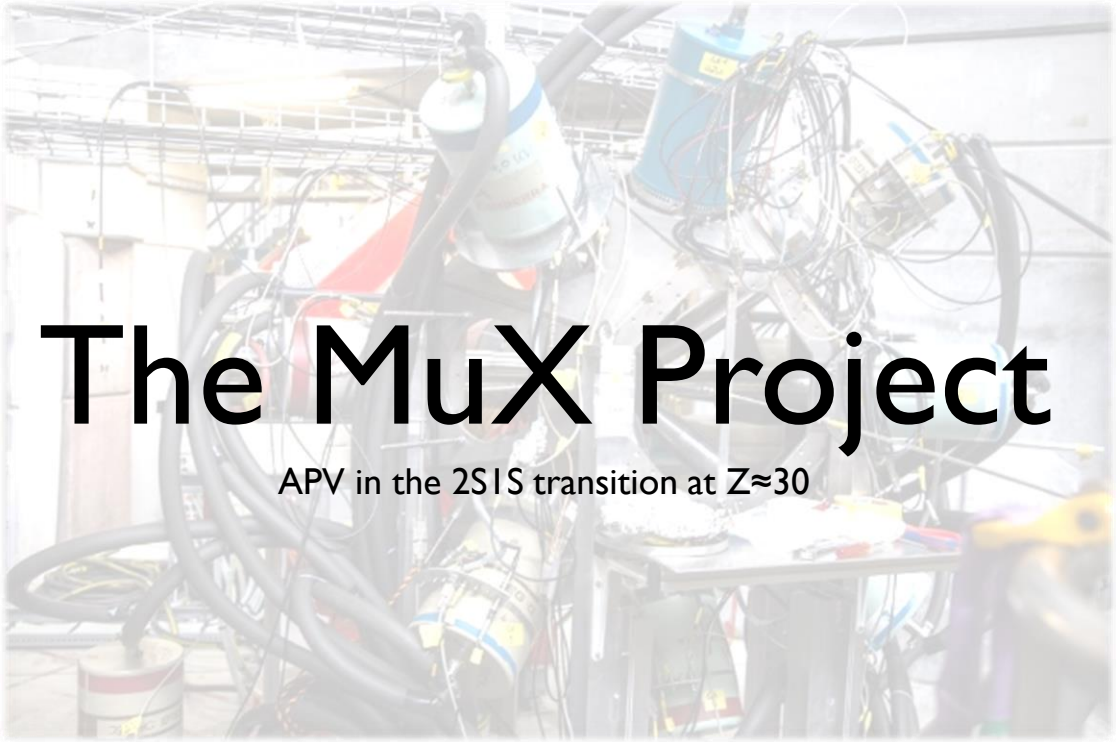
PAUL SCHERRER INSTITUT

PSI

DFG Deutsche Forschungsgemeinschaft



The MuX Project

APV in the 2S1S transition at Z≈30

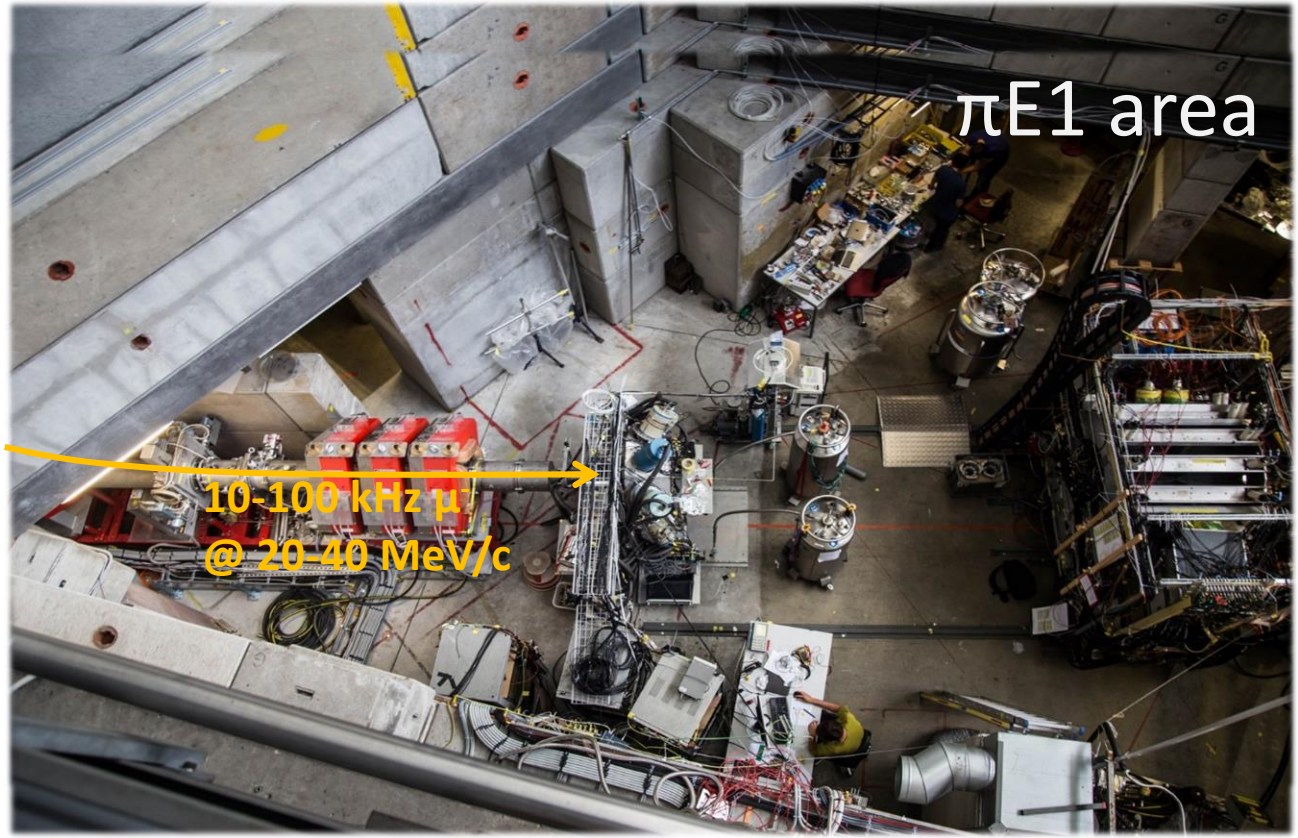
Frederik Wauters
Johannes Gutenberg University Mainz

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

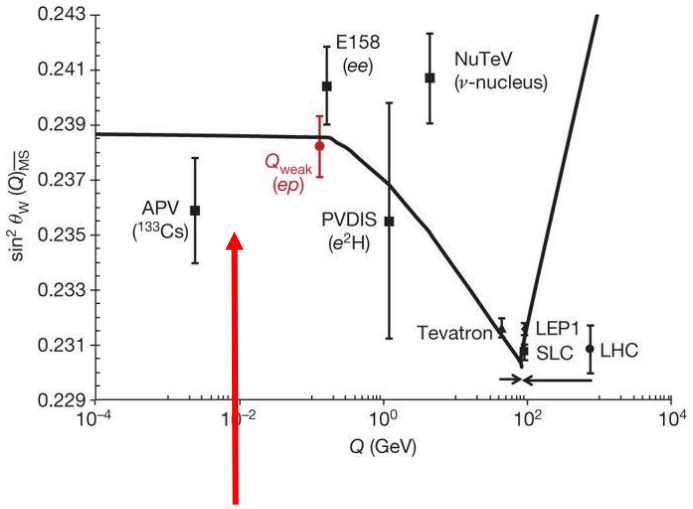
JG|U

Cluster of Excellence
PRISMA
Precision Physics, Fundamental Interactions and Structure of Matter

muX Detector setup



Atomic Parity Violation



Can we measure APV directly with muons?

Not a new idea, as reviewed by:

PHYSICS REPORTS (Review Section of Physics Letters) 118, No. 4 (1985) 179–238. North-Holland, Amsterdam

THE NEUTRAL WEAK CURRENT IN MUONIC ATOMS

John MISSIMER*
*Institut für Physik, Johannes-Gutenberg Universität, 6500 Mainz, Federal Republic of Germany and Swiss Institute for Nuclear Research,** 5234 Villigen, Switzerland*

Leopold M. SIMONS
Kernforschungszentrum Karlsruhe, Institut für Kernphysik und Universität Karlsruhe, Institut für Experimentelle Kernphysik Karlsruhe, Federal Republic of Germany

Received August 1984

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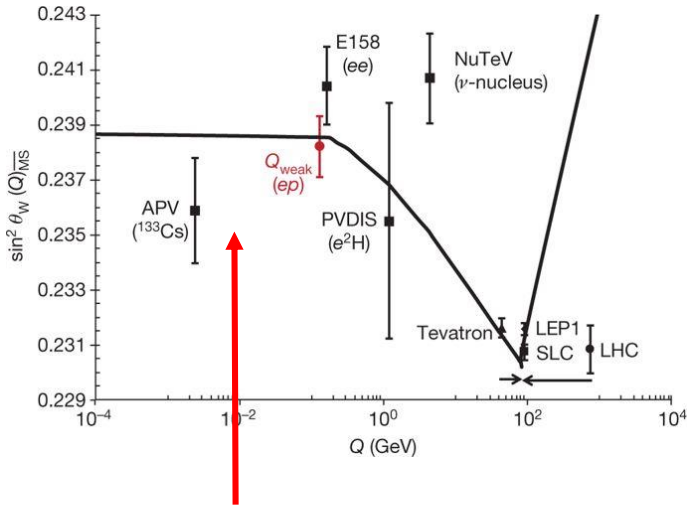

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Received August 1984

Can we measure APV directly with muons?

Renewed interested:

- Muon specific force related to g-2. Is the muon special? → Model specific
- Neutral currents are not tested with muons at low Q2! → Generic

Testing Parity with Atomic Radiative Capture of μ^-

David McKeen and Maxim Pospelov
Phys. Rev. Lett. **108**, 263401 – Published 29 June 2012

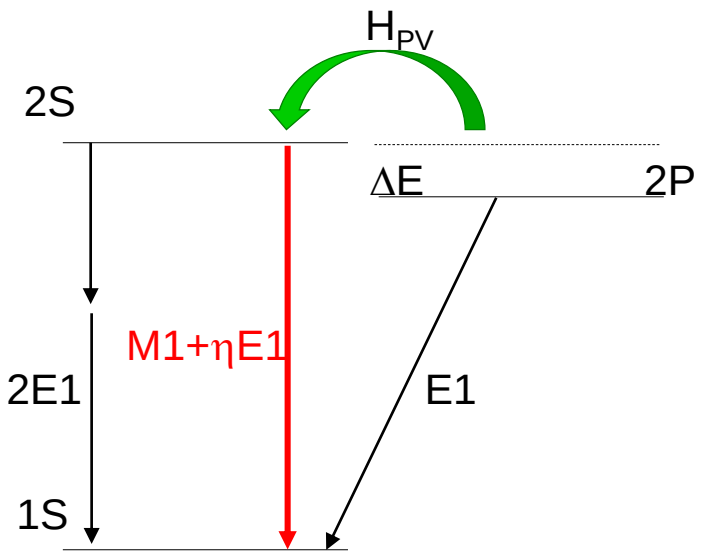
Constraints on muon-specific dark forces

Savely G. Karshenboim, David McKeen, and Maxim Pospelov
Phys. Rev. D **90**, 073004 – Published 13 October 2014; Erratum Phys. Rev. D **90**, 079905 (2014)

Extending theories on muon-specific interactions

Carl E. Carlson and Michael Freid
Phys. Rev. D **92**, 095024 – Published 23 November 2015

$Why\ Z = 30$



- Atomic parity violation (APV) in muonic atoms arises from an admixture of the opposite-parity 2p state in the 2s state, allowing for E1-M1 interference in the 2s-1s transition
- New physics > SM effect? E.g. a new vector force coupling to right-handed muons in light of recent muon anomalies.

- APV amplitude scales with $1/\Delta E_{2p-2s} \sim Z^{-4}$ → low Z (<10) preferred with a % level SM effect
- At low Z, 2 photon decay 2s-1s transition dominates over the single photon transition
- At Low Z, 2s-2p Auger transitions depopulate the 2s level.
  - Strip all electrons → low mass target ↔ high rate experiment
- Z ≈ 30 as an optimal point/compromise
  - Branching ratio 2s-1s ≈ **10^{-4}**
  - SM APV effect ≈ **10^{-4}**
- With 10^{12} on target (100 days at 100 kHz μ^-)
  - The high-purity germanium detectors survive the neutron yield
  - **Unity test SM APV within reach, new physics with a big APV effect primary goal**

Metastability of the Muonic Boron $2S$ State

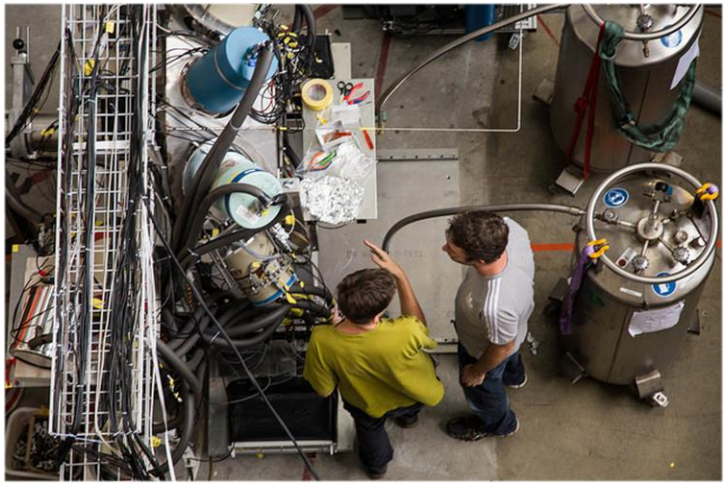
K. Kirch, D. Abbott, B. Bach, P. DeCecco, P. Hauser, D. Horváth, F. Kottmann, J. Missimer, R. T. Siegel, L. M. Simons, and D. Viel
Phys. Rev. Lett. **78**, 4363 – Published 9 June 1997

2S1S within muX

What is the 2s1s within muX?

- Observe the single photon M1 transition for the first time ← 2017-2018
- Achieve a signal to background of O(1) on the transition ← ongoing
- Determine the optimal APV odd observable
- Determine the reach of a APV experiment
- Mainly a Mainz effort, but very close collaboration with the 226Ra efforts at PSI

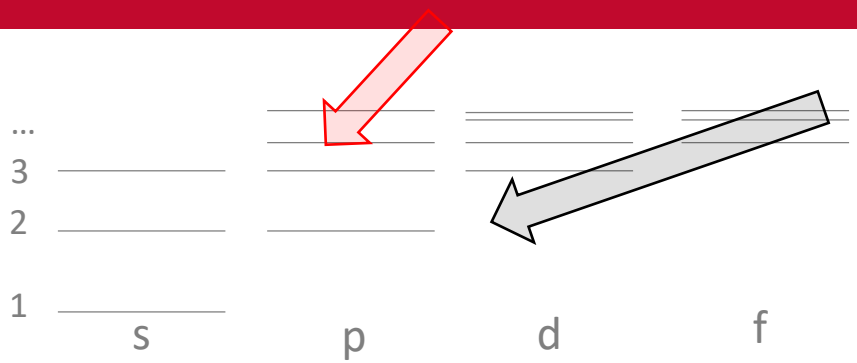
Supported by DFG, 3 year project WA4157/1-1,
PhD student next month

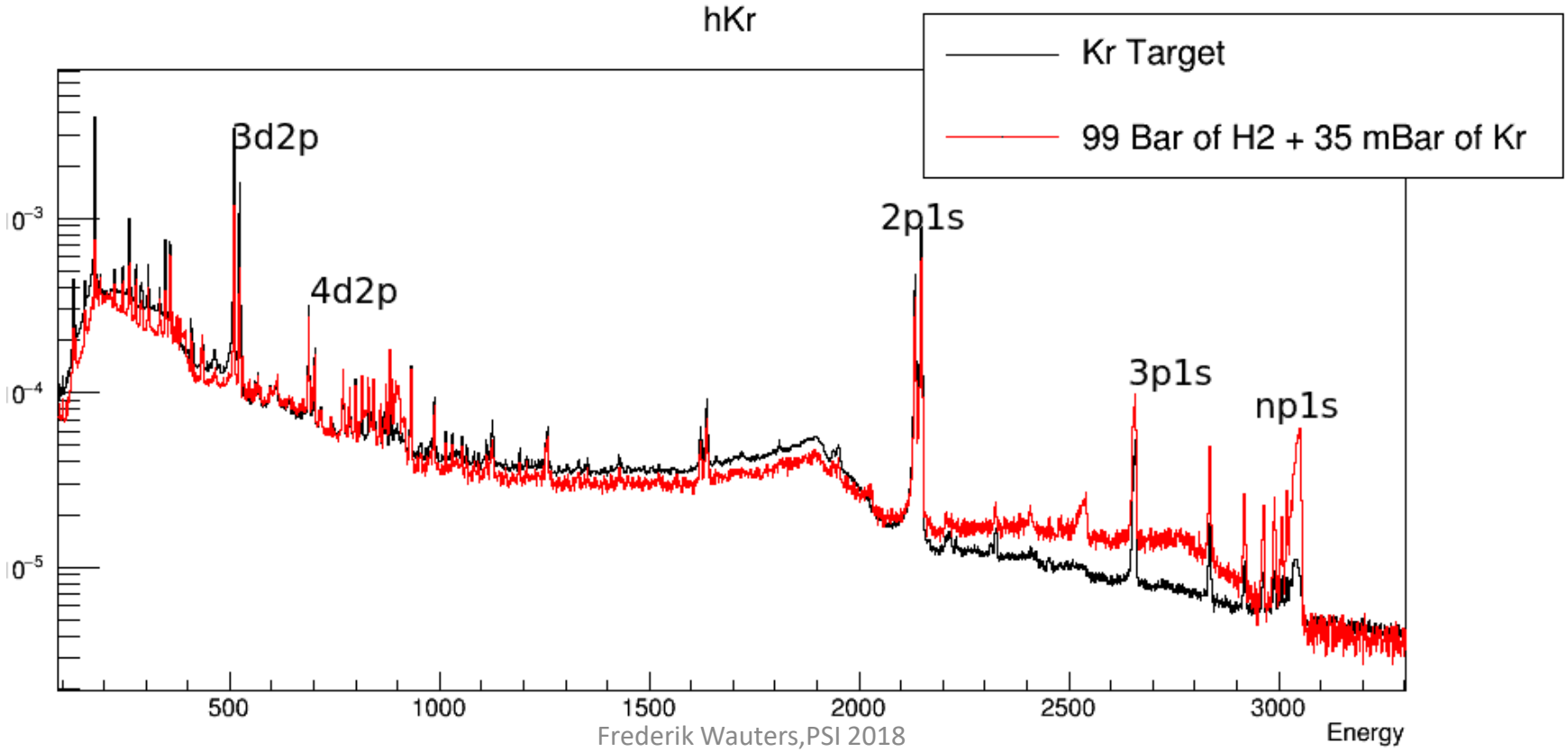


2S1S Observation in Kr 2017 – 2018

2S1S Kr runs:

- Increase 2S population by μH → μKr
- 2mm lead to shield against 2s2p+2p1s
- ~4 fold increase in 2s population

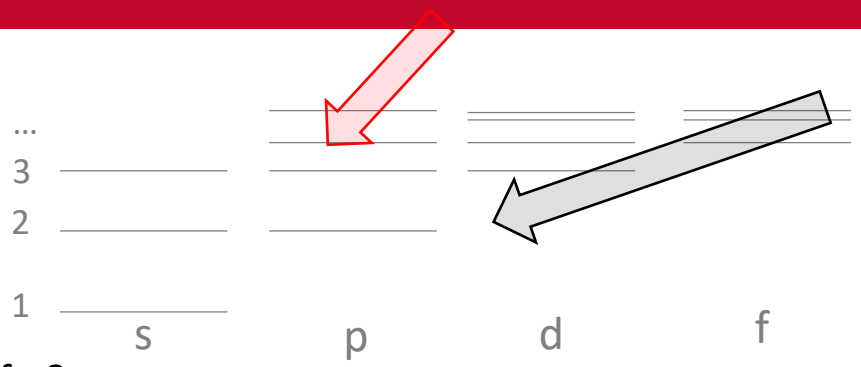


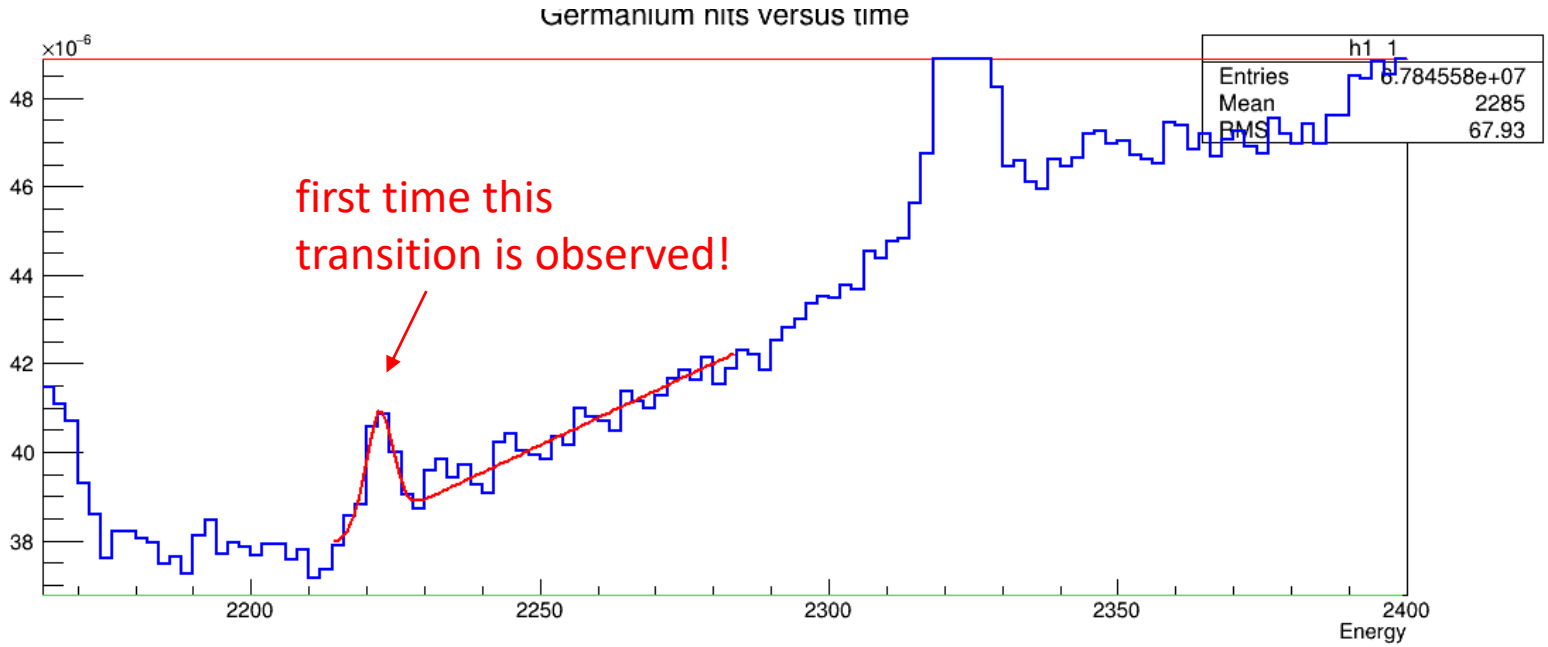


2S1S Observation in Kr 2017 – 2018

<u>2S1S Kr run (2 10^9 muons):</u>

- Increase 2S population by μH → μKr
- 2mm lead to shield against 2s2p+2p1s
- ~4 fold increase in 2s population
- Clean 2s1s peak! BR≈6 10^{-4}
- How to get polarized muons in 2s after μH transfer?

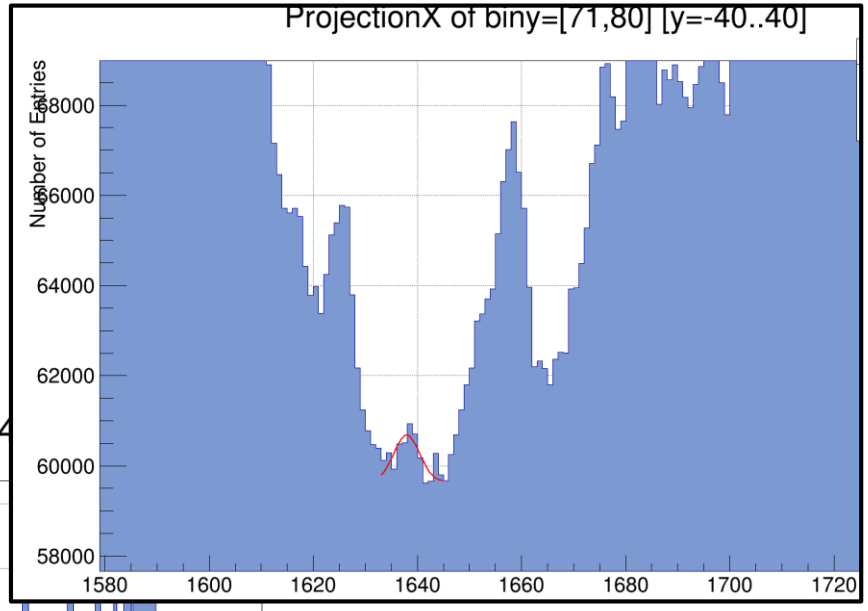


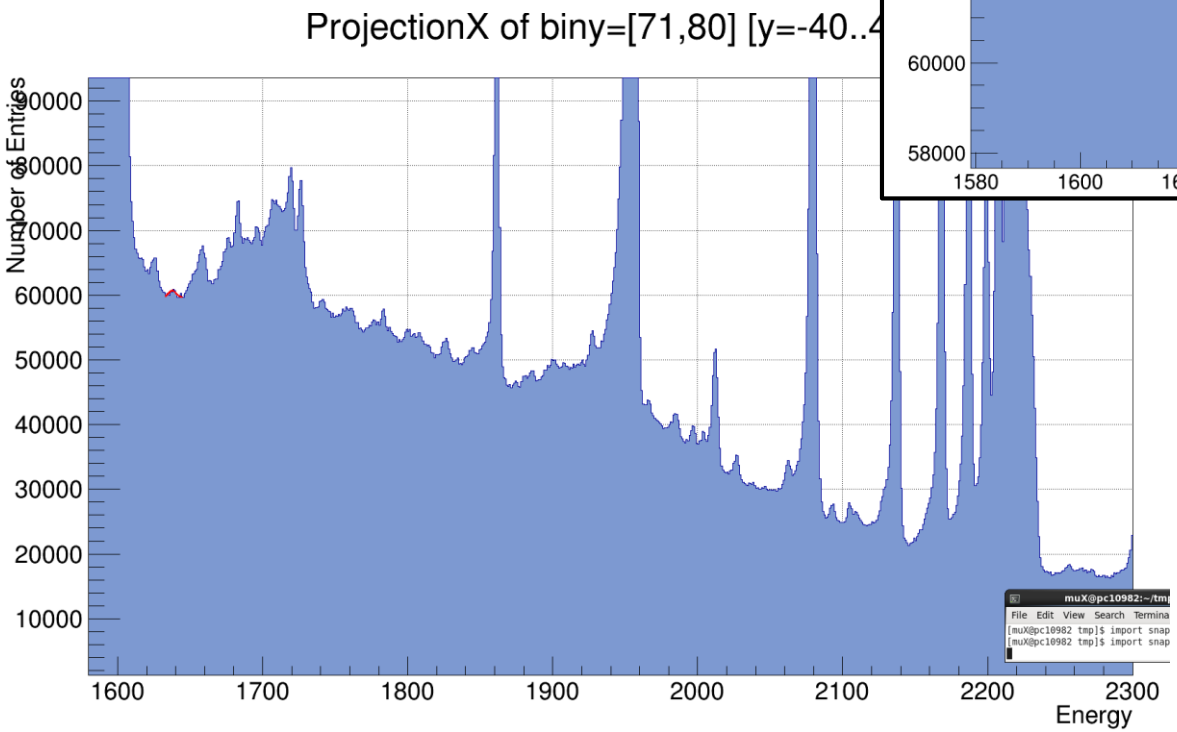


2017 *Zn run*

2S1S transition in Zn:

- Brute force
- Understand background peaks
- MSCB interface + muX GUI
- 7000(1000) ↔ 10000 expected
- Terrible signal to BG

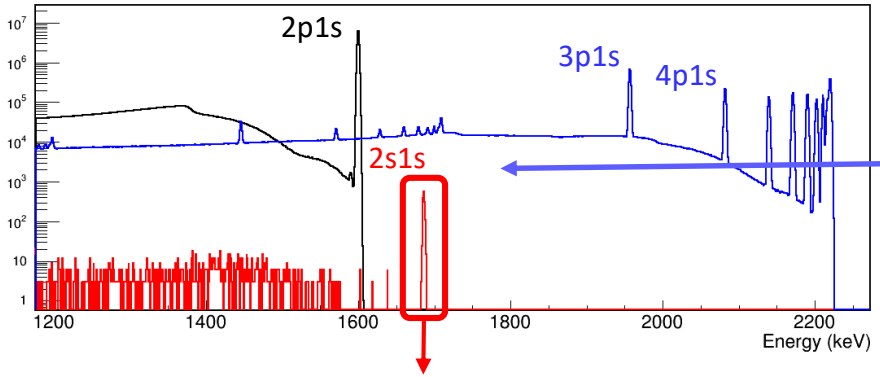




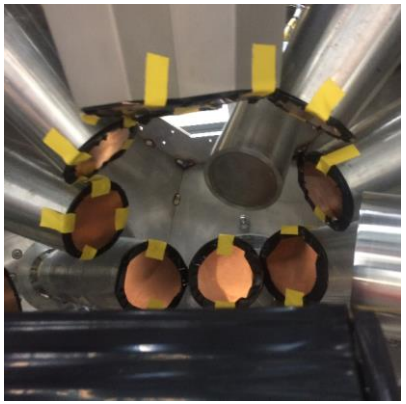
2017 *Zn run*

Backgrounds to 2s1s:

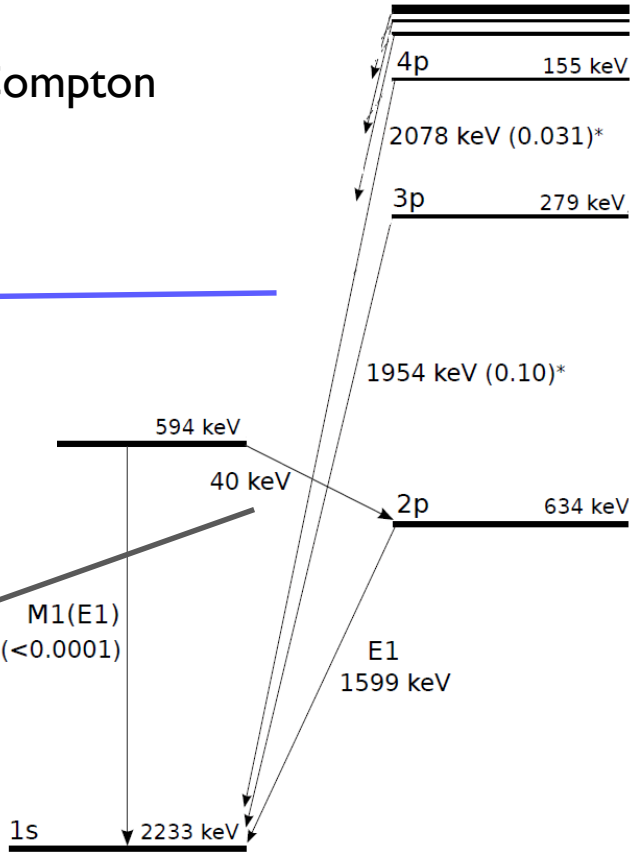
First order background is (n>2)p2s uncorrelated Compton



MC estimate of signal to background: 0.05



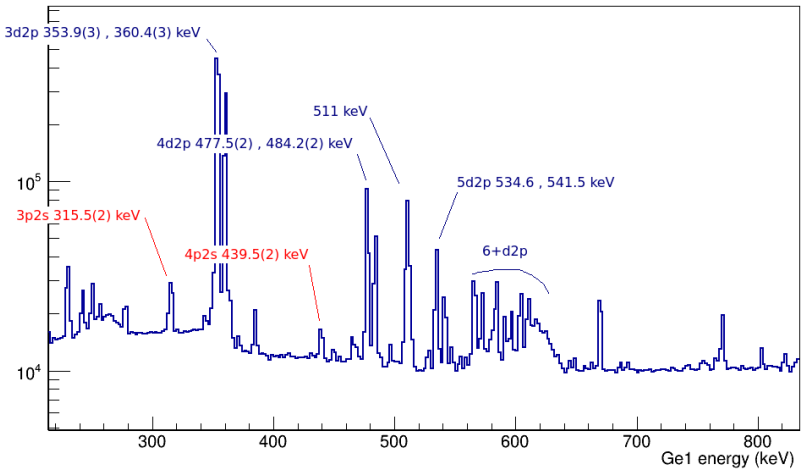
Shield against 2s2p+2p1s pile up (800 um Cu)

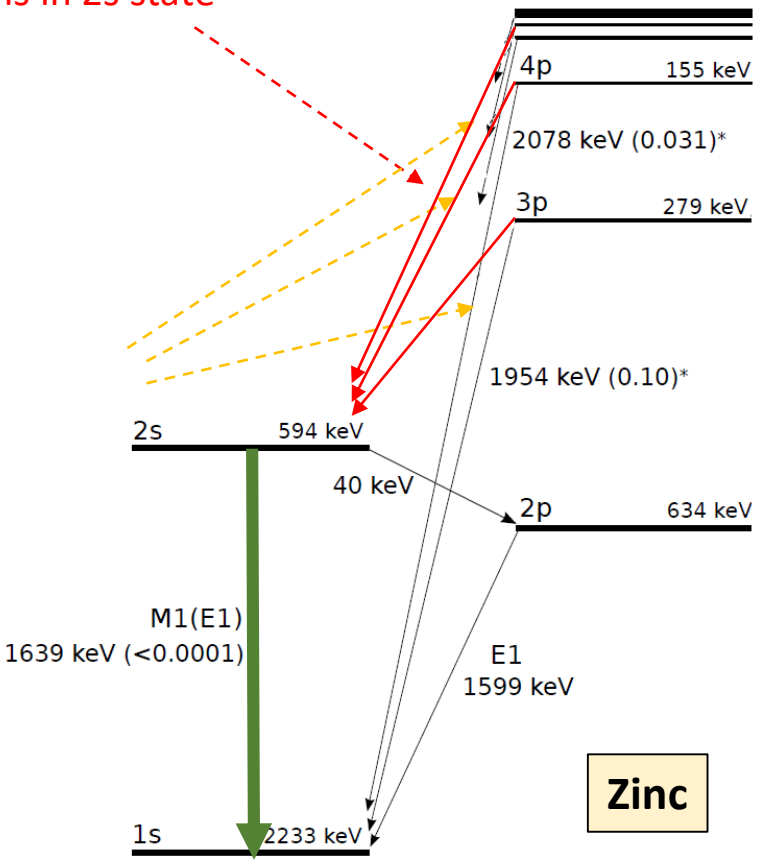


2017 *Zn run*

2017 beam time request

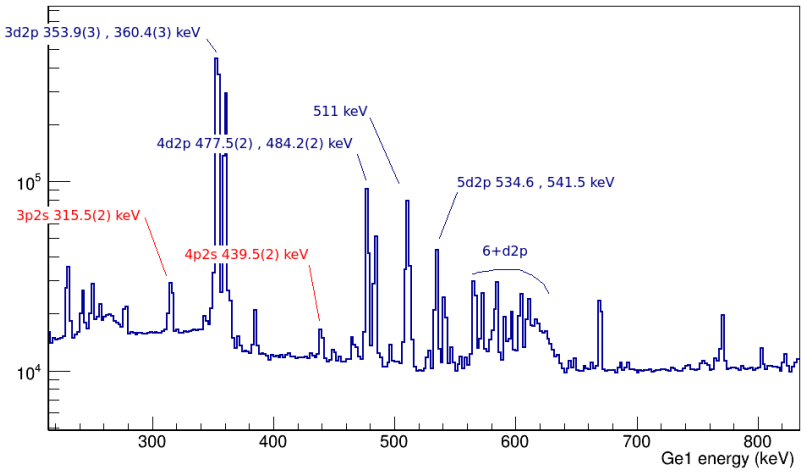
approach: tag muons in 2s state

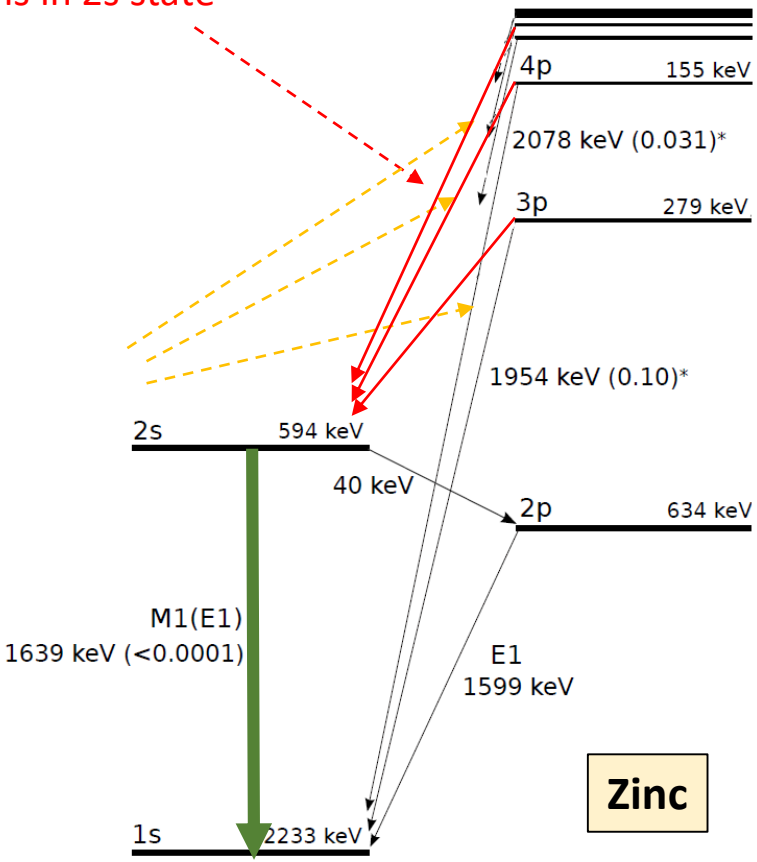




2017 *Zn run*

<u>approach:</u> tag muons in 2s state

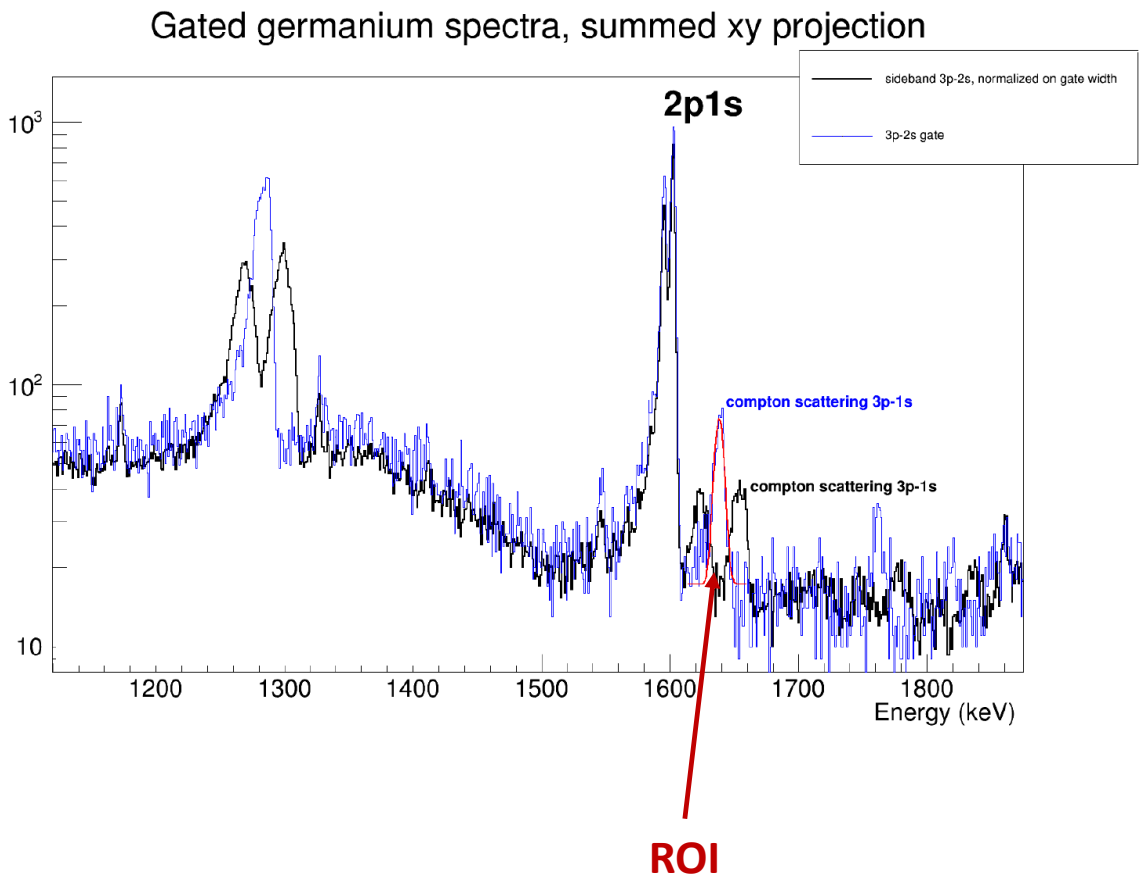




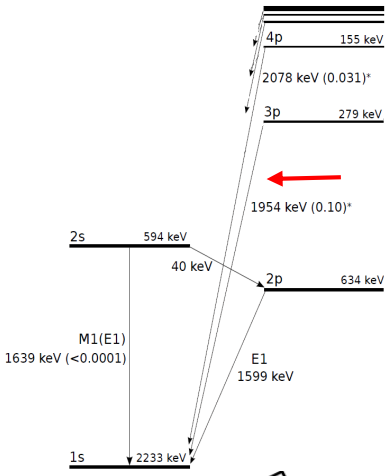
With the muX setup, 100-200 count /day

2017 *Zn run*

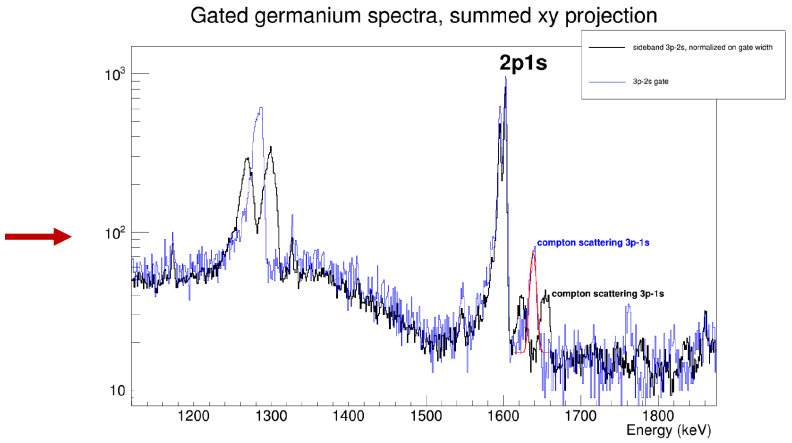
BUT!

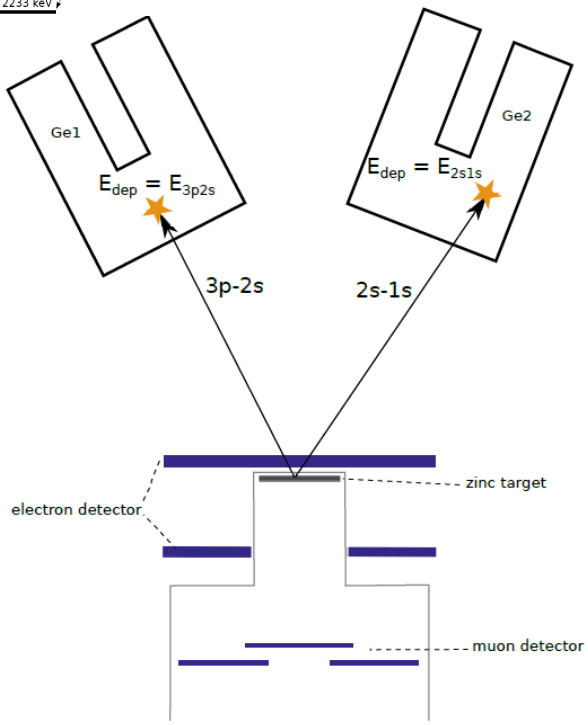


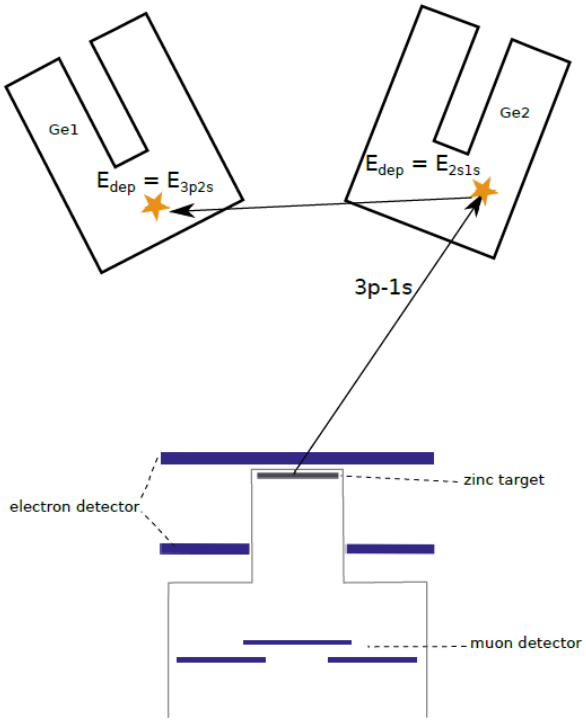
2017 *Zn run*



This the worst we could make it

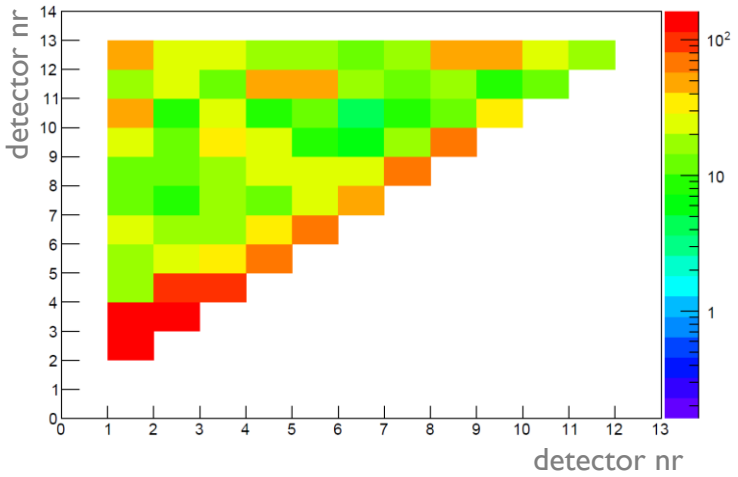






2017 *Zn run*

coincidence rate in ROI



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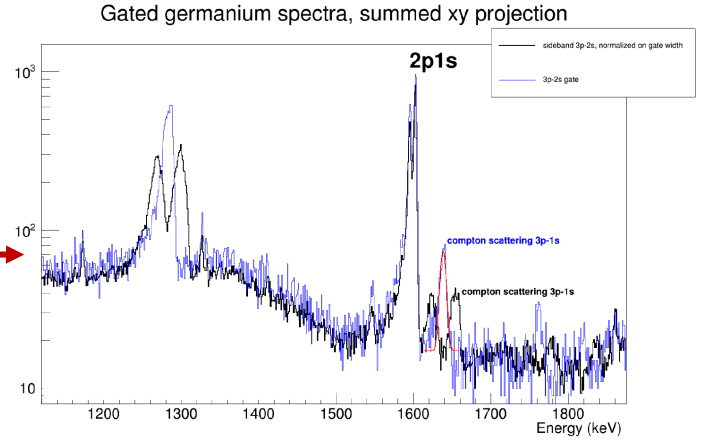
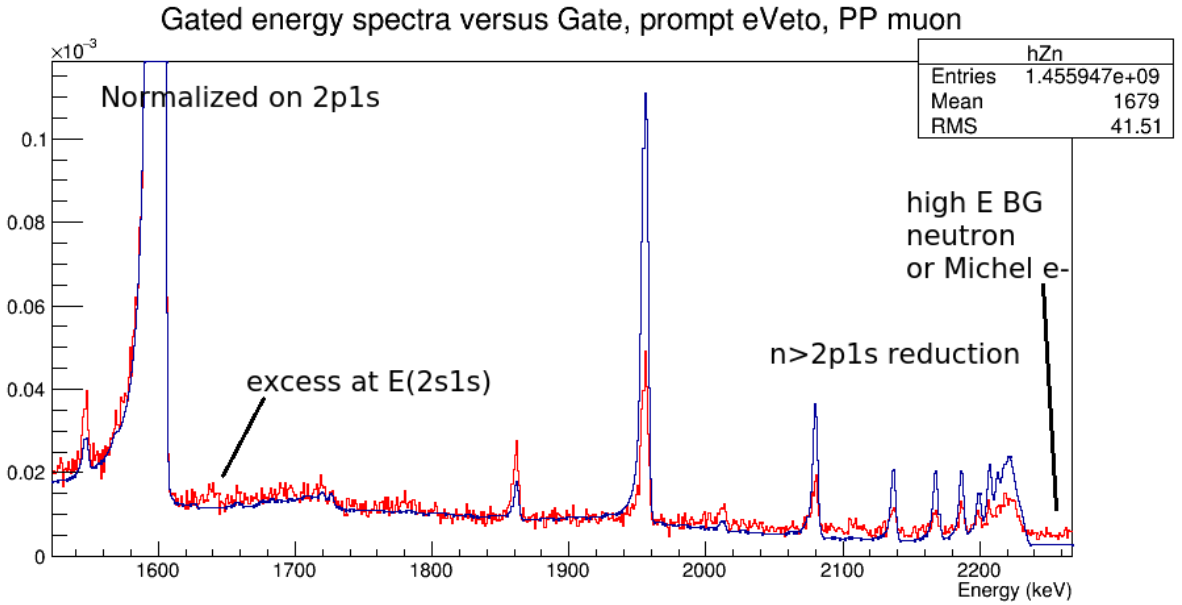
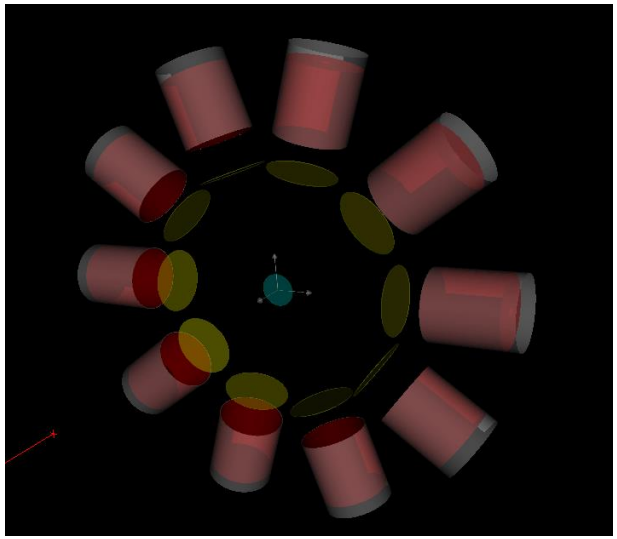


choose coincidence pairs wisely



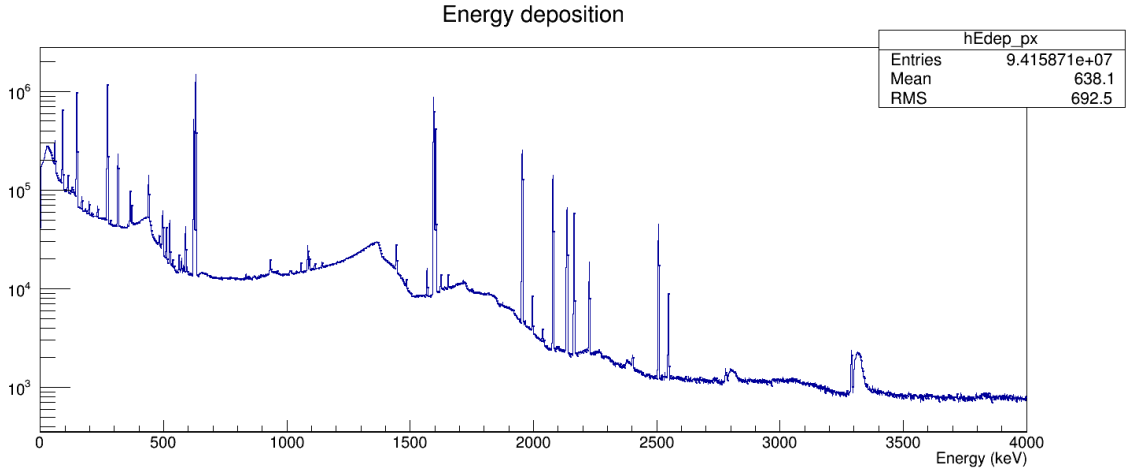
MC (ongoing)

Full MC to do it properly:



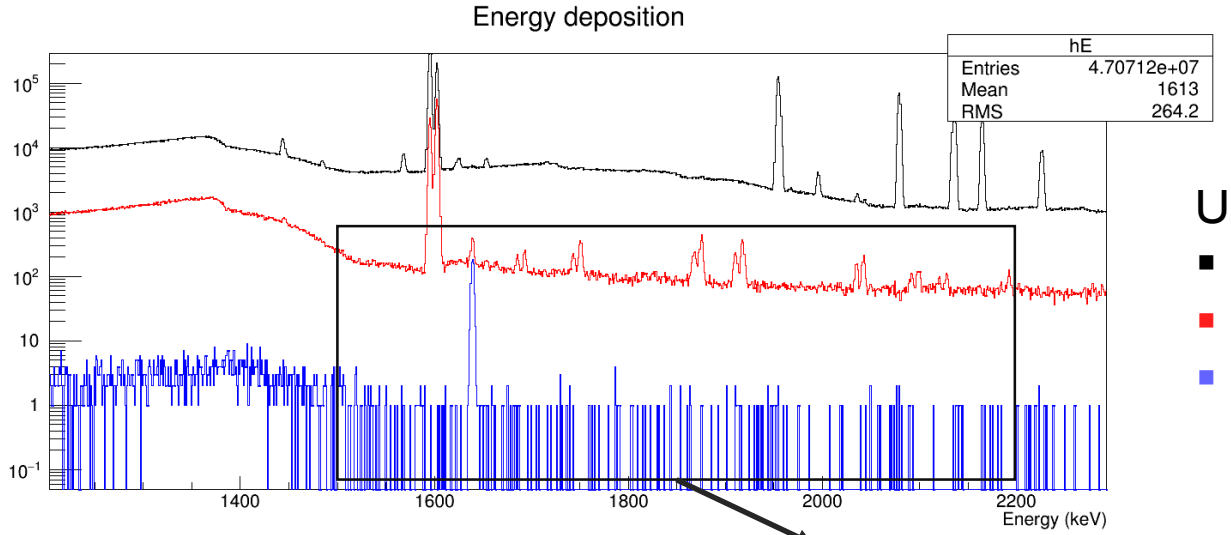
Start off with uniform angle distribution:

Full Cascade + electrons + neutrons:



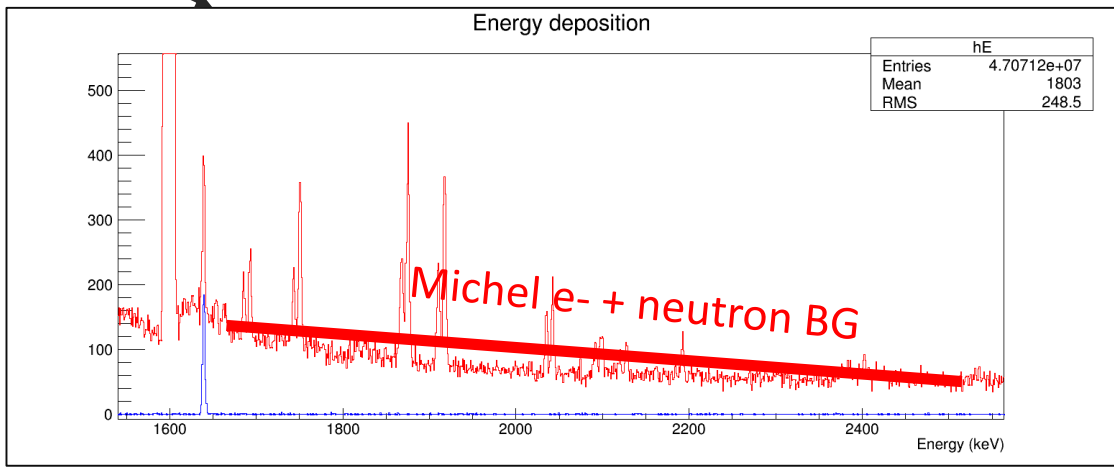
2s1s observation with Zn v 2.0

Full MC to do it properly:



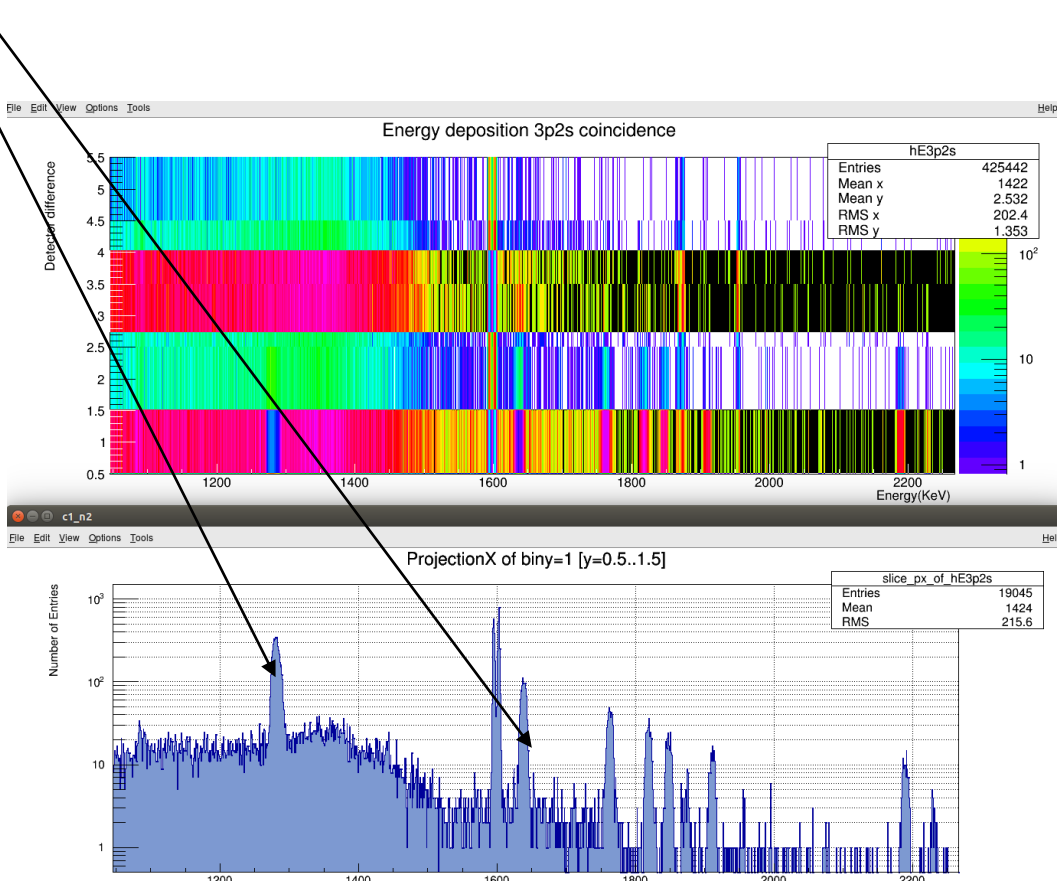
Use truth information:

- all
- has 2s level in cascade
- has 2s1s transition

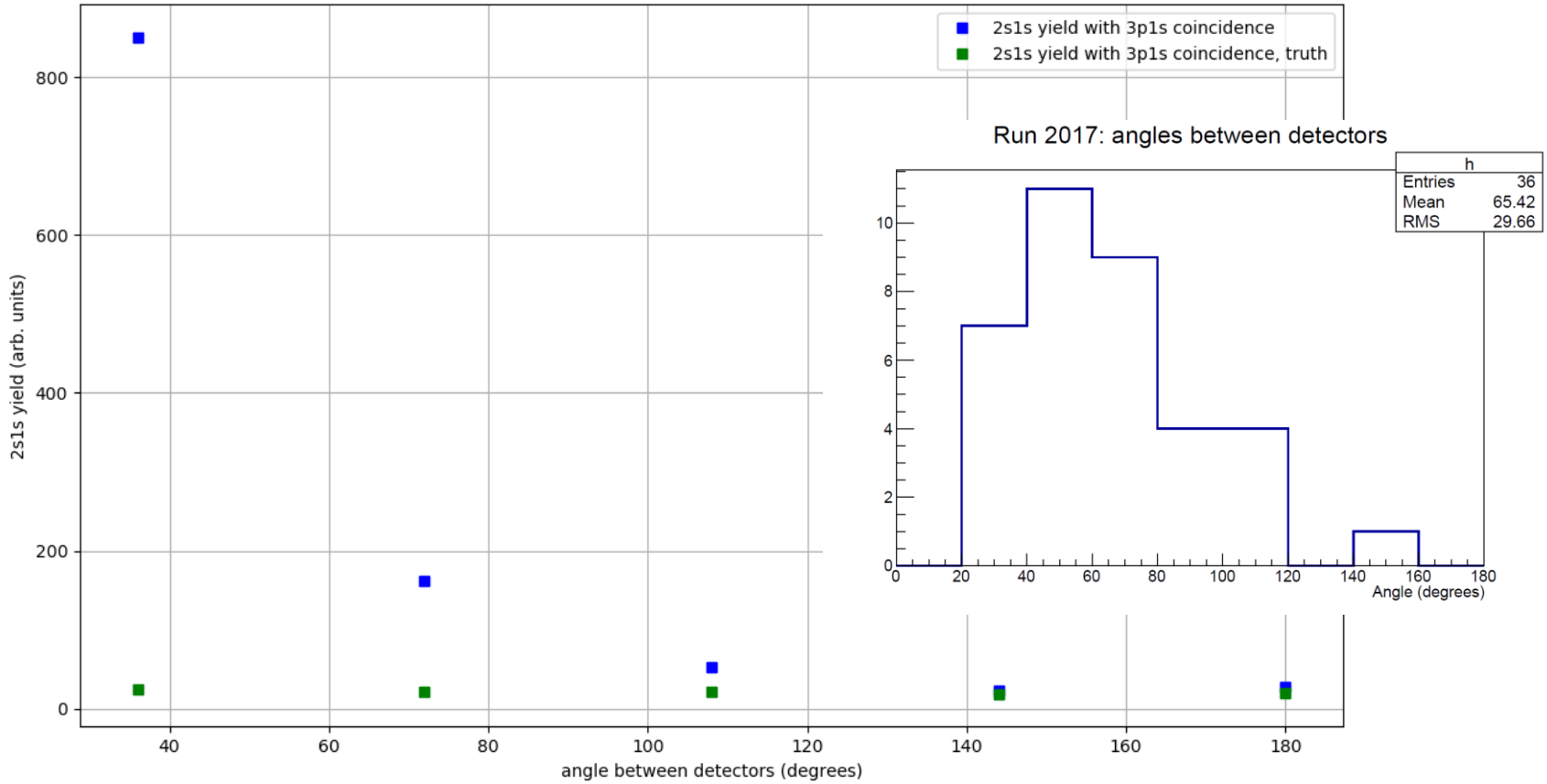


2s1s observation with Zn v 2.0

3p2s coincidence: we reproduce the effect!

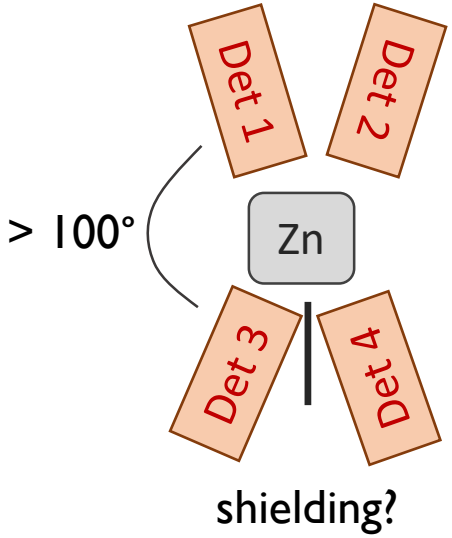


2s1s observation with Zn v 2.0

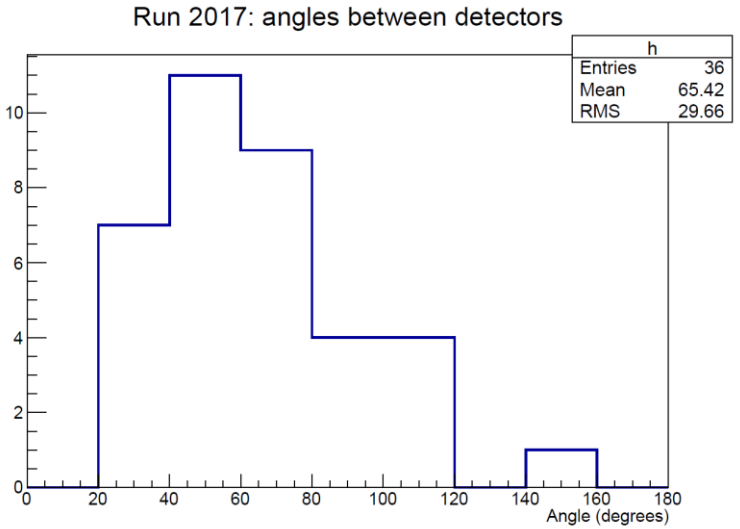


Conclusions

- 2s1s transition observed!
- Coincidence method is more complicated.
  2017 detector angles were unfortunate.



- Continuous high-energy ~~electron~~ neutron background
  - further optimize timing
  - quantify with MC
  - add neutron detector



Plans:

- Further quantify with MC
- If then still look promising:
  1 week Zn request at BVR

Future:

- Best S/B possible
- explore efficient Parity off observable