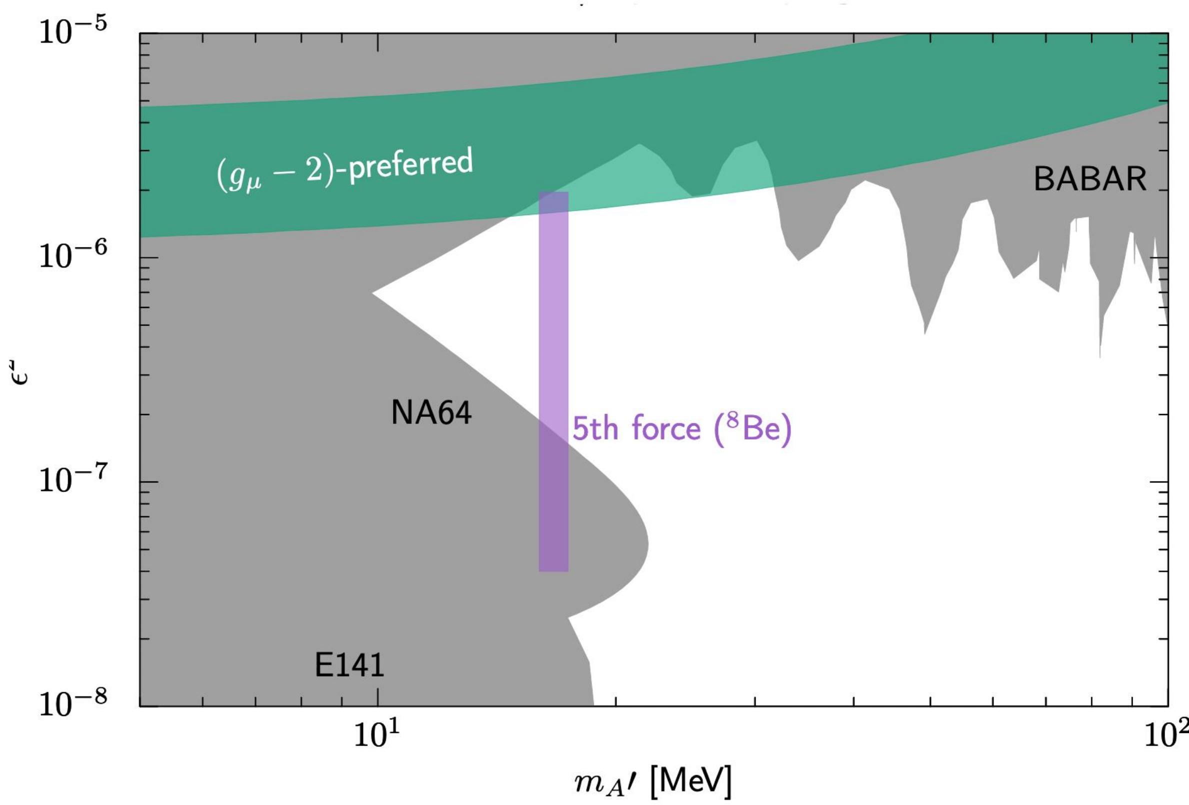
X17 Running at 4.4 GeV and Other X17 Business



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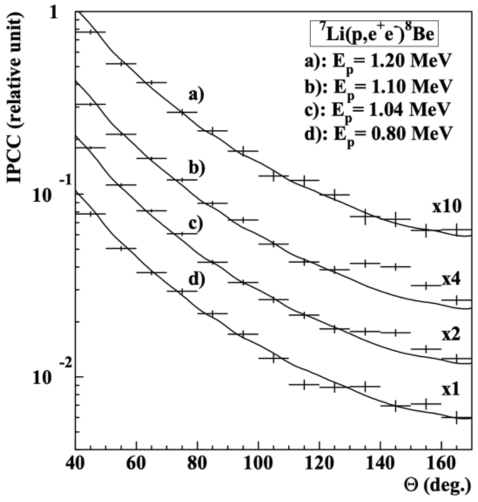
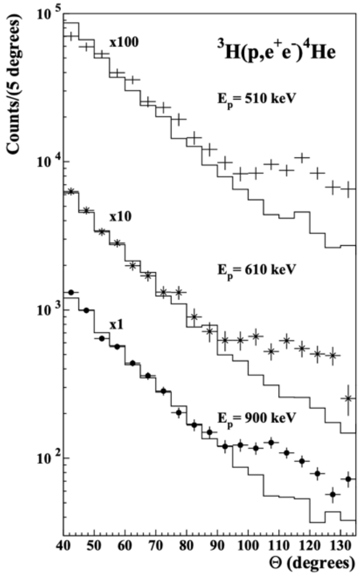
Experiment Motivation

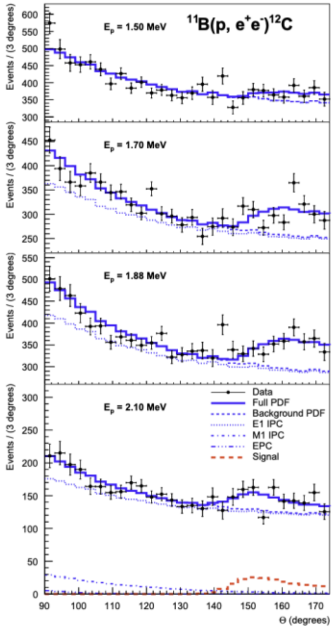
- ATOMKI group reported X17 anomaly in e+e- spectrum from excited nuclear states
- Posited to be a “dark photon” candidate
- Cross-section peaks at forward angles -> PRad setup

Figures below:

- Left – “Be8 Anomaly”
  - A.J. Krasznahorkay *et al.* (2015)
- Center – Anomaly seen in He4
  - A.J. Krasznahorkay *et al.* (2021)
- Right – Anomaly seen in C12
  - A.J. Krasznahorkay *et al.* (2022)



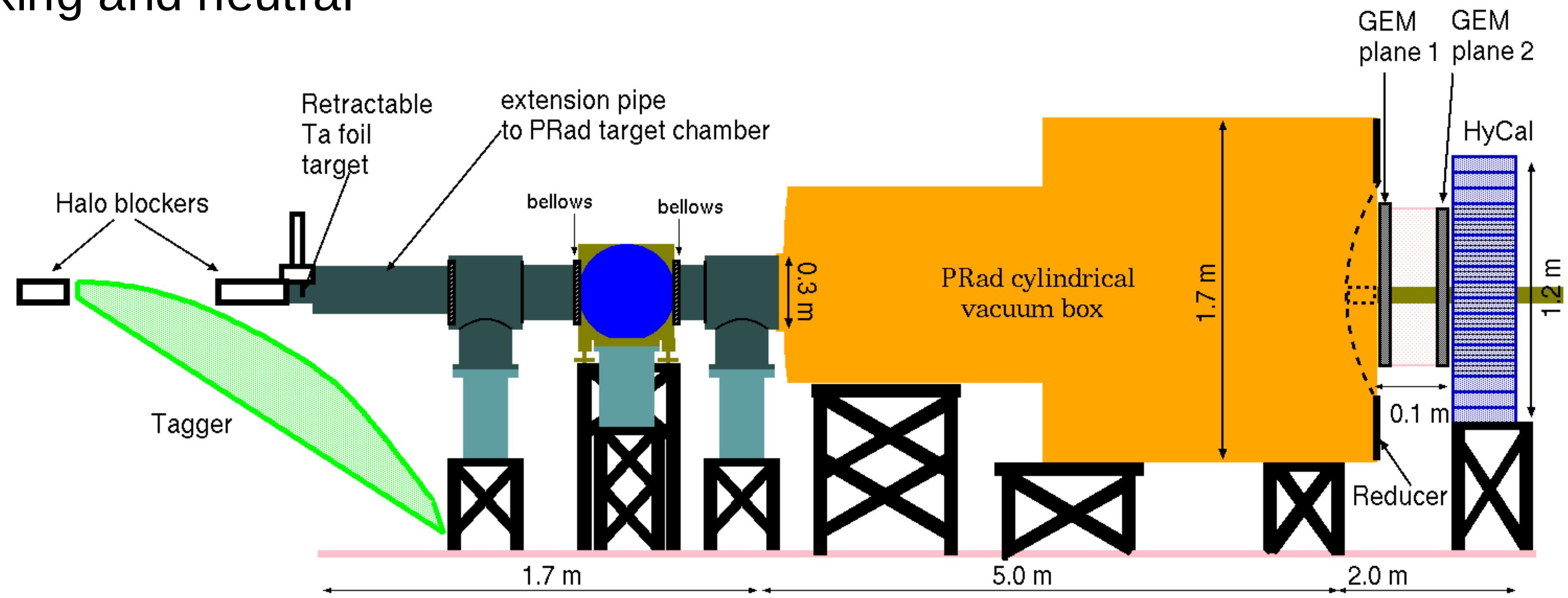




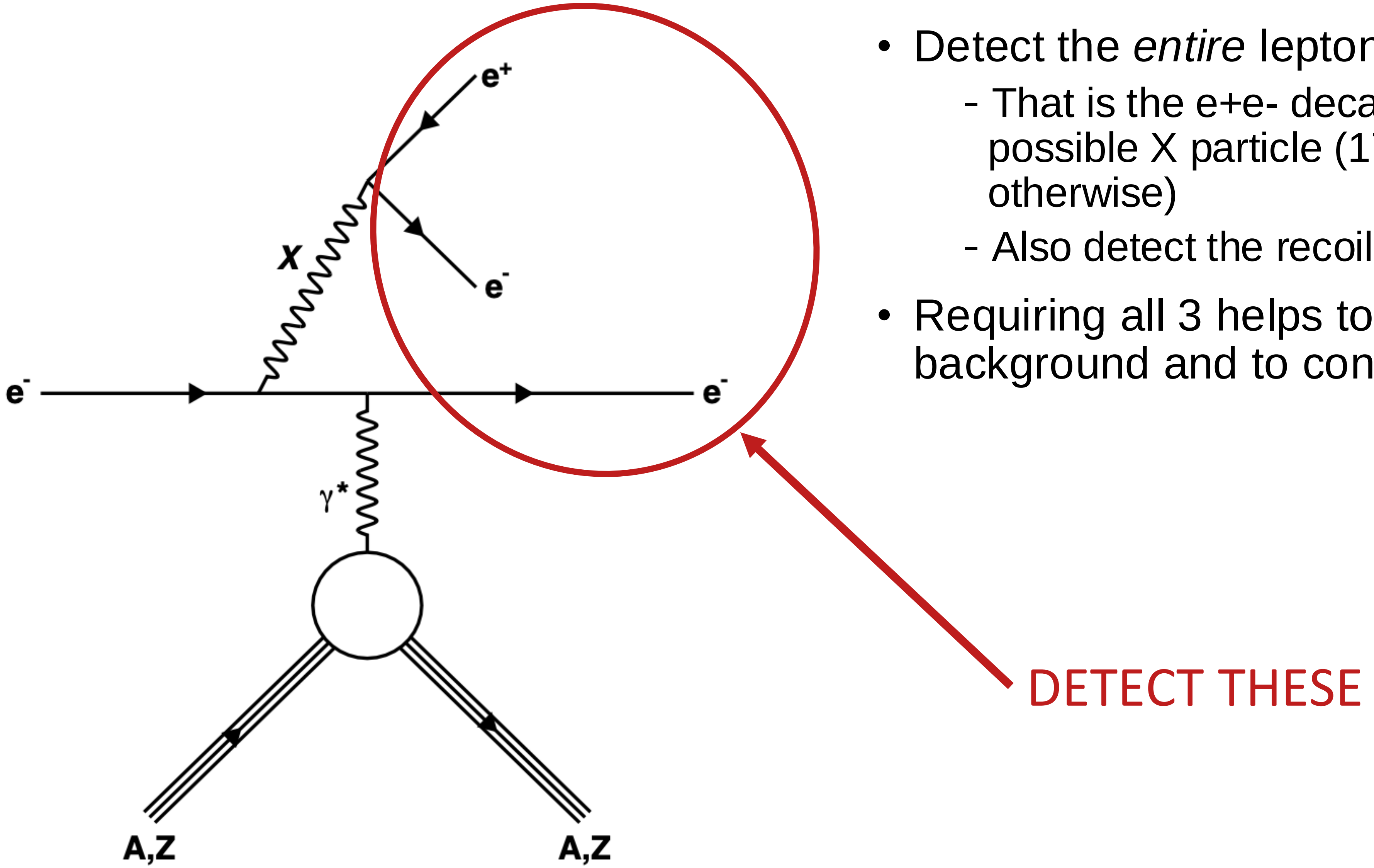
The PRad Setup for X17

- 1 micron Tantalum target mounted to harps
- 7.5 meters from target to HyCal
- Focus on using high-precision PbWO4 crystal region
- Two GEMs for tracking and neutral rejection

Experimental Setup (Side View)



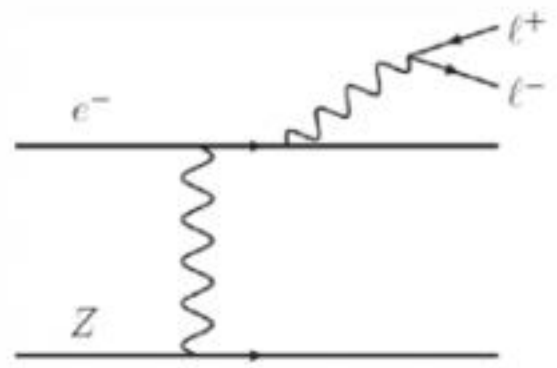
Planned Measurement



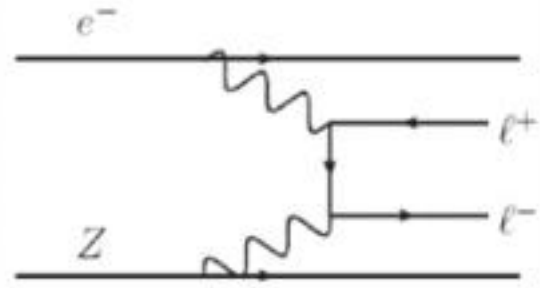
- Detect the *entire* lepton final state
  - That is the e+e- decay products of any possible X particle (17 MeV or otherwise)
  - Also detect the recoil beam electron
- Requiring all 3 helps to reduce background and to constrain kinematics

Backgrounds

- The primary backgrounds are
    - Bethe-Heitler
    - Trident Production
- Many generators do not agree on the Bethe-Heitler distribution in phase space
    - Proposal studied some variations
    - Need to eventually compare to data
- Additional combinatoric background from inability to distinguish electrons and positrons



"Radiative"



"Bethe-Heitler"

Run Plan and Possible Changes

- Proposal focused on running at 2.2 GeV and 3.3 GeV
  - Two beam energies helps to mitigate false positives

- JLab schedule would work better if we use 4.4 GeV instead of 3.3 GeV
  - Will show work from the proposal as well as ongoing studies

	Time (days)
Setup checkout, tests and 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
No target background sampling at 2.2 & 3.3 GeV	5.5
Total	60.0

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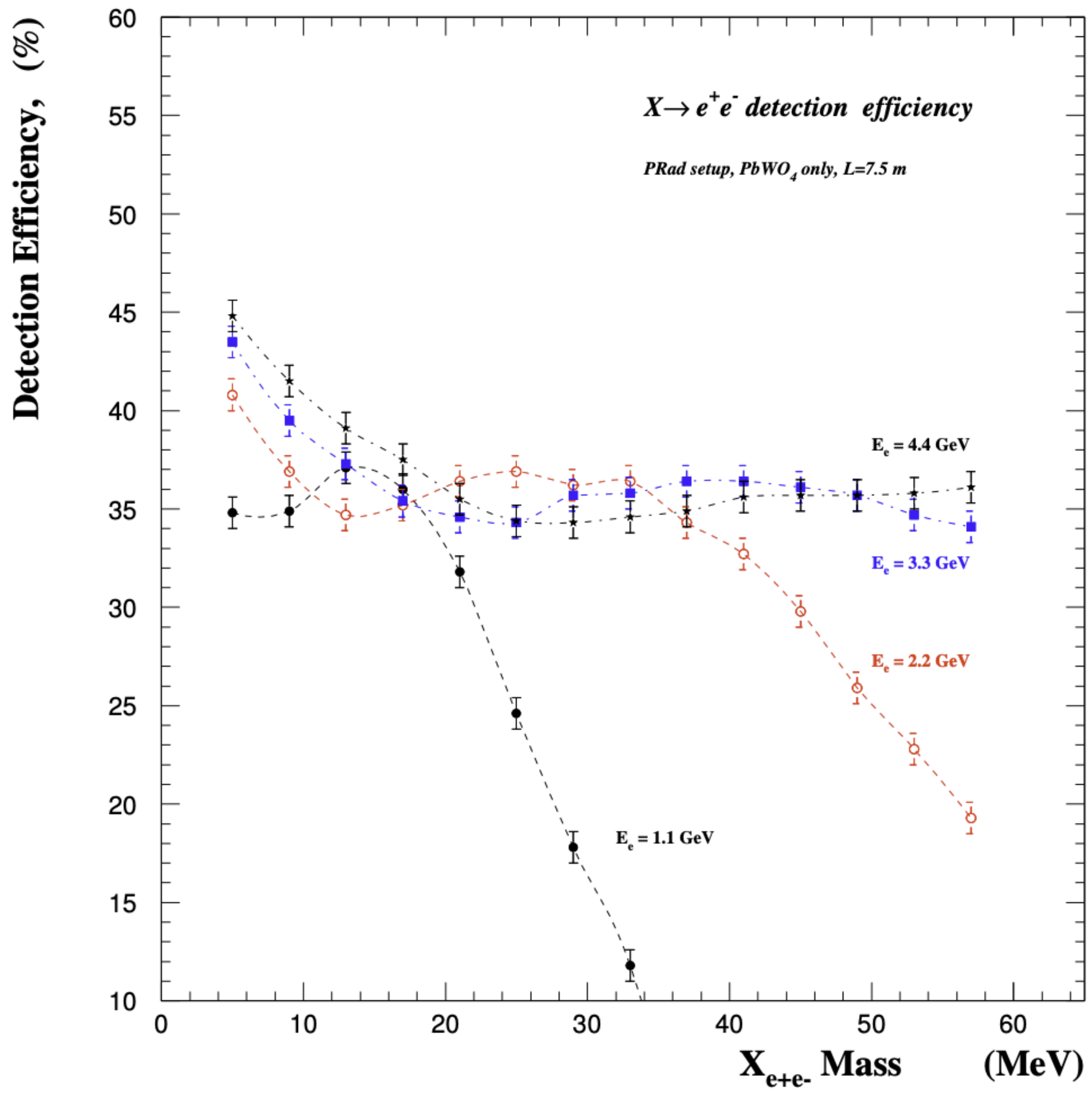
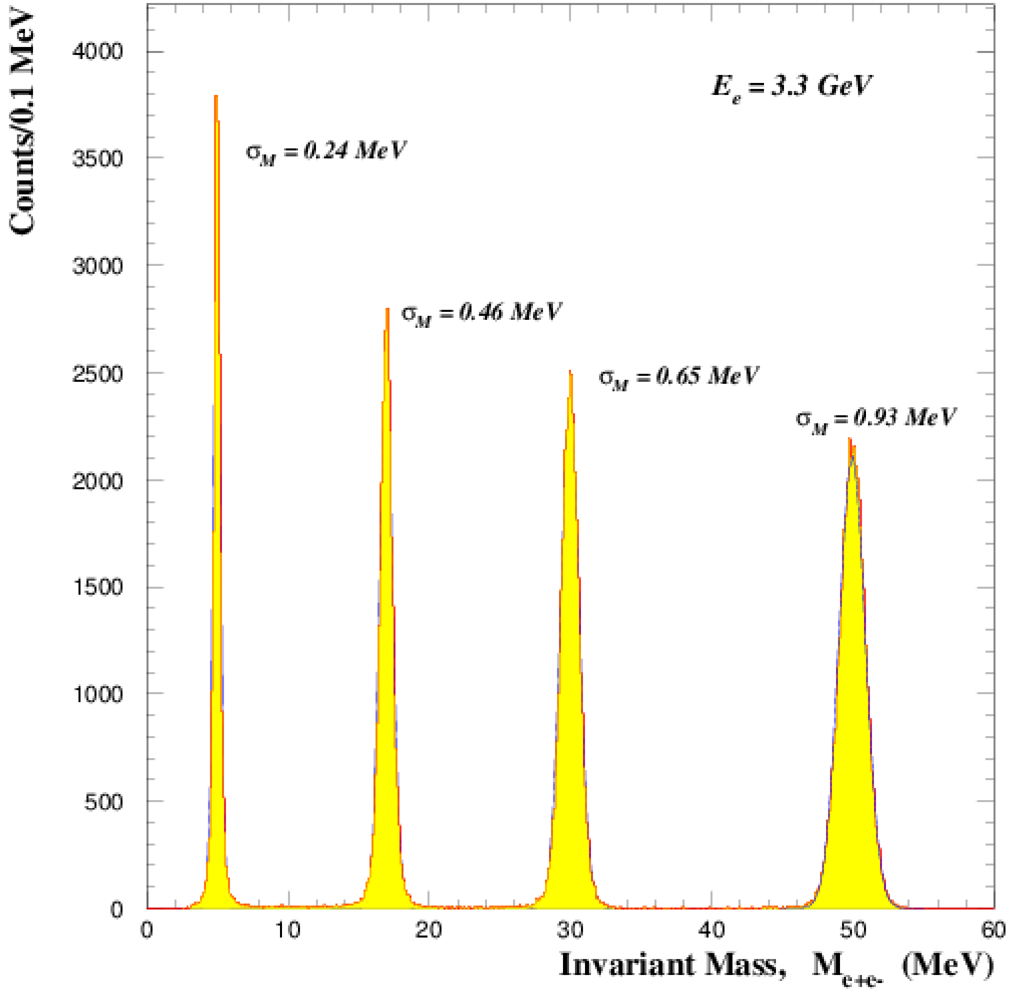
Geometric Acceptance of X Particles



- Plot from proposal shows that 4.4 GeV should work well
- Has similar detection efficiency to 3.3 GeV
- Other considerations
  - Mass resolution
  - Effect on cross section
  - Effect on background

Jefferson Lab

Mass Resolution



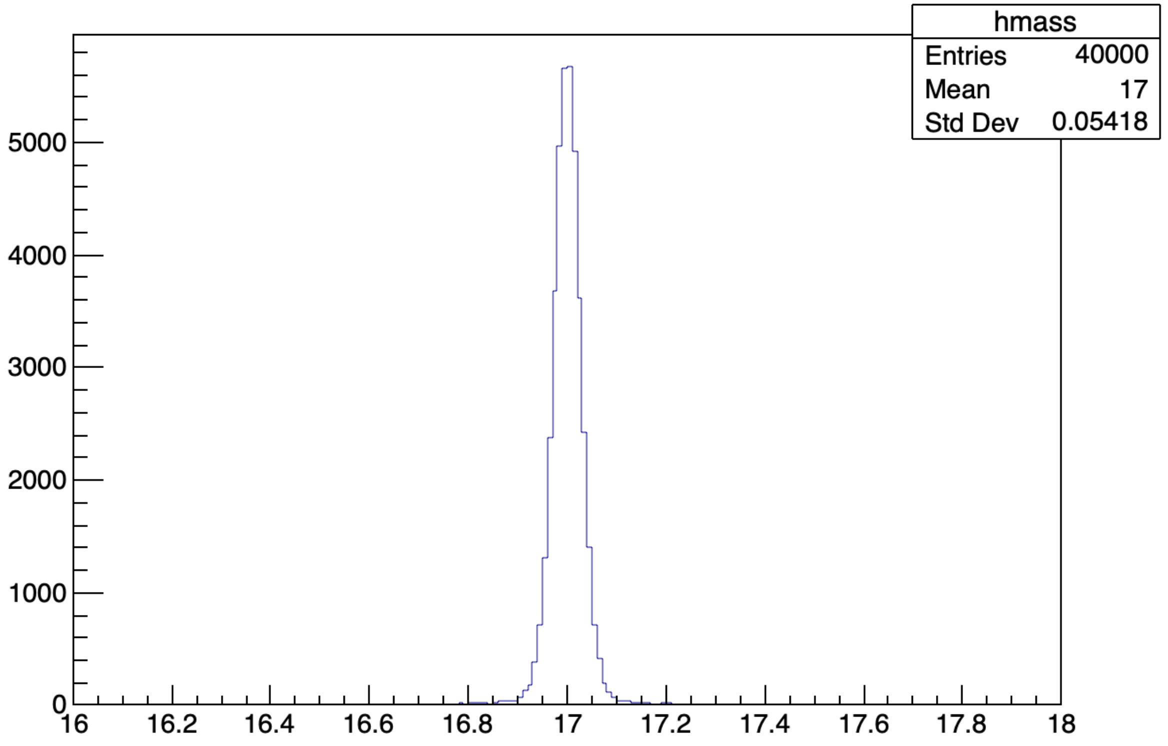
- 3.3 GeV Mass resolution from the proposal
- Dominant contribution to the resolution is energy uncertainty, which improves at higher energies

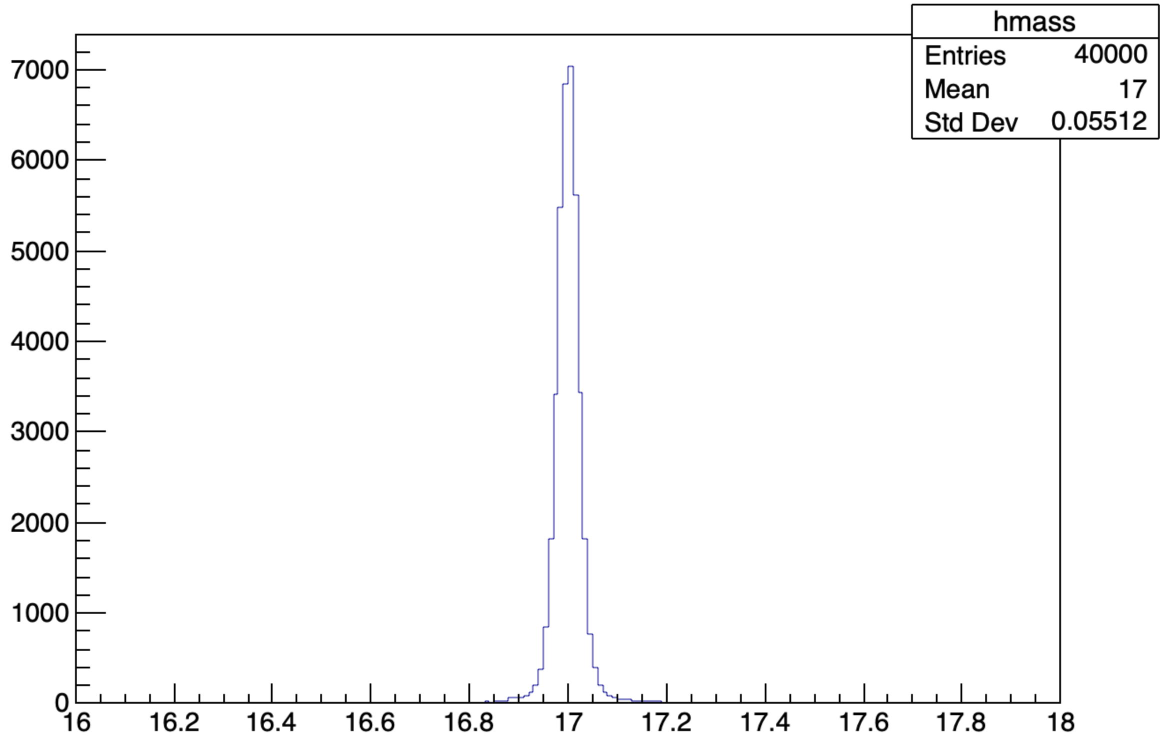
$$\frac{\sigma_E}{E} \approx \frac{2.6\%}{\sqrt{E}}$$

- This is the simplified case, plugging in a multiplication factor gives a very unrealistic expectation
  - However, it is clear from this that increasing the energy will improve the resolution

Mass Resolution – Ideal Case

- I have generated many events to test the 4.4 GeV case with the new simulation setup
- Ran out of time to pass the events through simulation after getting the setup working
- Hand smeared energy and position based on idealized detector responses
  - Absolute value of the resolution is unrealistic, but trend is valid





To-Do's and Important Caveat

- There are no background studies for 4.4 GeV yet
  - This is *critical* to the success of using 4.4 GeV beam
  - Doing this for 3.3 GeV was not a simple task and we need to do this for 4.4 GeV *ASAP*

BIG CAVEAT:

Increasing the energy gives all final state particles a larger forward momentum component

Generally, this means that more particles are sent down the beampipe and the first PbWO4 ring

- My studies of are ongoing and too preliminary to have useful plots
- However, for a 17 MeV A` production, I see around a factor of ~2 loss in events
- *If* the background decreases by a comparable amount, that's ok. If it doesn't, we need to think hard about the plan

SOMETHING ELSE TO THINK ABOUT:

I see a lot of loss to the first ring of PbWO4 in 3.3 GeV as well. 2.2 GeV may be better to spend more time on. This will be studied further.

- End of this section, not of slides
- To do:
  - Sanity check my generator
    - Based off of Bjorken paper (Weizsäcker-Williams Approximation)
    - Includes a realistic form factor to determine energy and momentum of recoil electron
  - Cross section weighted acceptance
  - Backgrounds at 4.4 GeV

X17 areas that need more people power – a brainstormed incomplete list

- Background studies
  - Our approach to studying the background used Geant4 and MadGraph5
  - These two generators disagree strongly on the Bethe-Heitler spectrum
    - We need some expertise in Bethe-Heitler and Radiative Pair Production to get an expectation of what is closest to reality
    - Expertise could possibly help us optimize cuts to reduce this background as well
- Analysis plans
  - Blinding (next talk will discuss this)
  - Cuts
- Online Analysis
  - What *needs* monitored?
    - Rate
    - GEM performance
    - HyCal performance
    - Blinded analysis means we must ensure we don't create/view plots that could bias the analysis
  - Background studies will give us rate estimates that can serve as sanity checks of incoming data