A Direct Detection Search for Hidden Sector New Particles in the 3-60 MeV Mass Range

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Conditionally Approved by PAC49 with C2

Outline

- physics objectives (very short)
- the method
- experimental setup and resolutions
- new background simulations and statistics
- summary

Physics Goals of this Proposal

- Most of cosmological observations suggest that:
  - ✓ ≈85% of Universe consist of matter with "unknown origin", the so-called Dark Matter (DM);
  - ✓ DM either does not interact with the known, ordinary matter (SM) or if interacts, then very weakly (WIMPs), weak enough we can not detect them so far;
  - ✓ many theoretical models, many search experiments …
  - ✓ no experimental detection of DM so far.
- DM can be detected through their interactions with the SM objects (particles/fields).
- A viable theoretical model suggests:
  - ✓ existence of "intermediate particles/fields" (portals) between DM and SM objects;
  - ✓ providing interaction between DM and SM through the so-called "kinetic mixing" mechanism;
  - ✓ U(1) gauge boson (dark photon or X-particle);
  - ✓ the [1 – 100] MeV mass range is well motivated.
- Recent experimental evidence: excess of e^+e^- pairs in excited ^{8}Be and ^{4}He decay spectrum (ATOMKI anomaly, → hypothetical X17 particle or 5th-force carrier).
  - ✓ **requires an urgent independent experimental validation.**
- We propose to search for hidden sector intermediate particles in low MeV-scale mass range through a direct detection method.

ATOMKI ^{8}Be and ^{4}He Experiments (Anomalies)

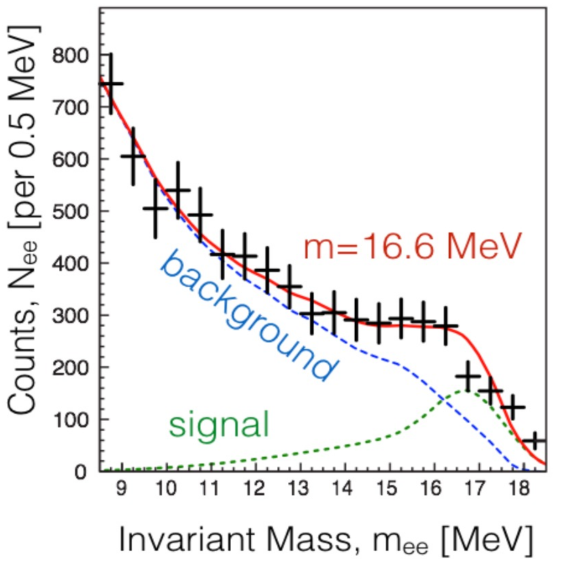
- ^{8}Be anomaly in nuclear transitions (*PRL 116(4):042501 (2016)*):
  - ✓ ^{8}Be excited states, decaying to ground state by E/M transitions.

  $p + {}^7Li \rightarrow {}^8Be^* \rightarrow 7Li + p$ (hadronic decay)

  $\rightarrow {}^8Be + \gamma$ (E/M decay)

  $\rightarrow {}^8Be + \gamma^*,\ \gamma^* \rightarrow e^+e^-$ (IPC)

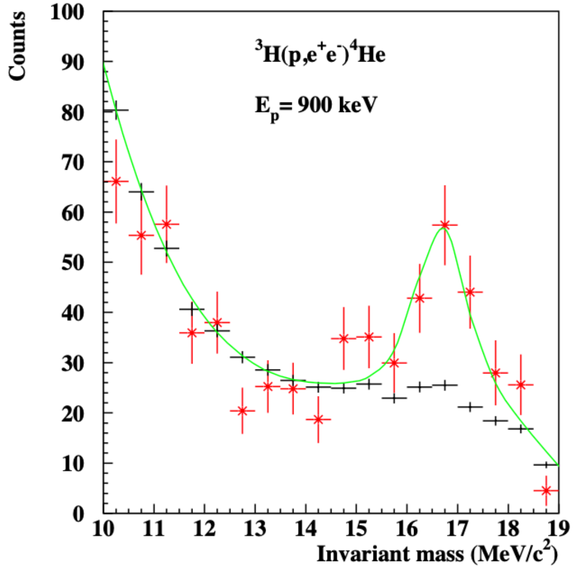
- ✓ excess of e^+e^- pairs in angular distributions (inv. mass) beyond the expectation of the Internal Pair Conversion (IPC).



- New results on ^{4}He with updated experimental setup and reduced background:

  $p + {}^3H \rightarrow {}^4He^* + \gamma \rightarrow {}^4He + \gamma^*,\ \gamma^* \rightarrow e^+e^-$ (IPC)

  - ✓ e^+e^- peak at different angles but the same invariant mass.
  - ✓ Recently published at Phys. Rev. C 104 (2021) 4, 044003



- Over hundred theory papers, no independent experimental confirmation.

- **Requires an urgent independent experimental validation.**

Experimental Objectives of this Proposal

- This proposal has two experimental objectives:

1) Validate existence or establish an experimental upper limit on the electroproduction of the hypothetical X17 particle claimed in two ATOMKI low-energy proton-nucleus experiments.

2) Search for "hidden sector" intermediate particles (or fields) in [3 − 60] MeV mass range produced in electron-nucleus collisions and detected in e^+e^- (or $\gamma\gamma$) channels.

Many past and recent publications suggesting models predicting existence of scalar or pseudoscalar new particles in low mass range, [1−50] MeV, decaying through $\gamma\gamma$ channel (Cheuk-Yin Wong, arXiv:2201.09764v1, QED bound state of quark-antiquark system).

The proposed experiment is equally sensitive to neutral decay channels ($X \rightarrow \gamma\gamma$). (significant advantage over many other proposals or running experiment).

arXiv:1707.09749

Experimental Method

- The method:
  - ✓ "bump hunting" in the invariant mass spectrum over the beam background.
  - ✓ direct detection of all final state particles (e', e^+e^- and/or $\gamma\gamma$) $\rightarrow$ full control of kinematics

- Electroproduction on heavy nucleus in forward directions:

$$e^- + Ta \rightarrow e' + \gamma^* + Ta \rightarrow e' + X + Ta, \quad \text{with} \quad X \rightarrow e^+e^- \text{ (with tracking)}$$
$$\text{and} \quad X \rightarrow \gamma\gamma \text{ (without tracking)}$$

in mass range of: [3 - 60] MeV
target: Tantalum, ($_{73}Ta^{181}$), 1 μm (2.4x10^{-4} r.l.) thick foil.

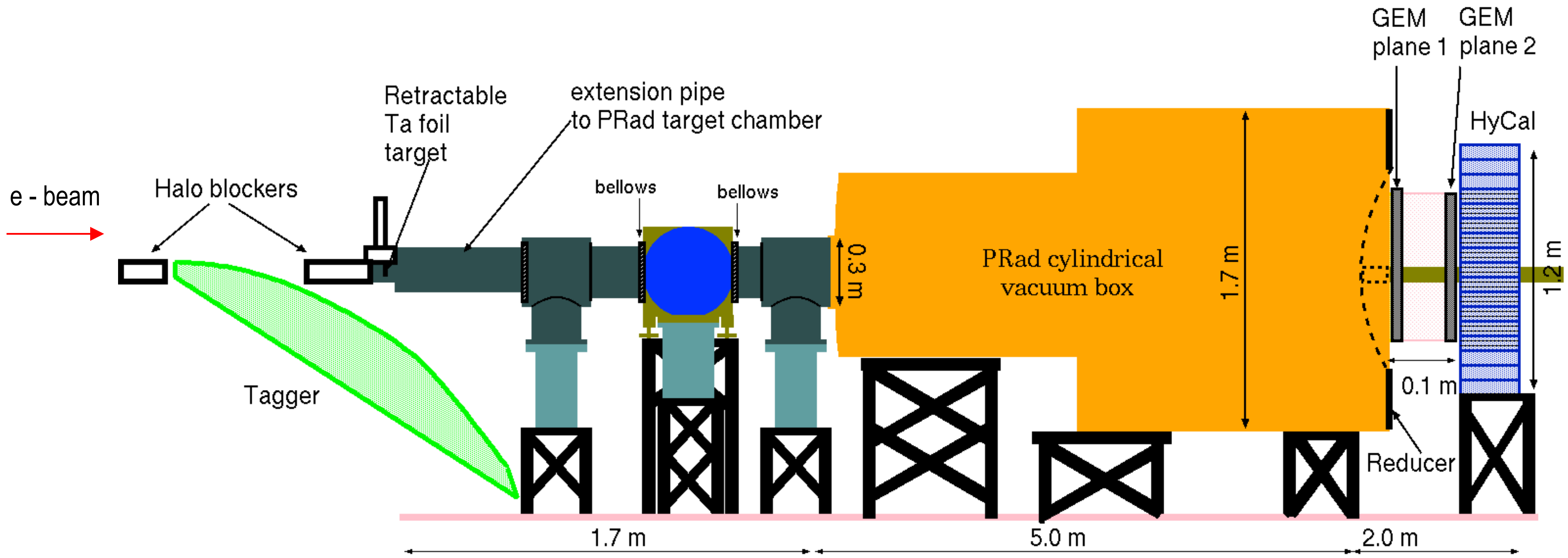
- All 3 final state particles will be detected in this experiment:
  - ✓ scattered electrons, e' , with 2 GEMs and $PbWO_4$ calorimeter;
  - ✓ decay e+ and e- particles, with 2 GEMs and $PbWO_4$ calorimeter;
  - ✓ or decay $\gamma\gamma$ pairs, with $PbWO_4$ calorimeter (and GEMs for veto).

- Will provide a tight control of experimental background.

Proposed Experimental Setup in Hall B

- Experimental setup is based on the PRad-II apparatus:
  - Hall B Photon Tagger will be used for $PbWO_4$ calorimeter gain equalization and initial calibration
  - ;
  - 1 μm Ta solid targets (2.4×10^{-4} r.l.) will be placed on the target ladder (and Harp, multiple foils);
  - Two planes of GEM detectors on front of the $PbWO_4$ calorimeter, providing limited tracking;
  - Only the $PbWO_4$ part of HyCal will be used in this experiment.

Experimental Setup (Side View)

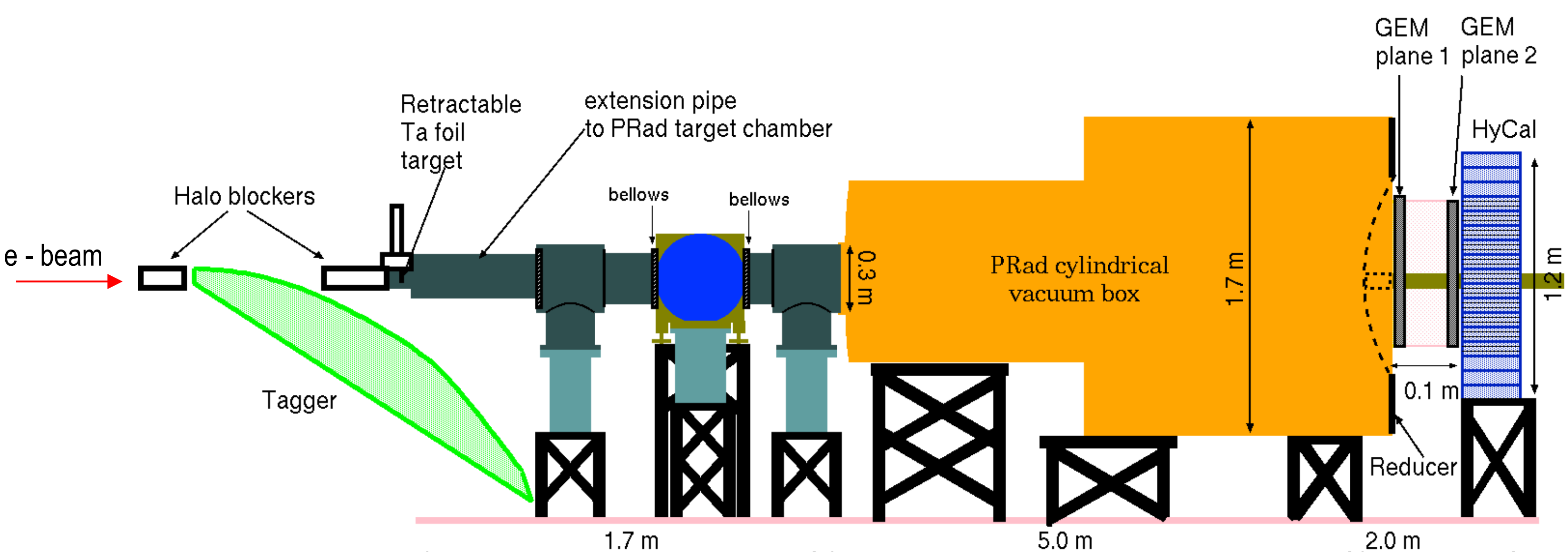


Proposed Experimental Setup in Hall B (TAQ Q#1)

- TAC Q#1: *"… There is no description of the blocker in the text. Depending on the requirements for the (halo) blocker, the existing wire harp and the pair of the Hall-B raster magnets currently mounted in that location may have to be removed or relocated. The wire harp is a crucial device for beam tuning. "*
- *Answer:* The exact location and size of the second beam halo blocker will be optimized in consultation with

Hall-B staff and the Hall-B engineering group. The rendering in Fig. 8 is meant as a schematic not the exact location. We do not intend to remove the wire harp. The Hall-B raster magnets (used only for polarized targets) will have to be removed to make way for the second halo blocker. Moreover, the beam halo blocker will be retractable similar to the HPS beam halo blocker. It will be retracted from the beamline if it is found to have a negative effect on the background.

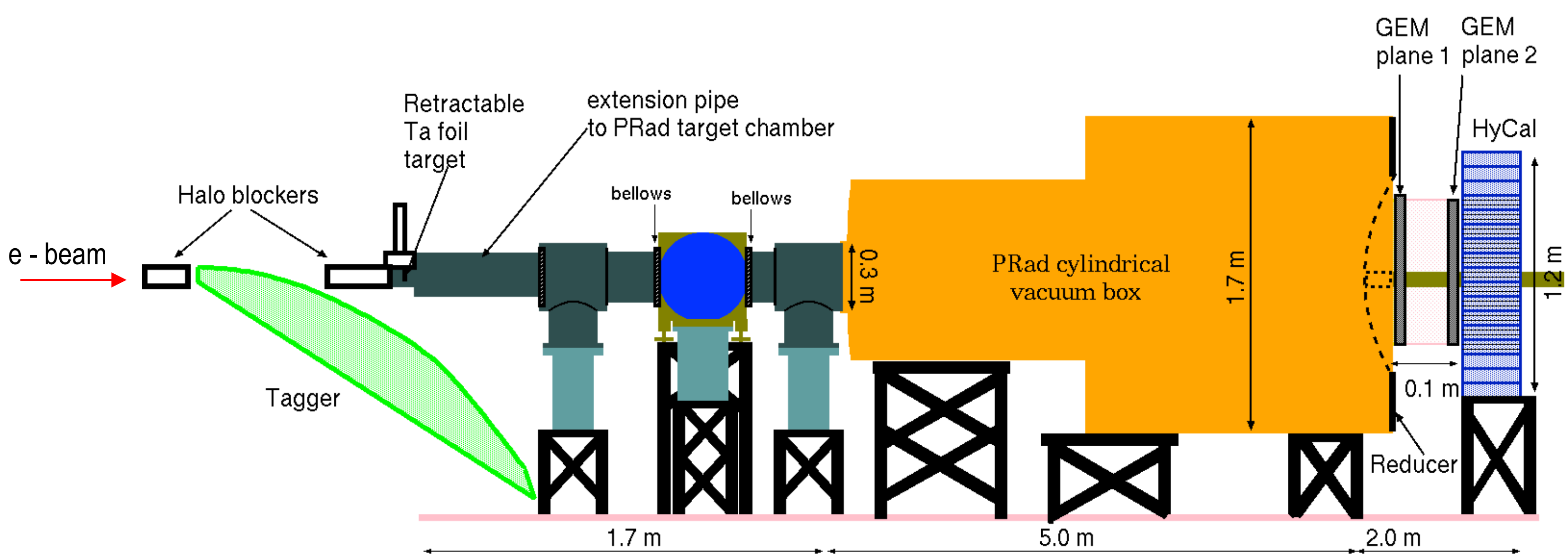
Experimental Setup (Side View)



Proposed Experimental Setup in Hall B (TAQ Q#2)

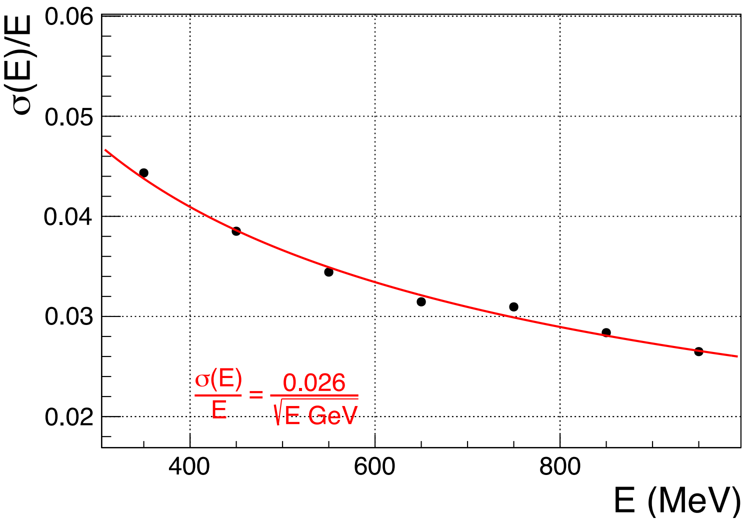
- TAC Q#1: *"… There is no mention of how HyCal will be calibrated for this run. For 12 GeV operations of CLAS12, we removed the photon tagger focal plane counters. Re-installation is possible, but the photon energy knowledge will not have the same accuracy as it was during the first PrimEx experiment. Also, over time vacuum in the tagger scattering chamber degraded due to the deterioration of the chamber window. This affects the photon beam energy resolution."*
- *Answer: Plans to use the Photon Tagger for the HyCal calibration are the same as the approved PRad-II experiment. It is planned to use the 25% of the focal plane.* Only three intervals of the focal plane detectors will be used: upper T1-T5, middle T28-T33, and lower T56-T61. We plan to install new window for the tagger chamber.

Experimental Setup (Side View)

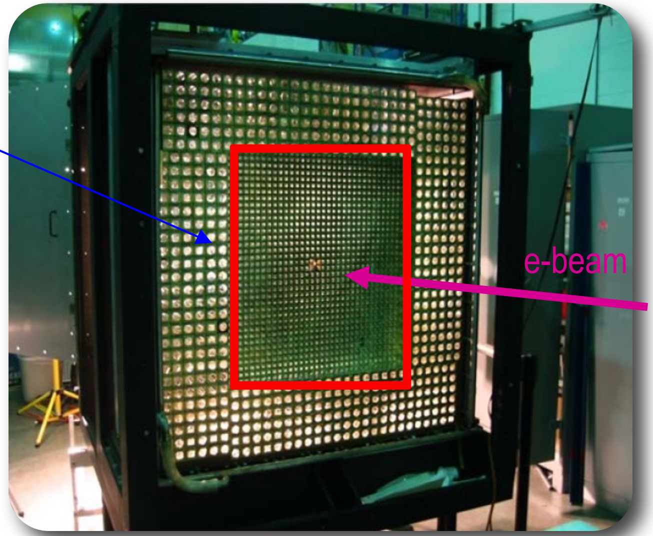


Experimental Apparatus: $PbWO_4$ Electromagnetic Calorimeter

- The inner $PbWO_4$ part of HyCal only will be used:
  - ✓ 34 x 34 =1156 crystal modules, each with 2x2x18 cm^3;
  - ✓ with 68 x 68 cm^2 total detection area;
  - ✓ 2x2 crystals are removed from center for beam passage



Energy resolution (PrimEx measurement, limited by Hall B Photon Tagger).



- $PbWO_4$ crystals have excellent detection characteristics at MeV range energies too.
- example: recent Mainz measurements down to 30 MeV energies (crystals were not cooled): similarly good energy resolutions.

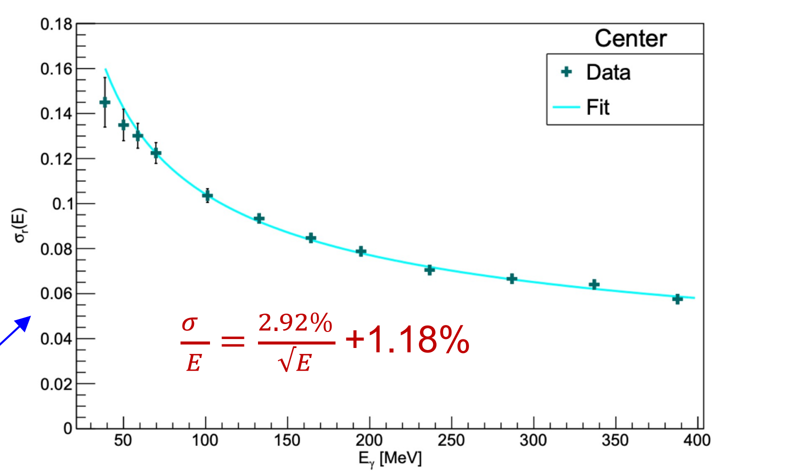
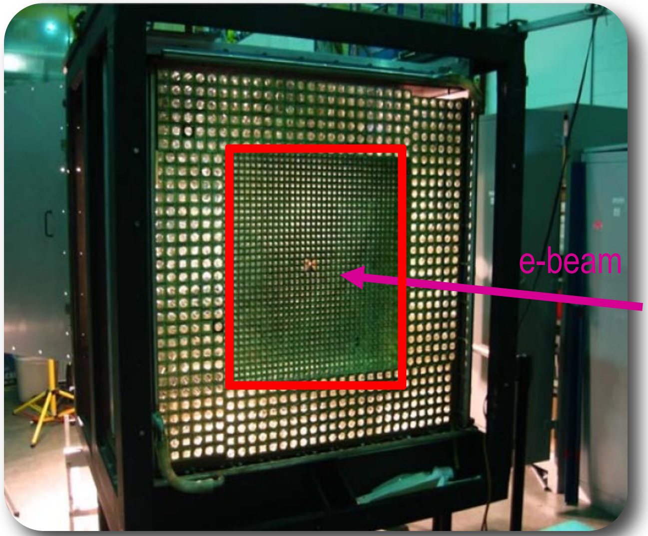


Figure 43: Measured relative resolution of the cluster energy response as a function of the incident photon energy E_γ for the center irradiation position in element 8. The errors are systematic.

M. Erzer, Masters Thesis, Mainz, 2020

Readout and Trigger Electronics (TAC Q#2)

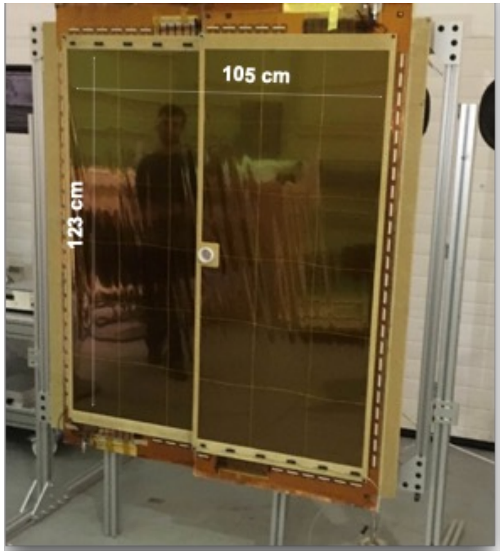
TAC Q#2: "…*Only the high-resolution part of the HyCal, consisting of more than 1100 PbWO4 crystals, will be used. The old readout based on NIM modules and Fastbus electronics must be replaced with fADC250 (similar arrangement as for PRAD-II experiment) to be compatible with the requirements for triggering. On page 21 of the proposal, it is stated that "A large fraction of the electronics needed for the DAQ and trigger, including the high voltage crates and all necessary cabling for the detectors, are available in Hall B from the PRad experiment." It should be clear that PRad in Hall-B does not have the required fADC250, VXS crates, or trigger modules. These are all new equipment that must be either purchased or borrowed.*



Answer: The statement quoted from the proposal is meant to include all of HV power supplies and readout electronics for the HyCal not just the DAQ electronics. The updated DAQ is a part of the approved PRad-II experiment, and the collaboration is exploring both internalJLab electronics pools to borrow for this experiments and/or external funding to upgrade the HyCal DAQ.

Experimental Apparatus: GEM Coordinate Detectors (Tracking)

- Two planes of GEM detectors for tracking:
  - ✓ similar to PRad-II GEMs but smaller size: 68x68 cm^2 each;
  - ✓ located on front of $PbWO_4$, after the vacuum window;
  - ✓ relative distance (10 cm), optimized between resolution and available material after the vacuum window;
  - ✓ good position resolution (σ=72 μm);
  - ✓ will veto neutral particles for $X \rightarrow e^+e^-$ channel and veto the charged particles for $X \rightarrow \gamma\gamma$ channel.
    (PAC49 recommendation #2)
- Electronics: APV-25 based readout system (available).



PRad GEMs

- TAC Q#3: *Two new GEM-based tracking detectors are planned for the experiment. These are not the same detectors that have been proposed for PRAD-II experiment. Substantial RD will be needed to make these detectors lightweight, 0.3% r.l.. We strongly advise that the proponents of these three proposals work together to develop one set of tracking detectors for the proposed E12-20-004, C12-21-003, and PR12-22-003.*

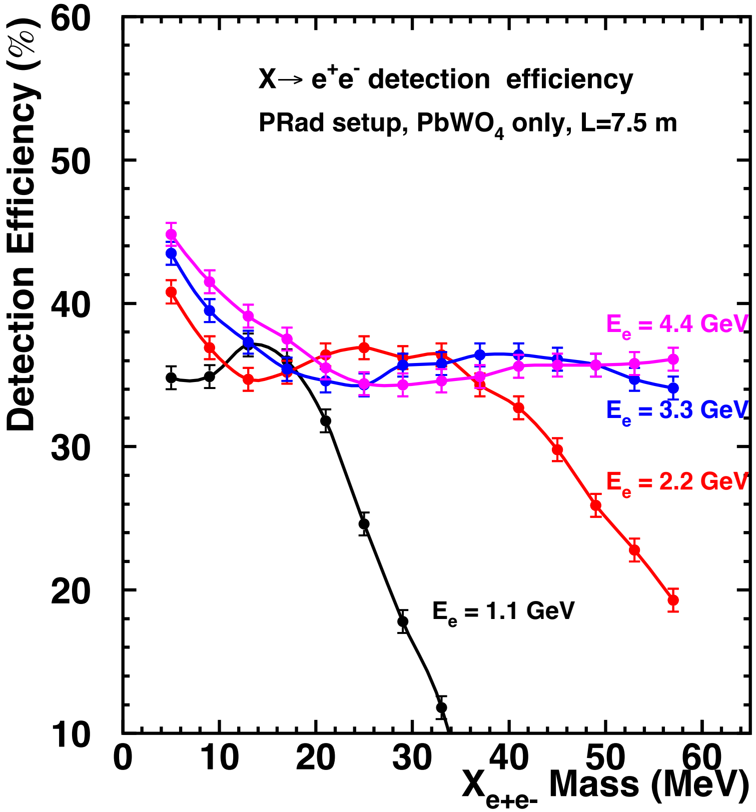
- Answer: There is no significant difference in experimental configurations between the fully approved PRad-II experiment and this conditionally approved proposal. The same GEM chambers can be used. If fully approved, this experiment could be run in sequence with PRad-II. In case the proposed experiment (if fully approved) is scheduled much later than PRad-II and there are significant improvements in the GEM technology (w.r.t thinner r.l. detectors) the collaboration may seek to build new detectors.

Detection Efficiency

- Trigger configuration:
  - ✓ total energy sum in calorimeter: $\Sigma E_{clust} > 0.7xE_{beam}$
  - ✓ 3 clusters in $PbWO_4$ calorimeter;
  - ✓ each cluster energy: 30 MeV $< E_{clust} < 0.8xE_{beam}$ (rejects the elastic scattered electrons)

- Large phase space for virtual photon, γ^*:
  - ✓ energy interval: $E_{\gamma^*} \approx [0.2 - 0.8]\ E_{beam}$;
  - ✓ $\vartheta_{e'} \approx [0.4^0 \text{ -- } 3.7^0]$ angular range.
  - ✓ provides X-particle production in wide energy spectrum and in forward solid angle

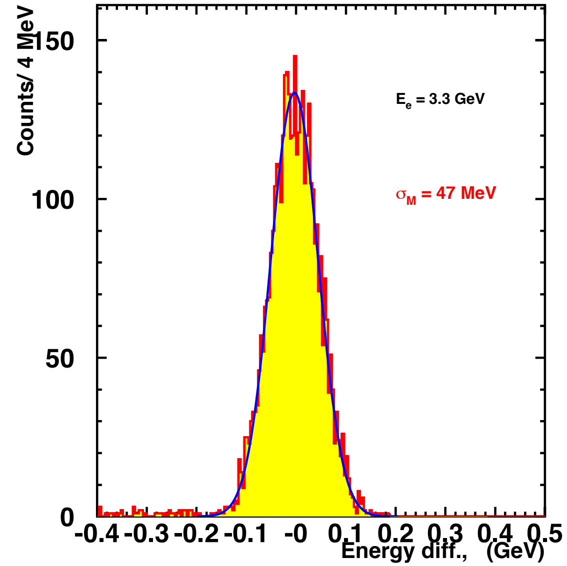
- Target to detector distance: L = 7.5 m provides good (integrated) detection efficiency in [3-60] MeV mass range for E_e = 2.2, 3.3 and 4.4 GeV.



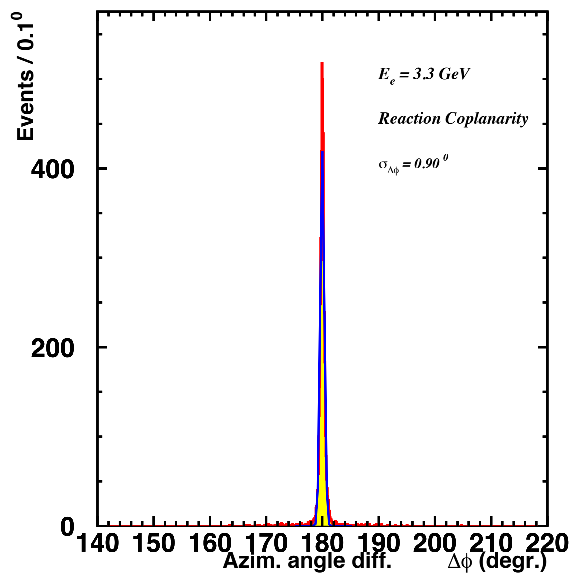
- E_e = 2.2 and 3.3 GeV were chosen for relative ease of scheduling during CEBAF low-energy runs.
- E_e = 2.2 and 4.4 GeV also feasible to ease scheduling between different experimental Halls. (TAC Q.#1)

Experimental Resolutions

- Good energy resolution of $PbWO_4$ calorimeter (2.6% @ E=1 GeV) and 1 μm thin target provides powerful energy selection cut in this experiment (ΔE = 47 MeV @ 3.3 GeV beam).
  - ✓ important selection criterion for multi-channel and; accidental events;
  - ✓ critical cut at low-mass range (see next slides).

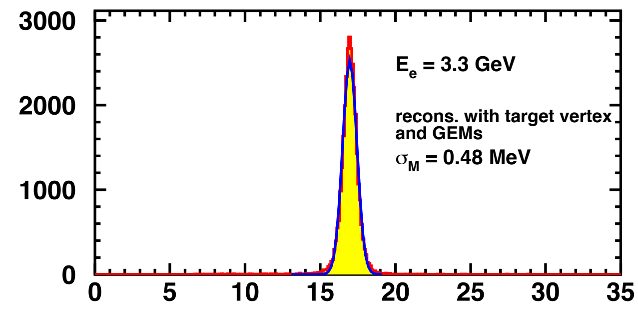


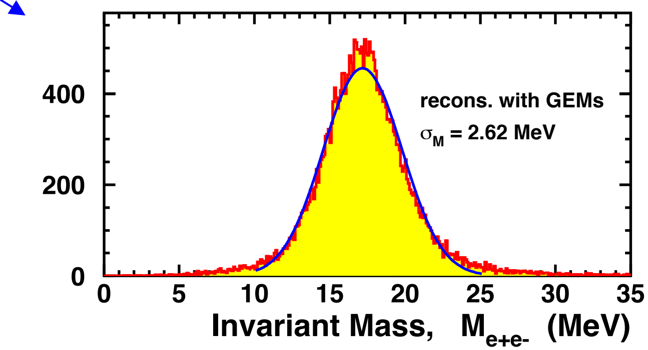
- Coplanarity (between $\overrightarrow{P_{e'}}$ and ($\vec{P}_{e+} + \vec{P}_{e-}$) vectors): ($\vartheta_{\Delta\varphi} = 0.9^0$)
  GEMs excellent position resolution (σ=72 μm), together with very thin 1 μm target (2.4×10^{-4} r.l.) provides event selection criterion ($\vartheta_{\Delta\varphi} = 0.9^0$), important for:
  - ✓ multi-particle and;
  - ✓ accidental coincidence events.



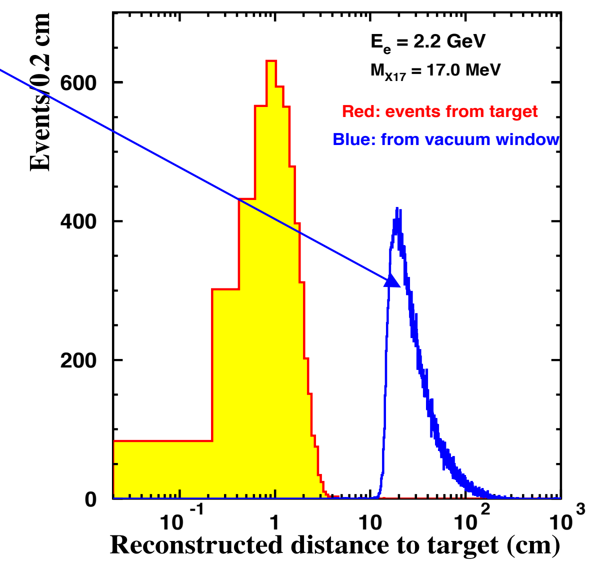
Experimental Resolutions (cont.)

- Invariant mass reconstruction (in two ways):
  - ✓ with vertex, GEMs and $PbWO_4$ calorimeter, σ_m =0.48 MeV for X17 particle;
  - ✓ with GEMs and $PbWO_4$ calorimeter (no vertex).
  - ✓ This will be used to check if "peak events" are coming from the target.





- Two GEM planes (with $PbWO_4$) will effectively discriminate events not originating from the target (for example, from the vacuum chamber exit window).



- However, in this proposal GEMs are not designed to measure the "decay length".
  This is not a "displaced vertex" search experiment.

Physics Background Simulations (PAC49 recommendation #1)

- Physics background was simulated in two different ways and by two different groups (PAC49 recommendation) using:
  1) GEANT based MC simulation package with;
     - ✓ GEANT3 package, results reported in PAC49;
     - ✓ GEANT4 new simulations, results reported and compared here.
  2) MADGRAPH5 EM event generator and GEANT for secondary interaction and tracking.
     - ✓ MadGraph5 with GEANT3 reported in PAC49;
     - ✓ MadGraph5 with GEANT4 reported and compared here.

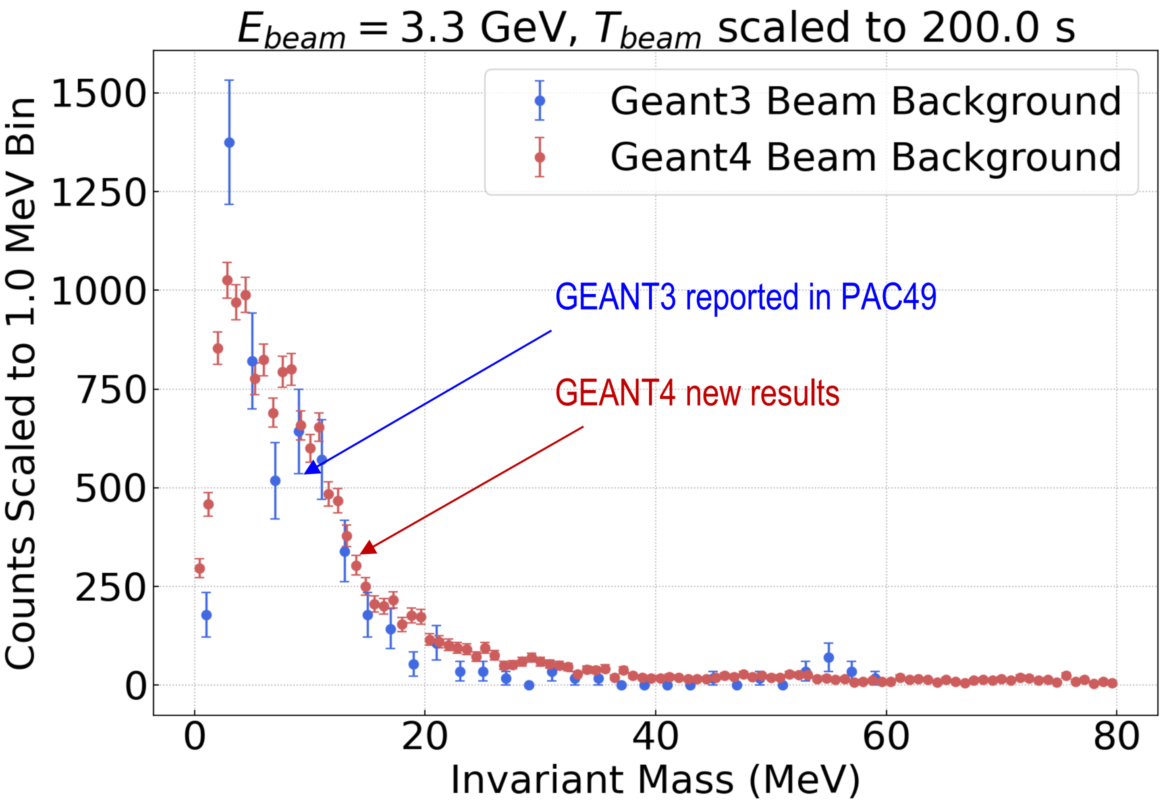
1) GEANT based Monte Carlo background simulations:
   - ✓ PRad experimental setup was adapted for these simulations;
   - ✓ all physics processes had been activated in GEANT;
   - ✓ large amount of beam electrons passed through the target;
   - ✓ events with $N_{cluster} \geq 3$ were analyzed in the same way as the signals.

2) MadGraph5 EM event generator-based background simulations:
   - ✓ large statistics (~2M) trident events (Bethe-Heitler, Radiative, Interference);
   - ✓ these events were fed into the GEANT MC simulation package;
   - ✓ same analysis procedure was applied for these events.

Physics Background Simulations
(comparison between new GEANT4 and previous GEANT3 results)

1) GEANT based full MC background simulations from two quasi-independent groups:

- GEANT3 previous results:
  - ✓ used only basic experimental setup;
  - ✓ limited statistics;
  - ✓ reported in PAC49.
- GEANT4 new results:
  - ✓ full PRad-II detector package included and modified for these simulations;
  - ✓ significantly improved statistics;
  - ✓ new for this PAC50.

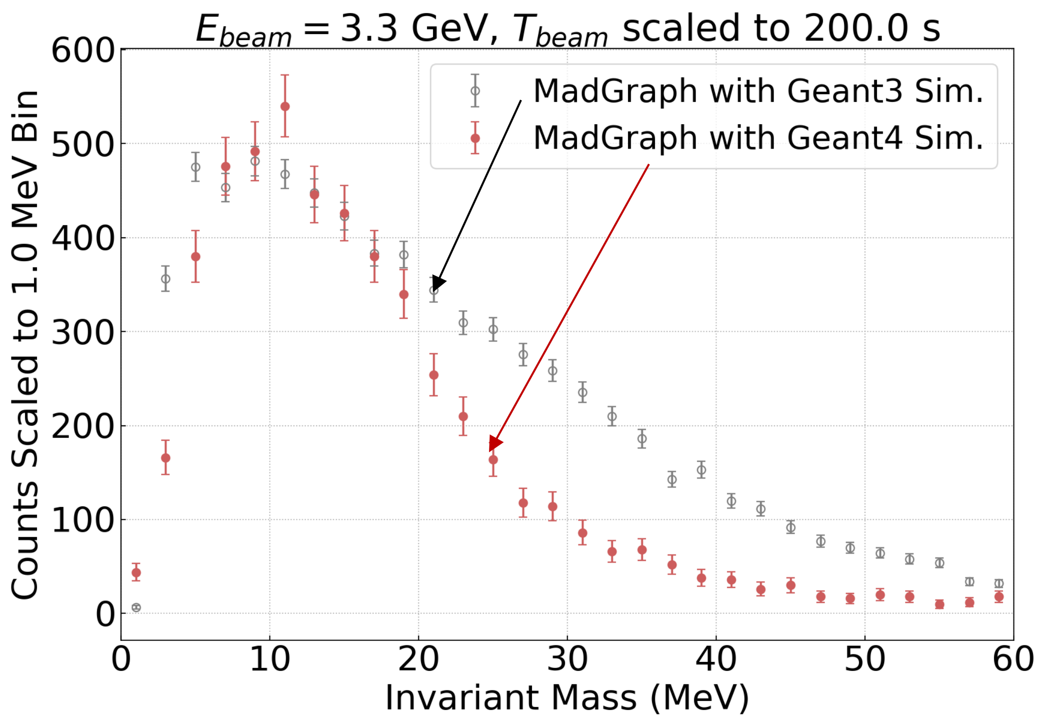


- Consistent results

Physics Background Simulations (EM Background)
(comparison between new MadGraph5 and previous MadGraph5 results)

2) MadGraph5 EM event generator-based background simulations from two quasi-independent groups.

- ✓ large statistics (2M) trident events (Bethe-Heitler, Radiative, Interference);
- ✓ these events were fed into the GEANT MC simulation package;
- ✓ same analysis procedure was applied.



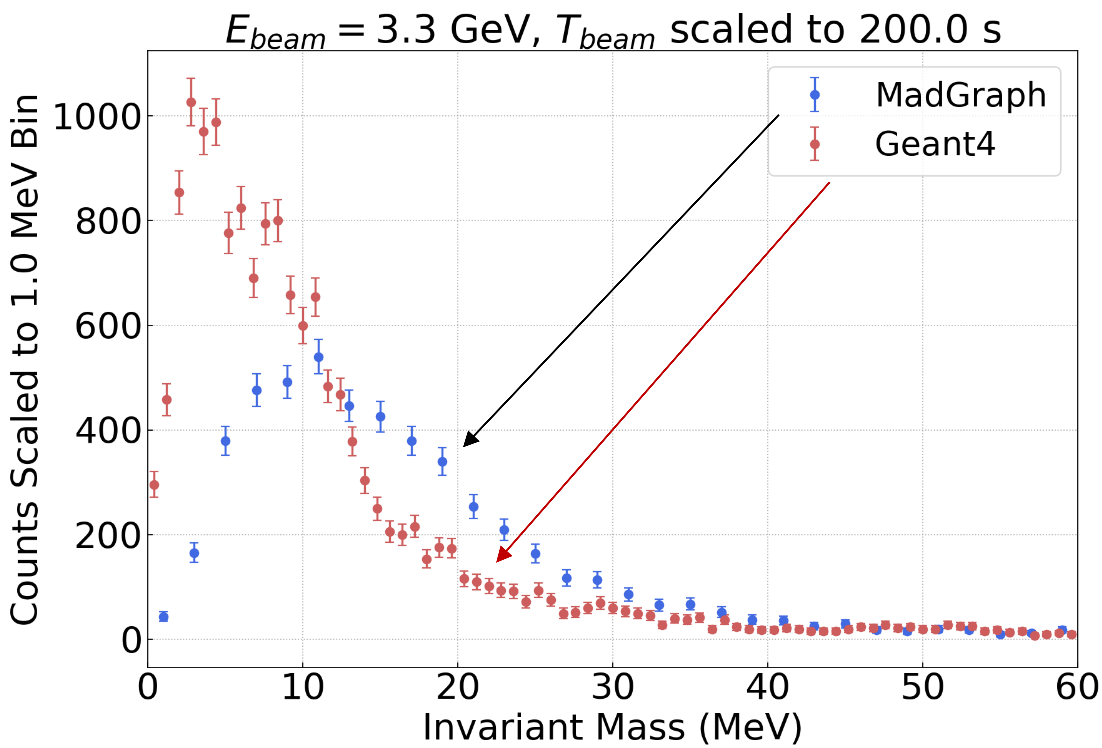
- MadGraph5 + GEANT3 from PAC49
- MadGraph5 + GEANT4 new results

- ✓ consistent results at low mass region;
- ✓ relatively smaller tail at larger masses due to more detailed experimental setup

- Obviously, this experiment is more sensitive to basic EM processes, and description of experimental setup in the simulation package.

Physics Background Simulations
(comparison between new MadGraph5 and new GEANT4 results)

- GEANT4 with full setup, with all physics processes, new results.
- MadGraph5 + GEANT4, new results.

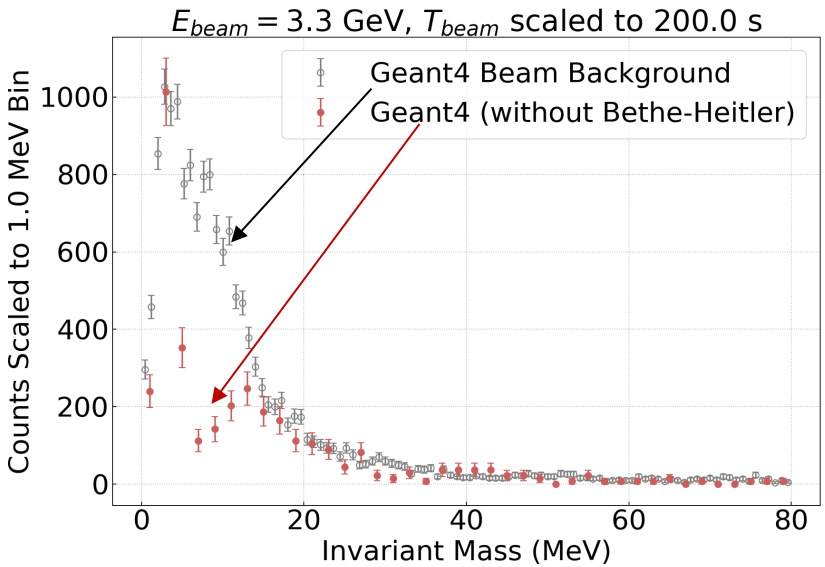


- ✓ consistent results at large mass region;
- ✓ more GEANT events at very low mass range; (small angle scattering effects);
- ✓ factor of 2 difference at middle masses, showing that:

- ➢ the experiment is more sensitive to basic EM processes;
- ➢ MadGraph5 is more advanced EM event generator than those used in GEANT.

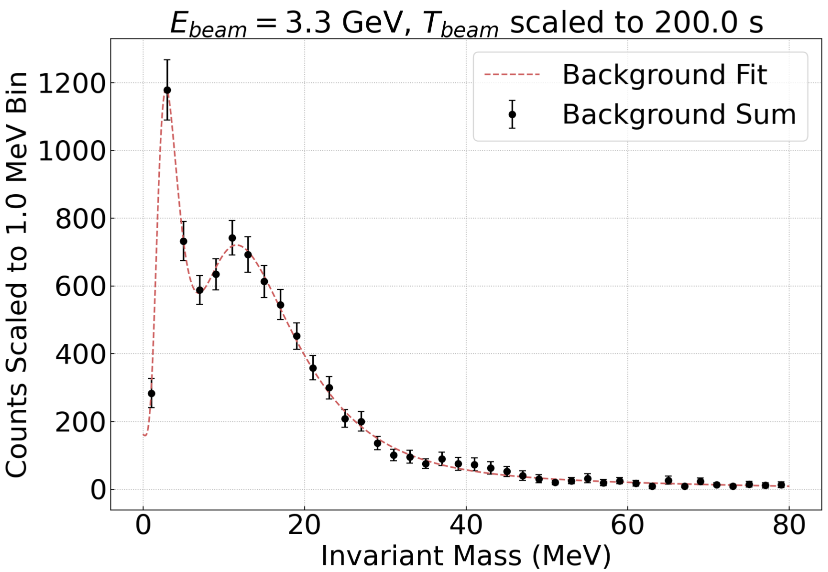
Physics Background Simulations (Hybrid Method) (new GEANT4 without BH + MadGraph5)

- Therefore, we combined:
  - ✓ GEANT4 without the Bethe-Heitler process activated;



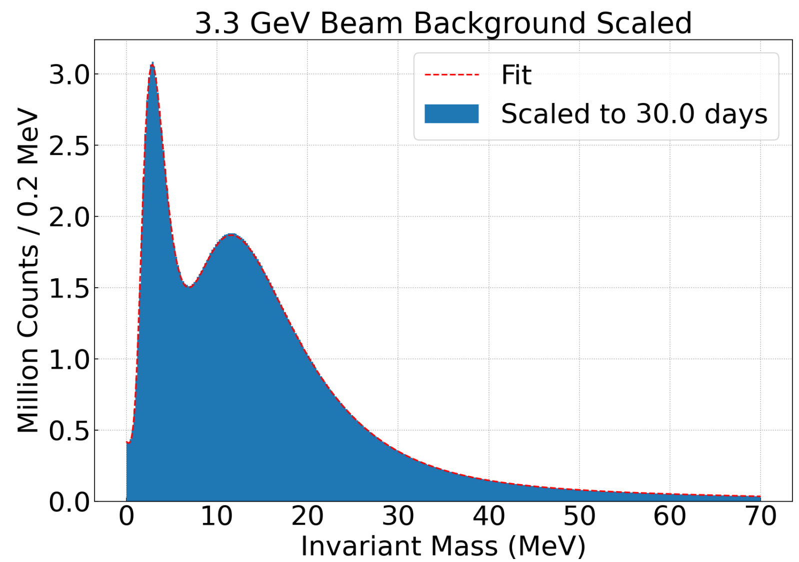
  - ✓ and summed with the results simulated with the full MadGraph5 event generator.

- The resulting background shape was fit with: Landau + Log + constant terms.

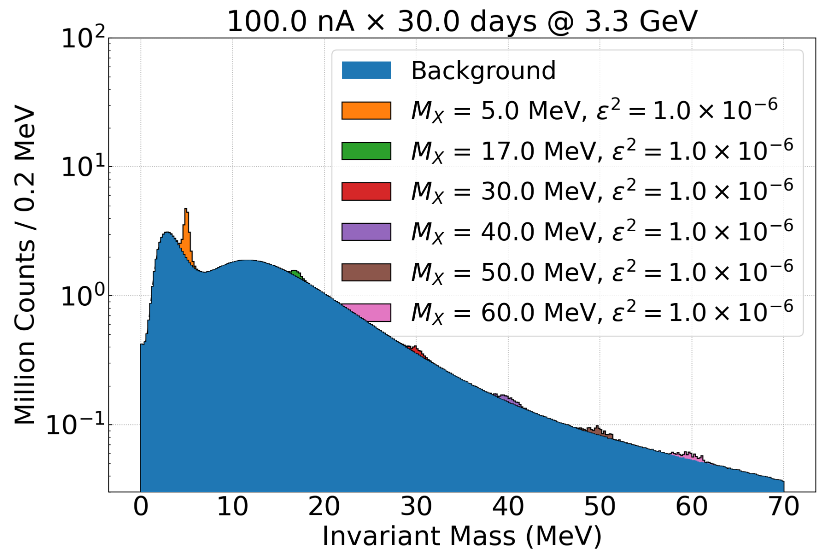


Physics Background Simulations (Hybrid Method)
(fit and scaled to the beam time)

- The simulated hybrid background was scaled to 30 days of beam time (I_e = 100 nA, 1 μm Ta target)



- and projected signal events with $\varepsilon^2 = 1.0\text{x}10^{-6}$



Beam Time Request and Statistics

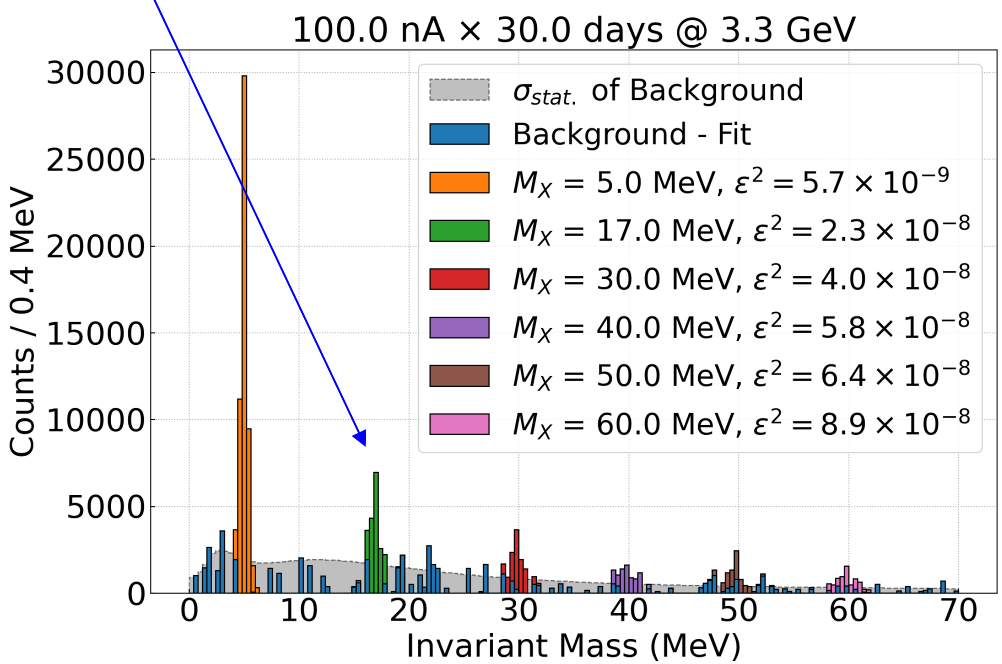
- Target: Ta; thickness: 1 μm ($t = 2.4\times10^{-4}$ r.l.), $N_{tgt} = 0.56\times10^{19}$ atoms/cm^2
  for $E_e = 3.3$ GeV and $I_e = 100$ nA ($N_e = 6.25\times10^{11}$ e^-/s),

  Example: the estimated X17 production rate (J. D. Bjorken, et al. Phys. Rev. D, 80:075018. 2009):

  $N_{X17} \sim N_C * N_e * t * \varepsilon^2 * (m_e/m_x)^2$

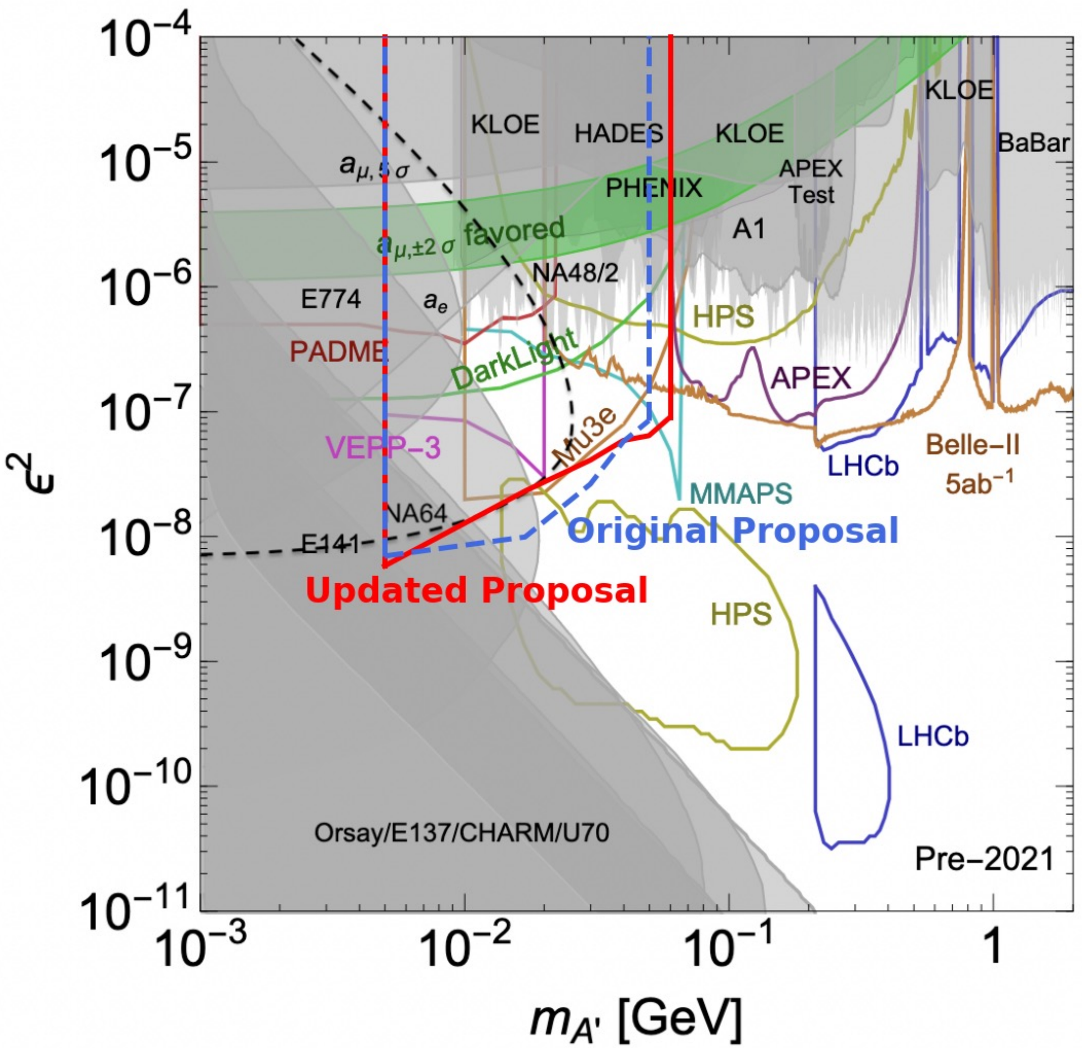
  $\approx$ 32 K produced events per 30 days for $\varepsilon^2 = 2.3\times10^{-8}$ ($N_C = 5$)

	Time (days)
Setup checkout, calibration	4.0
Production at 2.2 GeV, 50 nA	20.0
Production at 3.3 GeV, 100 nA	30.0
Energy change	0.5
Empty target runs	5.5
Total	60



ε^2 *vs.* Mass Parameter Space

- Invariant mass range: [3 -- 60] MeV
- Coupling constant: $\varepsilon^2 \approx [10^{-8} - 10^{-7}]$
- This proposal uses 5σ limits (discovery criterion as per PDG), while the common practice is to use 2 - 2.4 σ.



$X \to \gamma\gamma$ Decay Channel
(PAC49 recommendation #2)

- *"… it is not discussed in the current proposal how to detect the $\gamma\gamma$ final states, and in particular how to suppress background when tracking information is not available. The PAC suggests the proponents to develop the $\gamma\gamma$ part of the proposal further. "*

The approach of this proposal:

- The current design of the experiment is focused on the $X \to e^+e^-$ channel detection, providing a maximum resolution for e^+e^- invariant mass determination (no converters on front of GEMs). However, with this design:
  - ✓ the $\gamma\gamma$ decay photons will also be detected by the $PbWO_4$ crystal part of HyCal (providing measurement of each photons energy and position).
  - ✓ both GEMs will act as veto detectors.
  - ✓ assuming the vertex origin (the target) that will provide reconstruction of the $\gamma\gamma$ invariant mass with $\approx 3\ MeV$ resolution.
  - ✓ still providing an effective "bump hunting" search for the $X \to \gamma\gamma$ channel.
- In case of any experimental indication of a "signal", or for the second stage of this experiment we will develop a new experimental proposal focusing on the neutral decay channels:
  - ✓ add a converter on front of second GEM. The first GEM will still play as a veto detector.
  - ✓ the second GEM will effectively provide the positions and directions of the decay photons by detection the converted charged EM particles.
  - ✓ providing significantly approved $\gamma\gamma$ invariant mass determination (by factor of 2).

Summary

- We propose a cost-effective, ready-to-run experiment based on the PRad apparatus to:

  1) validate existence or set an experimental upper limit on a search for hypothetical X17 particle, recently claimed by the ATOMKI group (up to $\varepsilon^2 \approx 1.9\text{x}10^{-8}$ level).
  2) search for hidden sector new particles in [3 ÷ 60] MeV mass range within a coupling constant sensitivity in $\varepsilon^2 \approx [10^{-8} - 10^{-7}]$ range;

- It is a non-magnetic experiment with the detection of all 3 final state particles (including both $X \rightarrow e^+e^-$ charged and $X \rightarrow \gamma\gamma$ neutral channels), providing a tight control of background, reaching to a low range in coupling constants.

- The new background MC simulation results performed by a quasi-independent group are in a good agreement with the results previously reported in PAC49.

- The proposed experiment is fully complimentary to currently approved and/or running experiments by its suggested experimental method and by the mass range of sensitivity (including HPS and APEX at JLab), more focusing on the low-mass range.

my research work is supported in part by NSF award: PHY-1812421

Backup Slides

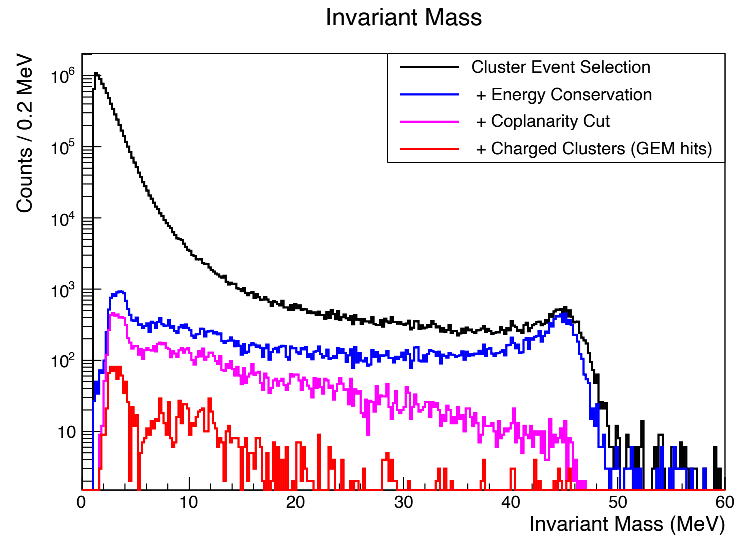
Event Selection Criteria

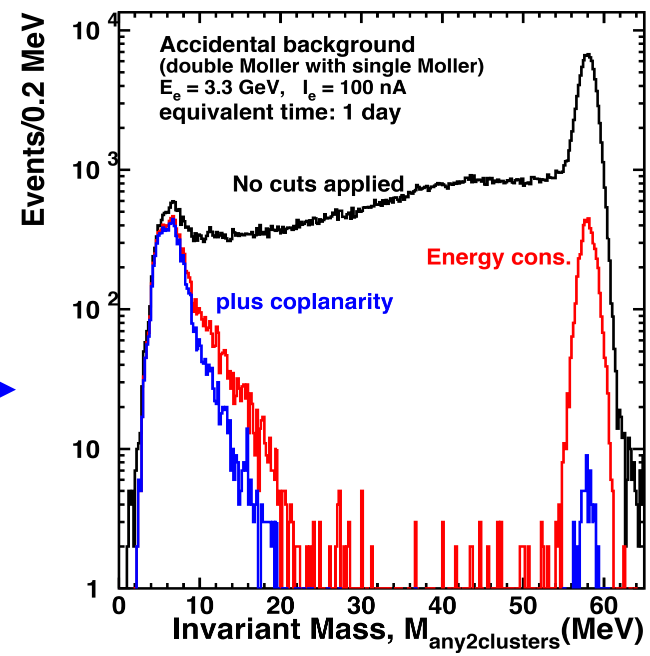
- Detection of all 3 final state particles provides following event selection criteria:
  - ✓ conservation of total energy;
  - ✓ reaction coplanarity;
  - ✓ invariant mass;
  - ✓ particles charge;
  - ✓ reconstructed position on target plane.

- Important feature of this experiment.

- Effects of these "cuts" are shown for PRad short test run on ^{12}C target.

… and for MC accidental events simulated for this experiment.

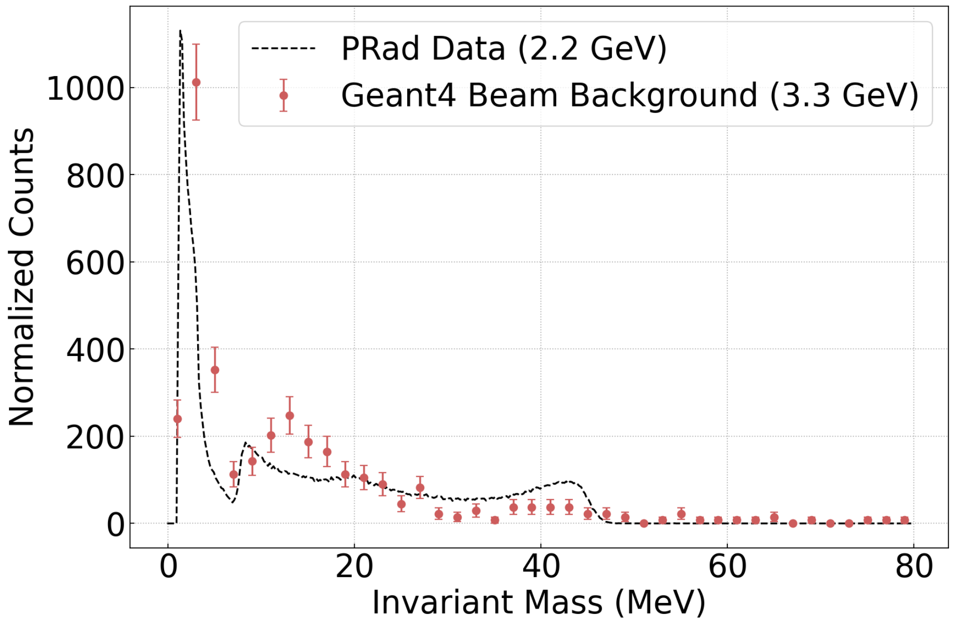




Background Simulation for PRad Hydrogen Data
(Reader's Q#2)

- PRad data on hydrogen target analyzed in the same way as the "signal" events.

- GEANT4 based MC simulation was performed to describe the experimental data:
  - ✓ currently, only E_e = 3.3 GeV simulation results are available to compere with the experimental data;
  - ✓ there is a good qualitative agreement between the MC simulation and experimental data.



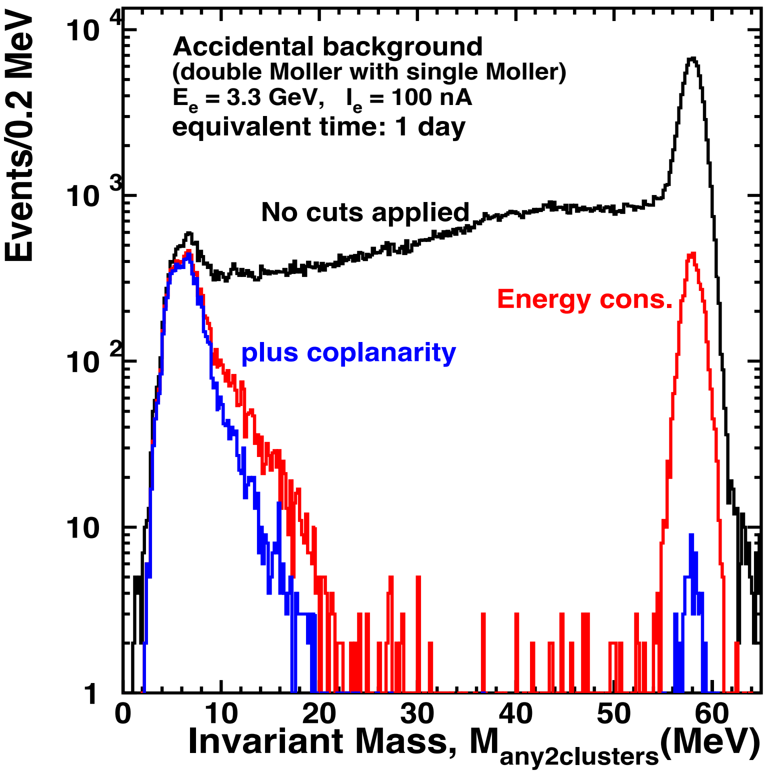
Accidental Background (Accidental Coincidence Rate)

- Hardware trigger requires 3-claster events:
  - ✓ $N_{cluster} \geq 3$
  - ✓ each one within: 30 MeV < $E_{cluster}$ < $0.8xE_{beam}$
  - ✓ $E_{total} > 0.7xE_{beam}$

- Two high-rate processes in this experiment are:
  - ✓ electron-nucleus (Rutherford) elastic scattering (trigger will effectively suppress these events).
  - ✓ Moller scattering (source of major accidentals).

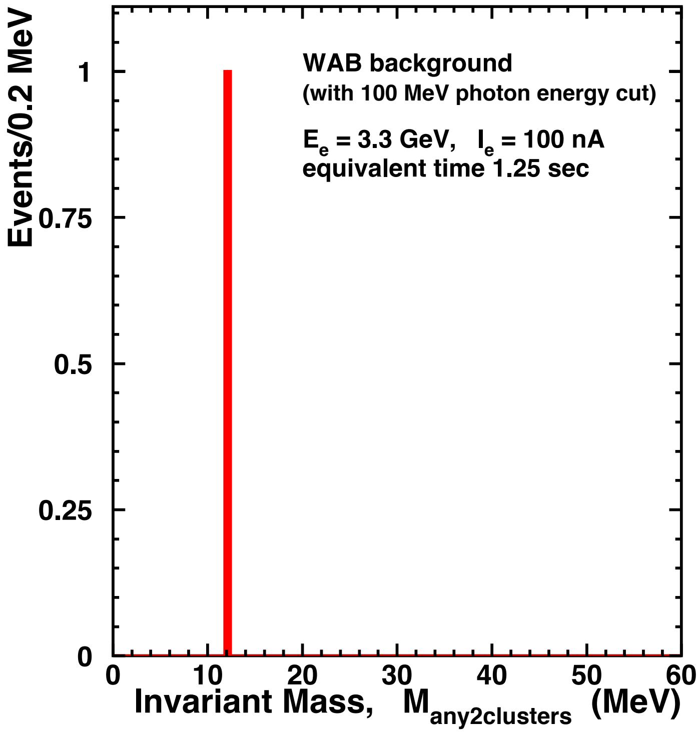
- Estimated rates for two main sources are:
  - ✓ singles from Moller: Rate ≈ 107 kHz
  - ✓ doubles from Moller: Rate ≈ 81.7 kHz

- Assuming 2 ns time resolution (bunch size):
  - ✓ accidental coincidence rate: ≈17 Hz
  - ✓ is not significant background contribution.



Physics Background Simulations (WAB Generator)

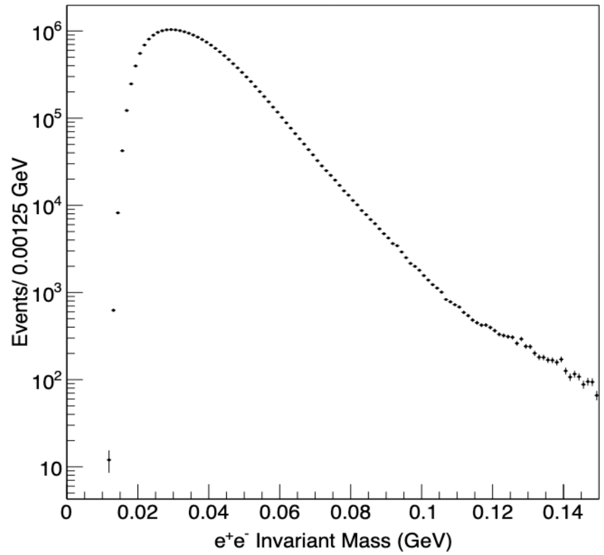
- Wide Angle Bremsstrahlung (WAB) generator was also used to estimate the background (suggested by HPS people).
  - ✓ 1 M events were generated for $E_e = 3.3$ GeV beam, equivalent to 1.25 sec of $I_e = 100$ nA beam;
  - ✓ generator thresholds: $E\gamma = 100$ MeV, $\vartheta_{x,y} = 0.003$ rad;
  - ✓ these events also fed to the GEANT MC code,
  - ✓ detected events with $N_{cluster} \geq 3$ were analyzed same way as the signals.



- Estimated rate for this process is: $\sim$1 Hz
  - ✓ not significant contribution to the background

Other Similar Experiments/Projects at JLab

- HPS (running experiment at JLab)
  - ✓ search for $A' \to e^+e^-$ in $M_{A'}$ = [20-1000] MeV;
  - ✓ magnetic spectrometer method;
  - ✓ only e^+e^- detected, $\varepsilon^2 > 10^{-7}$;
  - ✓ with displaced vertex detection: $10^{-8} \leq \varepsilon^2 \leq 10^{-10}$



HPS: [hep-ex] arXiv:1807.11530, 2018

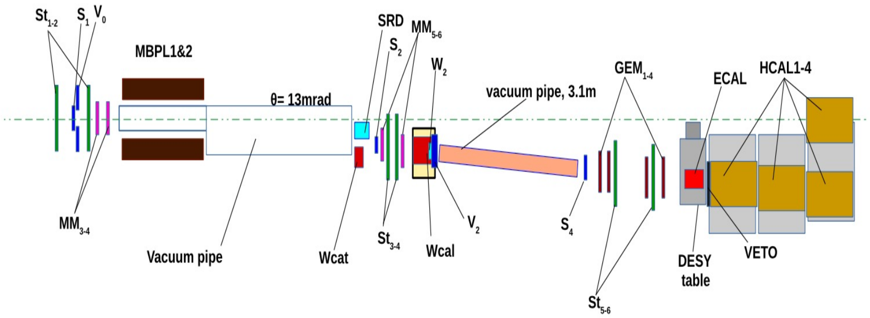
- APEX (running experiment at JLab)
  - ✓ search for $A' \to e^+e^-$ in $M_{A'}$ = [$65 - 525$] MeV;
  - ✓ magnetic spectrometer method;
  - ✓ only e^+e^- detected, $\varepsilon^2 > 9\times10^{-8}$;

- DarkLight (approved JLab experiment)
  - ✓ search for $A' \to e^+e^-$ in $M_{A'}$ = [10-90] MeV;
  - ✓ magnetic spectrometer method;
  - ✓ e^+e^- detected, $\varepsilon^2 > 3\times10^{-7}$;

- The proposed experiment:
  - ✓ non-magnetic, will detect all 3 particles, e', e^+, e^-
  - ✓ search for $X \to e^+e^-$ $(\gamma\gamma)$ in M_X = [$3 - 60$] MeV;
  - ✓ similar range: $10^{-7} \leq \varepsilon^2 \leq 10^{-9}$
  - ✓ sensitive to neutral channels.

Other Similar Experiments/Projects

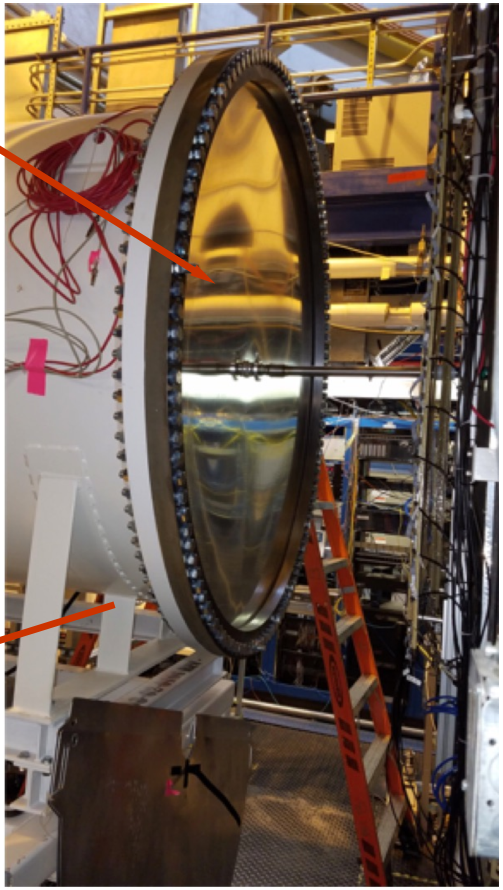
- NA64 (experiment and new proposal with SPS at CERN
  - ✓ combination of “beam dump” and direct e^+e- detection;
  - ✓ first EM calorimeter is an active “dump” (~40 r.l.), second EM detects e+e- pairs;
  - ✓ assumes relatively long decay length for A’ (or X);
  - ✓ total energy conservation;
  - ✓ mass range: $\leq$ 23 MeV,
  - ✓ experiments in 2018 and 2020:
    $1.4\text{x}10^{-8} \leq \varepsilon^2 \leq 4.6x10^{-7}$ (90% confidence limit)
  - ✓ new proposal for 2021.

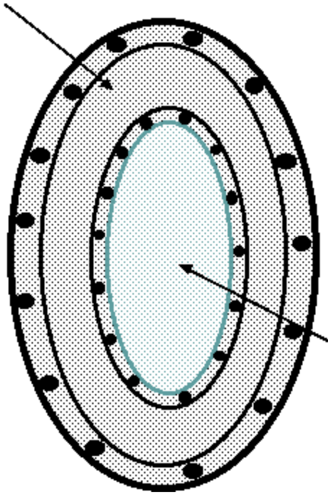


- MAGIX (proposed experiment with MESA at Mainz)
  - ✓ search for $A' \rightarrow e^+e^-$ in $M_{A'} = [8 - 70]$ MeV;
  - ✓ magnetic spectrometer method;
  - ✓ only e^+e^- detected, $\varepsilon^2 \approx [2\text{x}10^{-7} - 8\text{x}10^{-9}]$

New Vacuum Window

- Twice reduced vacuum window will be used: 1m diameter and 1mm Al foil





TAC Questions

This proposal is compatible with the existing HyCAL but requires a different DAQ setup. The proposed flash ADCs require about a 1 million US $ investment and does not include the required VXS crates with CPU, trigger interface and switch slot modules. It would however make the NIM crate system forming the trigger energy sum obsolete as this can be done with the flash ADC system. The DAQ will not be able to read out full wave forms at a trigger rate of 25kHz.