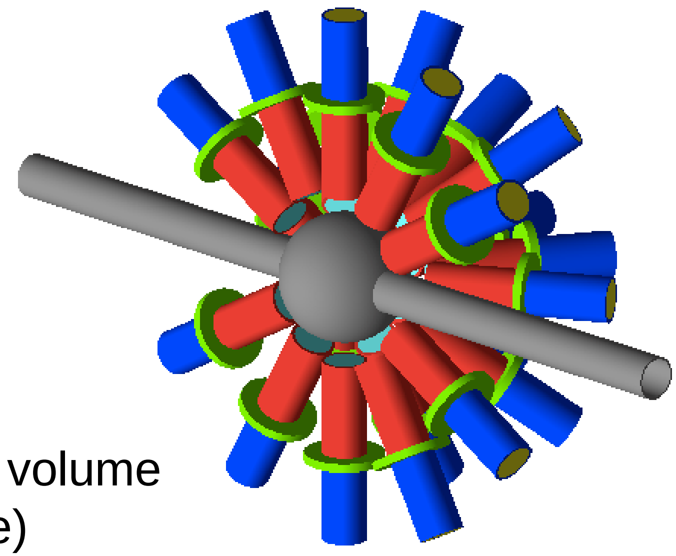
- ^{208}Pb measurements at iThemba LABS





⇒ gas filled
⇒ operates at low pressure (~20 mbar)
⇒ no wires, HV plane at the top/bottom
⇒ electrons drift vertically ⇒ TPC-like
⇒ position determined from cathode pads

See R. Neveling (next talk)



ALBA (23 large volume $LaBr_3$:Ce)

In summary…

- Need for understanding the nature of modes of nuclear L=0 states; *breathing* or *shape changing / coexistence*

- Electron spectroscopy theme ongoing at iThemba LABS, capacity development, research enhancements, look out !

- Study of 0^+ states through internal-pair formation

- Dilepton spectrometer PEPSI to be commissioned with K600 spectrometer in 0^o mode

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