Darklight ~~Onesie~~ 1c at the CEBAF injector

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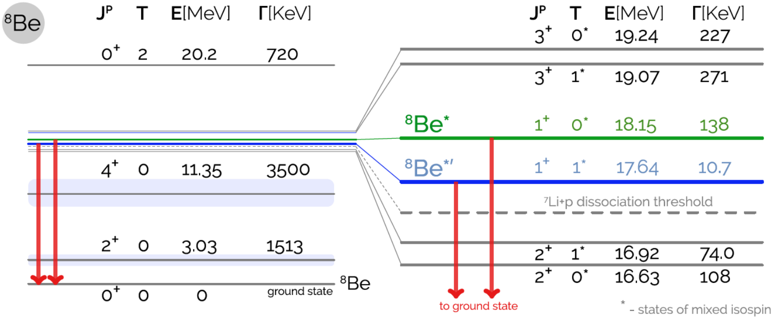
^8Be is special

Many images from arXiv:1707.09749

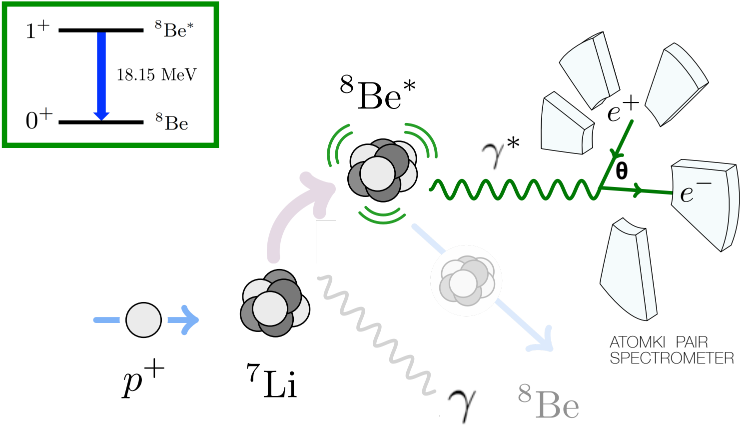
^8Be is special: two narrow, highly energetic states which can decay to ground state via E/M



Decay modes of $^{8}Be(18.15)$

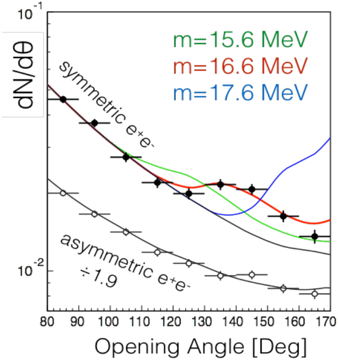
Hadronic, electromagnetic and through internal pair conversion

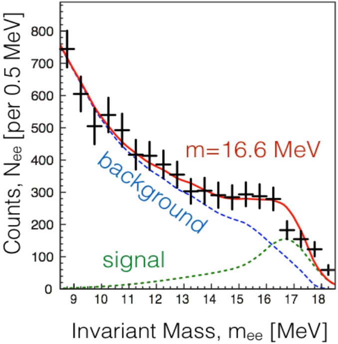
The Atomkin experiment



1.04 MeV proton beam on ^7Li to $^8Be(18.15) + \gamma$. Followed by decay. Looked at $e^{\pm}$ pairs from internal conversion.

The beryllium anomaly





Why believe it?

- This model has $\chi^2/d.o.f.$ of 1.07, significance of 6.8σ
- Bump, not last bin effect
- Rises/falls when scanning through proton energies around resonance
- Excess only happens for symmetric-energy pairs
- Preliminary reports of same excess in $^8Be(17.6)$ (same group)

Why not believe it?

- Group has a history of finding peaks
- IIUC, the detector acceptance has a minimum at 140°
- DM boson interpretation is proto-phobic to evade NA48/2 limits
  - Actually: $\frac{\epsilon_p}{\epsilon_n}$ coupling below $\pm 8\%$. Z^0 is $\sim 7\%$

We can measure it!

In DarkLight, production is via Bremsstrahlung, predominantly ISR off the electron.

We can look at $e^- p \to e^- pX$, followed by $X \to e^- p(e^- e^+)$

Irreducible background: $e^- p \to e^- p\gamma^\star \to e^- pe^+ e^-$

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Best kinematics:

- highest production rate if X takes all electron energy. CS rise beats all
- with limited out-of-plane acceptance, symmetric angle optimal

In reality...

- Replace hydrogen target with tantalum. Point like, and more luminosity
- Main background is NOT the irreducible one. Random coincidences between
  - radiative elastic electrons
  - positrons from (virtual) photon pair-production where e^- is missed
- Can optimize by moving electron arm backward

Proposed setup

- 45 MeV beam, 150 μA on 10 μm tantalum foil
  $\longrightarrow$about 0.3 inv. fb/s hydrogen equivalent
- Positron spectrometer at 16°, 28 MeV
- Electron spectrometer at 33.5°, 15 MeV

Spectrometer design parameters

Kinematic var.	Acc.	Inv. mass res.	est. res. on focal plane	Error
in-plane angle	$\pm 2°$	$22\ \frac{keV}{mrad}$	5mm/7cm$\rightarrow$1.4 mrad	$32\ keV$
out-of-plane angle	$\pm 5°$	$5\ \frac{keV}{mrad}$	$1°$ and $1.14° \rightarrow 1.5°$	$133\ keV$
momentum	$\pm 20\%$	$85\ \frac{keV}{\%}$	5mm/30cm$\rightarrow < 0.2\%$	$17\ keV$

Sum for two spec: $194\ keV$, assumed $250\ keV$

Background rates

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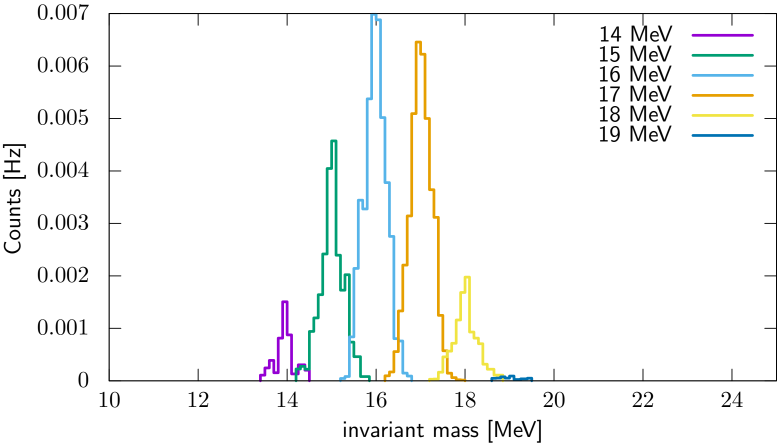
Elastic e^- + internal Bremsstrahlung: 6 MHz

$\longrightarrow$ Random coincidence rate 500 Hz

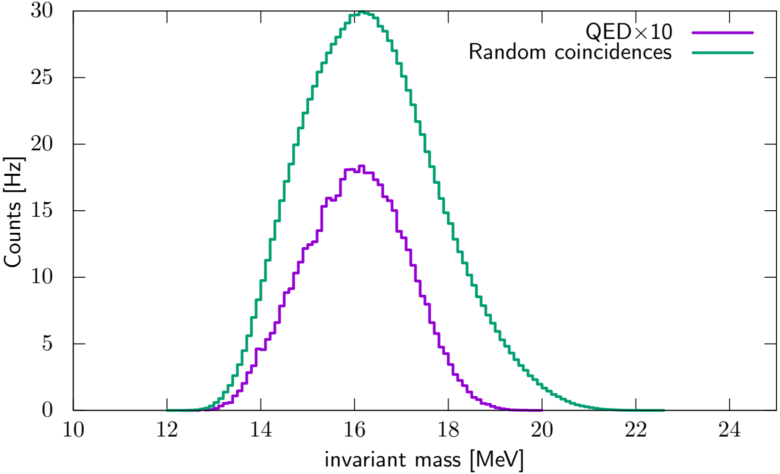
(at 1.5 GHz bunch rate)

This is the minimum trigger rate and sets the sensitivity.

Counting rates: A' signal



Counting rates: Backgrounds



Dominated by accidental background

- Random coincidences dominate
- Scaling with instantaneous luminosity:
  - Signal S ~ $\mathcal{L}$
  - QED background Q ~ $\mathcal{L}$
  - Accidental background A ~ $\mathcal{L}^2$
  - Sensitivity $\frac{S}{\sqrt{Q+A}} \sim 1$

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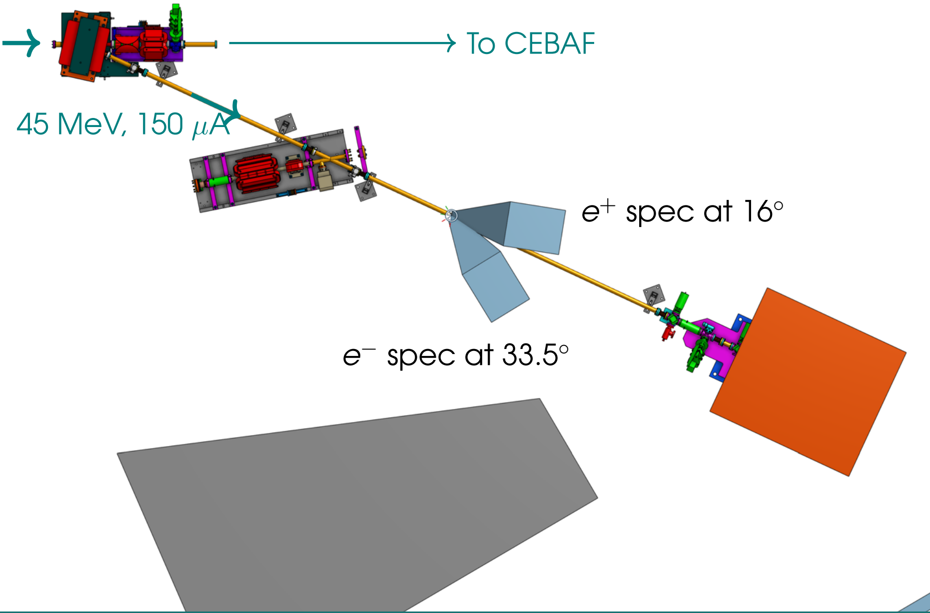
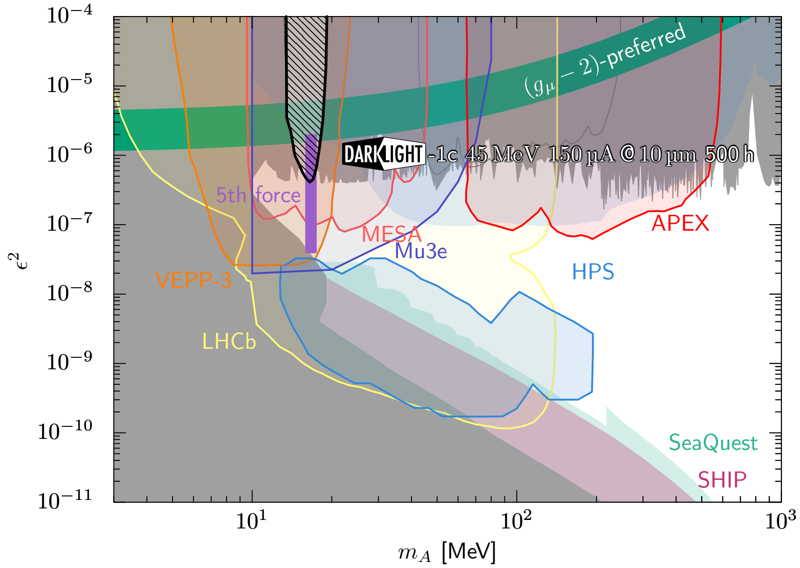
- Sensitivity almost independent of luminosity. Scale is set by bunch-clock / time resolution

Space requirements



Reach



10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
ϵ^2
10^1
10^2
10^3
m_A [MeV]
$(g_\mu - 2)$-preferred
DARKLIGHT -1c 45 MeV 150 µA @ 10 µm 500 h
5th force
MESA
Mu3e
APEX
HPS
VEPP-3
LHCb
SeaQuest
SHIP

Misc

- Reach plot assumes that we can associate tracks to bunches on the 1.5 GHz level.
  Fast trigger detectors!
- Need to study more background sources, but I think we have most.
- 1c can/should be test platform for streaming readout.
  What approach works best?