Searching visible decays of dark photons with thin target

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PADME Kickoff meeting

LNF-INFN

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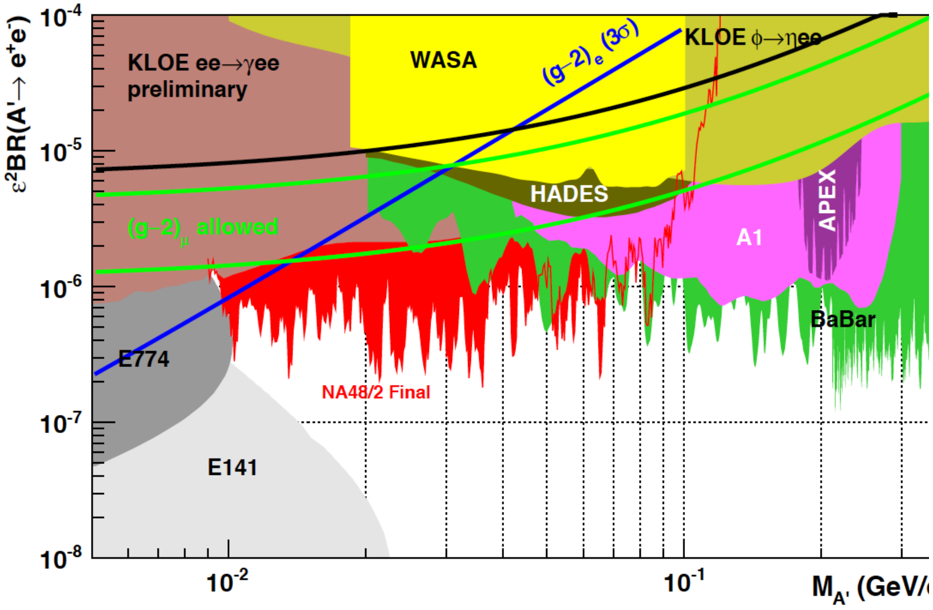
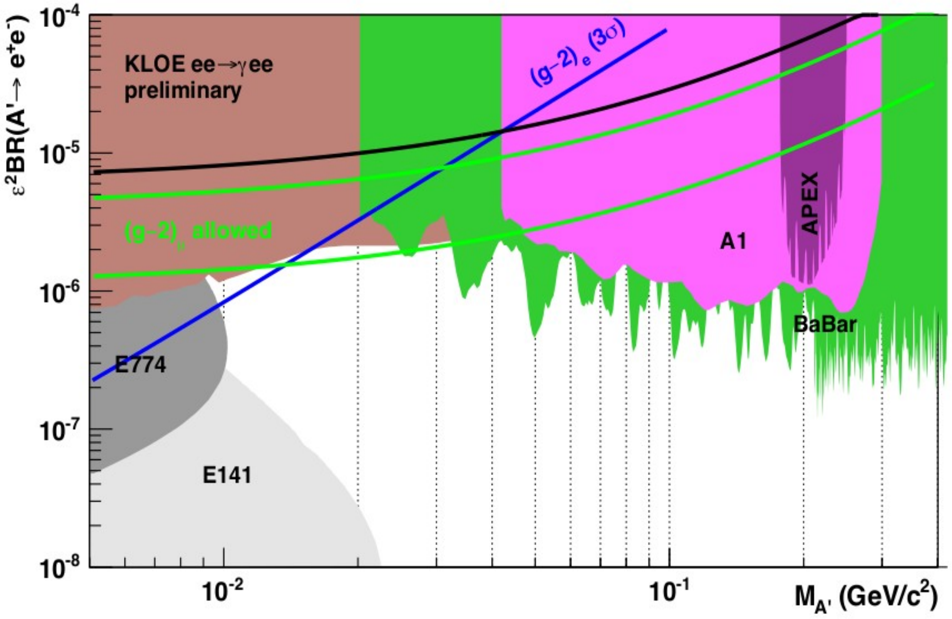
Outline

- What do we want to adress
- Conceptual experimental setup
- Beam
- Possible outcome
- Difficulties (or steps to go)
- Conclusions

Plots of interest

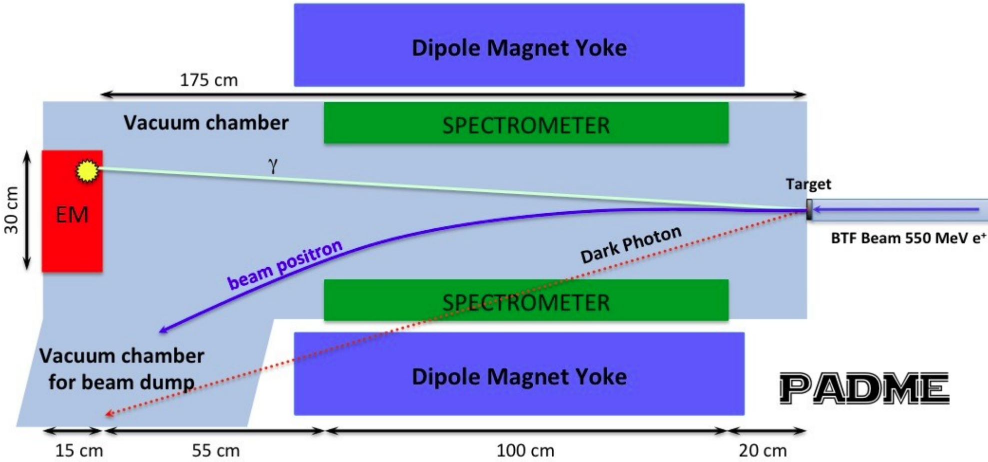


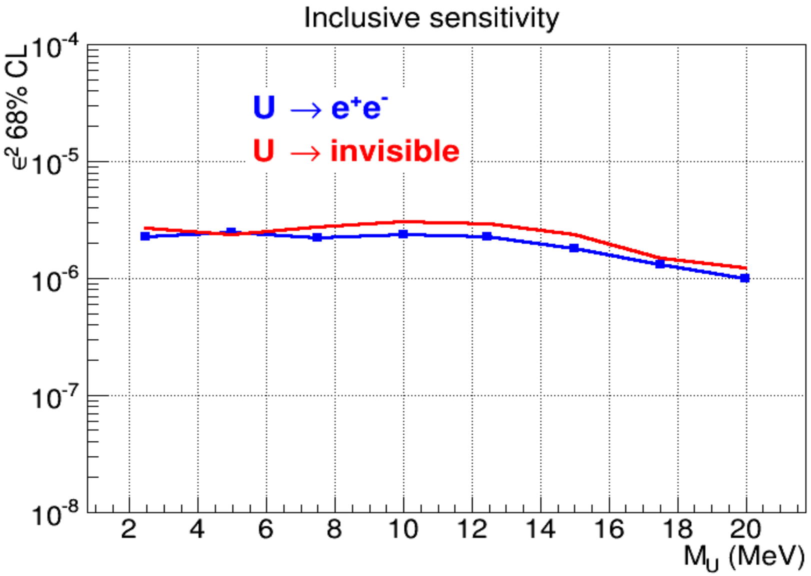


- There exists even a small region preferred by the g-2
- A lot of unexplored region to be studied

Visible decays in annihilation

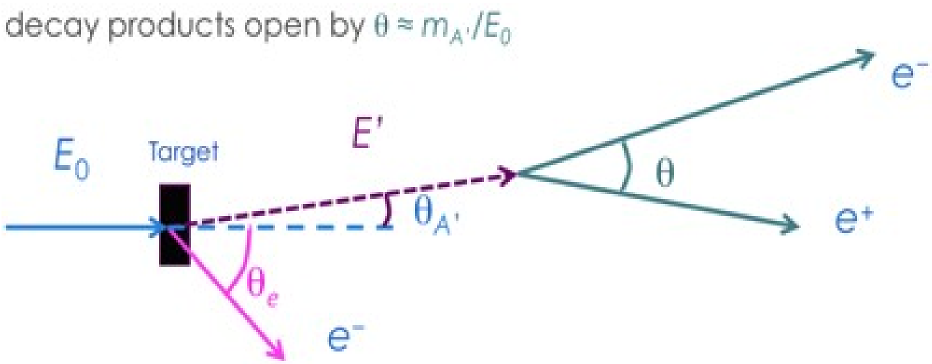
- PADME approach to the analysis is inclusive
  - Selection optimized for both – visible and invisible decays of the U boson





- Advantage:
  - The searches are performed in parallel
  - 1 year with 60% efficiency (data taking)
  - 50 bursts/s, 10^4 positrons/burst
- Disadvantage:
  - Few positrons on target (~10^{13}) limiting the sensitivity

U → ee decay searches



$$\sigma_{\gamma'}^{\text{ft}} \sim \frac{\alpha^3 Z^2 \varepsilon^2}{m_{\gamma'}^2}$$

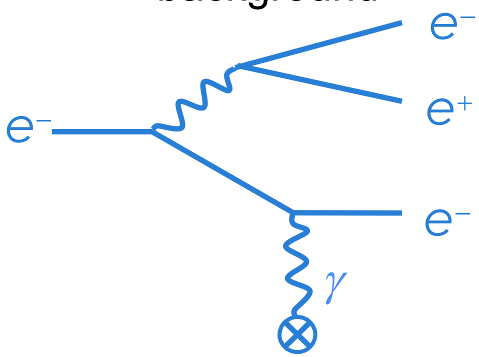
$$\sigma_{\gamma'}^{\text{coll}} \sim \frac{\alpha^2 \varepsilon^2}{E^2}$$

- Profit from the bremsstrahlung production
  - Higher mass regions within reach
  - Higher cross section
- Use electron beam instead of positron
  - Higher intensity
  - Better knowledge of the beam geometry
- Searching for peaks in the M_{e+e-} distribution
  - Have to measure the momentum (and the origin) of the tracks to reconstruct the decay vertex and the DP mass
  - Depends a lot on the quality of the spectrometer

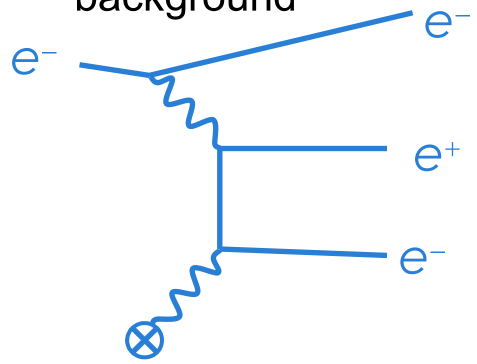
Characteristics

- Events kinematics
  - *A*' takes nearly all the beam energy E_0 (sharp peak at x≈1)
  - Electron takes a small energy ≈ $m_{A'}$
  - *A*' emission almost collinear to the beam: $\theta_{A'}=(m_{A'}/E_0)^{3/2}$
  - Electron going at "wide" angle: $\theta_e=(m_{A'}/E_0)^{1/2}$
  - *A*' decay products open by $\theta \approx m_{A'}/E$
- Background – tripod events

Radiative background

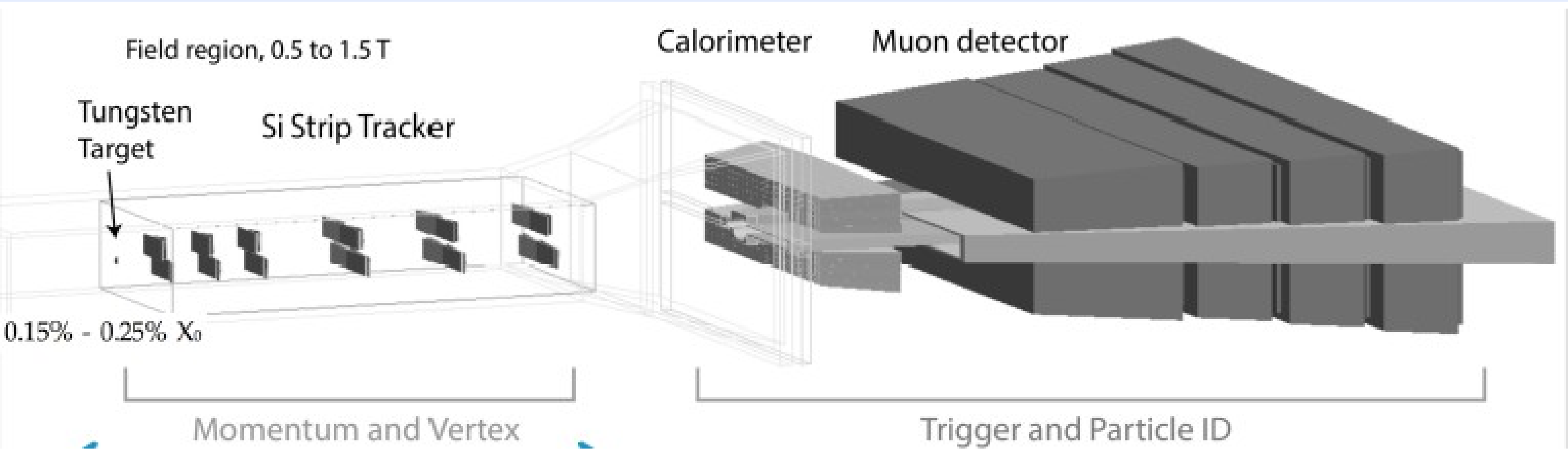


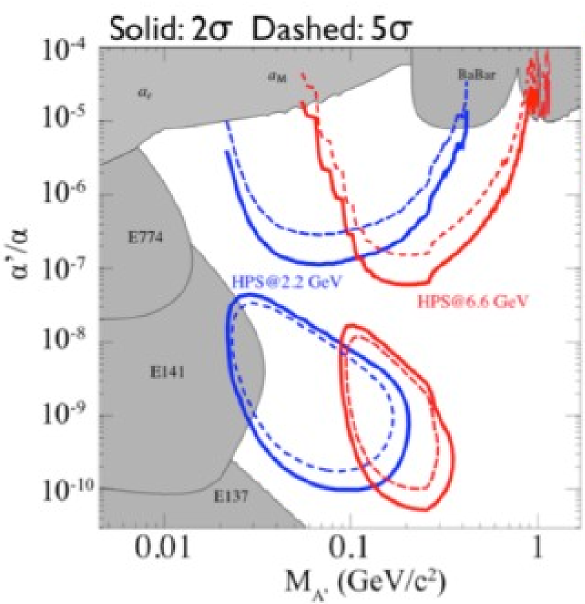
Bethe-Heitler background



Represent the unbeatable background

U → ee decay searches: HPS





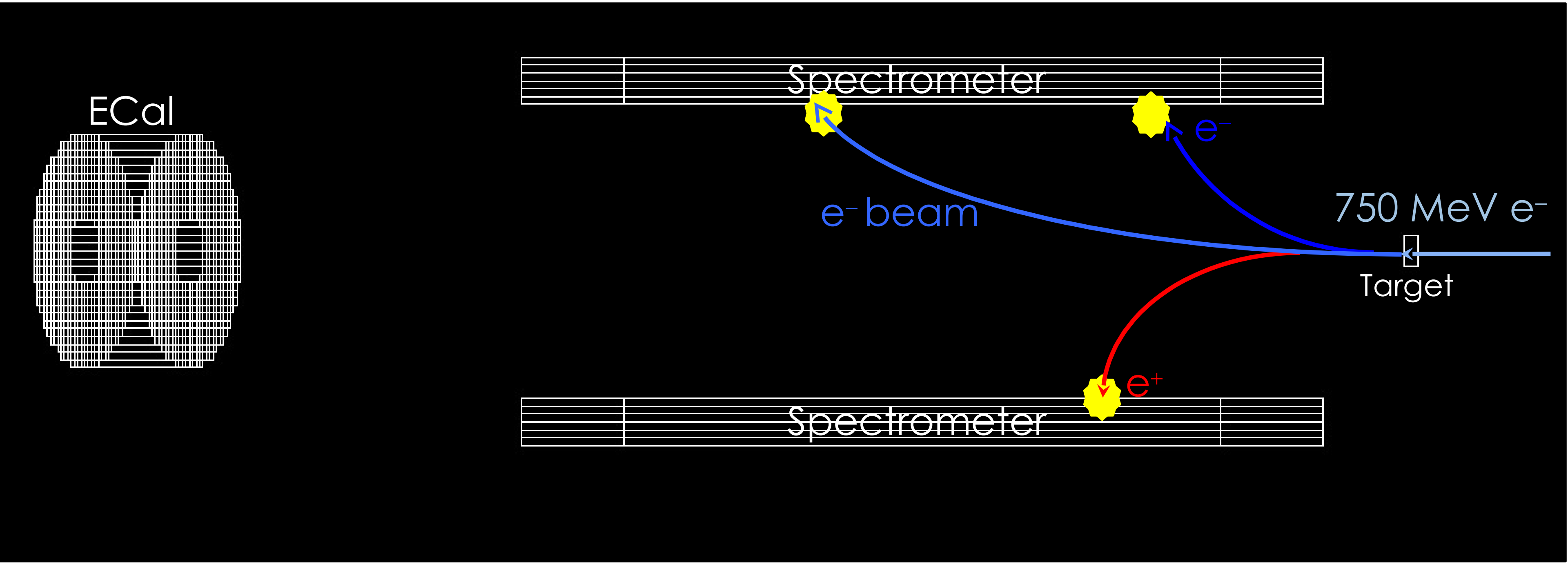
Blue:
Beam = 2.2 GeV@200 nA
Target = 0.125%

Red:
Beam = 6.6 GeV@450 nA
Target = 0.25%

3 months of running each energy = 180 days

- Reference experiment:
  - Sophisticated design incorporating Si tracker, calorimeter and muon detector
  - Not in vacuum!
  - Higher beam energy

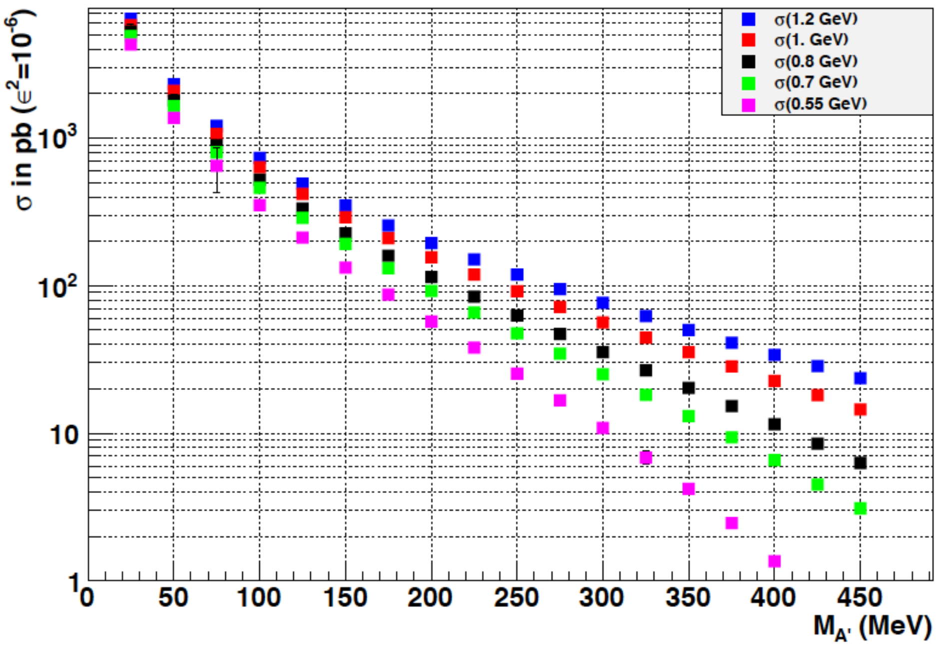
PADME searching for visibles



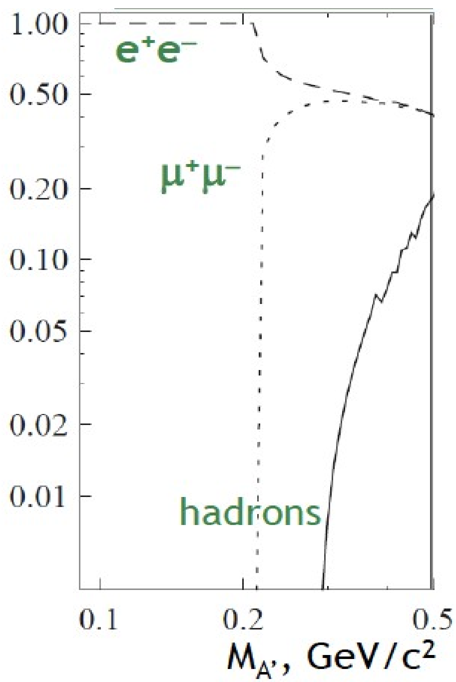
- PADME case: ability to perform alternative (visible) study with almost the same setup
  - May be apart from the spectrometer
-

A' in bremsstrahlung

Production cross section



Decay probability



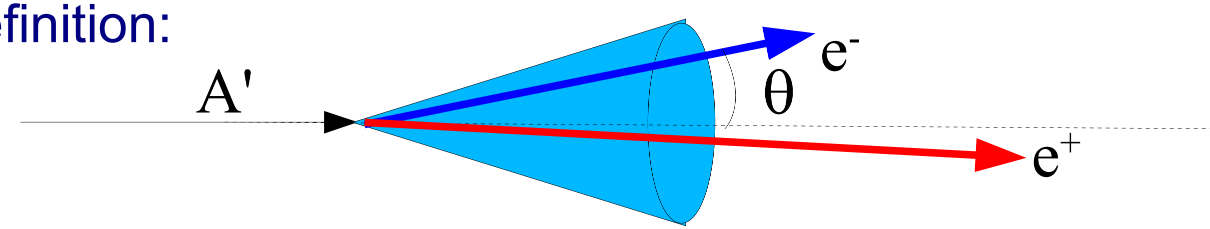
Universal coupling assumtion:

$$\frac{\Gamma\,(U \rightarrow \text{mode})}{\Gamma(\text{visible})}$$

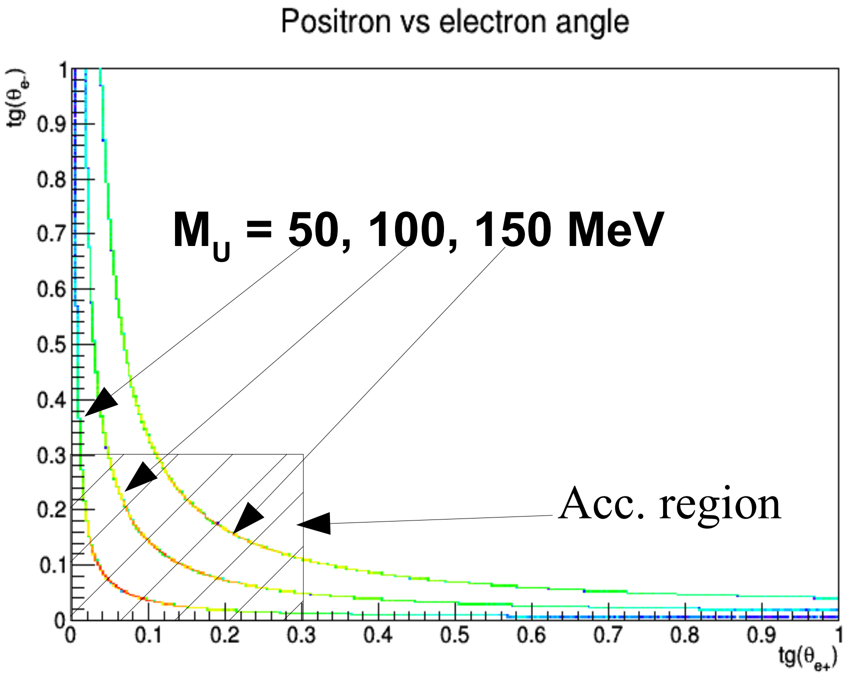
- Bremsstrahlung searches allow access to higher masses and opens new possible search channels
  - $\mu\mu$, πions, $\pi\gamma$ …
- However not easy to reconstruct the event due to unknown full kinematics

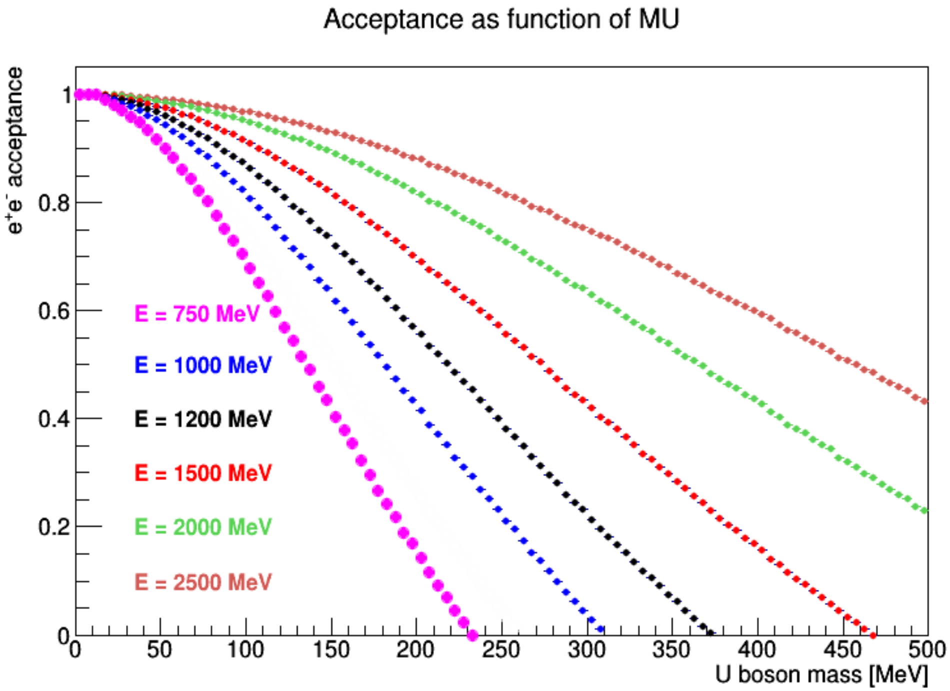
Toy studies

- Acceptance definition:



  - Both $e^+ e^-$ within a cone of $tg(\theta) < 0.3$, $P_{trk} > 50$ MeV
  - Could be well justified since the magnetic field deflects all such particles in the tracker

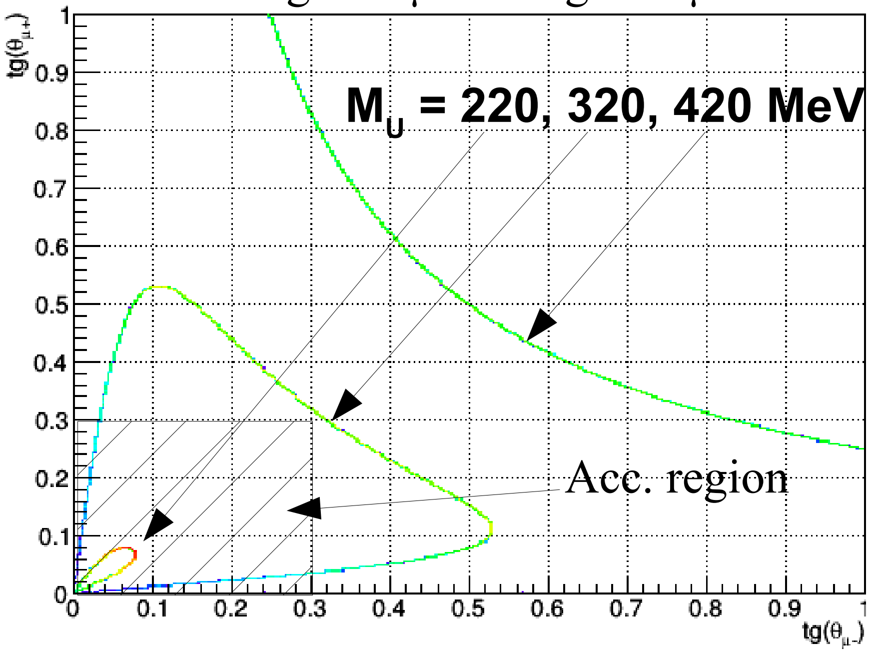


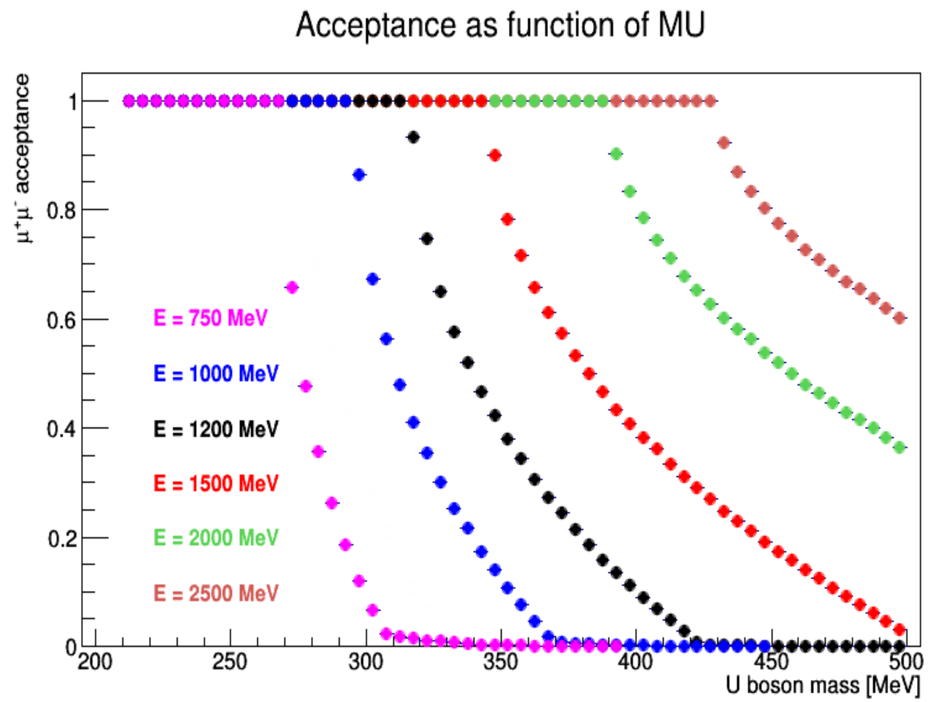


And also to muons...

Ebeam = 840 MeV

Angle of μ^+ vs angle of μ^-

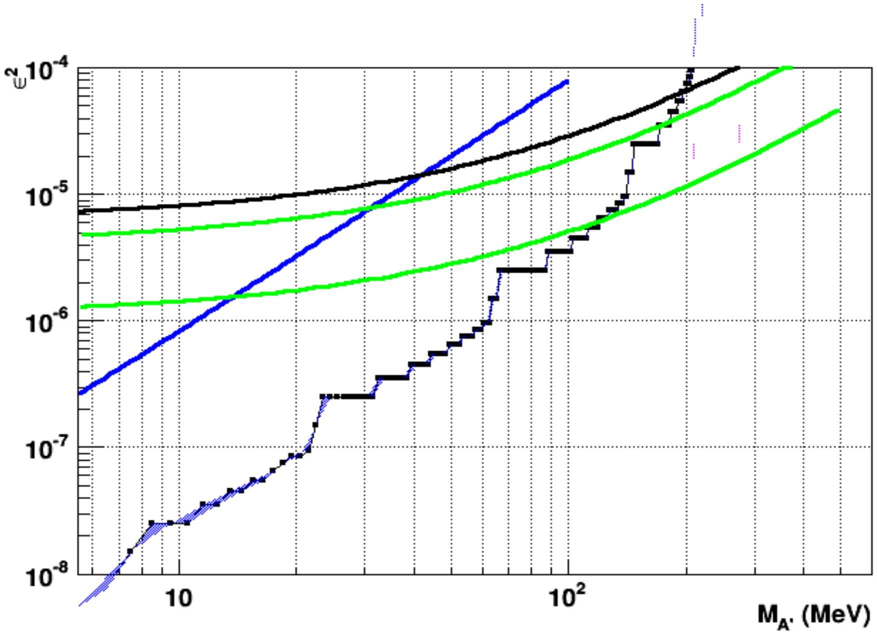




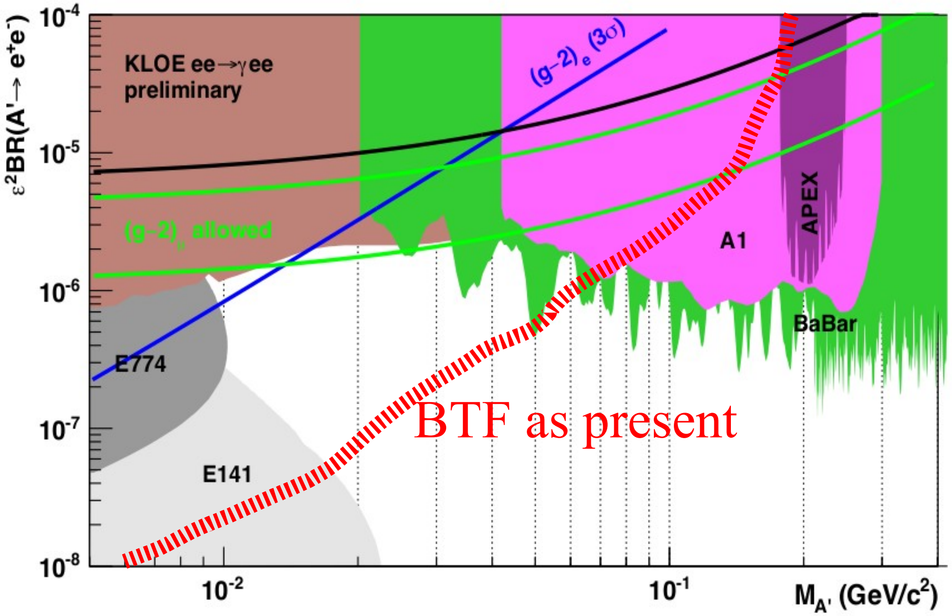
- Acceptance to muons is lower because at higher masses the DP gets smaller boost
- But there is still region of interest that can be studied even without modification on the setup
- However a dedicated detector experimental setup might be ineresting

Expectations

- Toy MC games: consider target thickness, acceptance (again toy), production cross-section (Madgraph)
  - Do not consider background … or we can do a background free experiment?

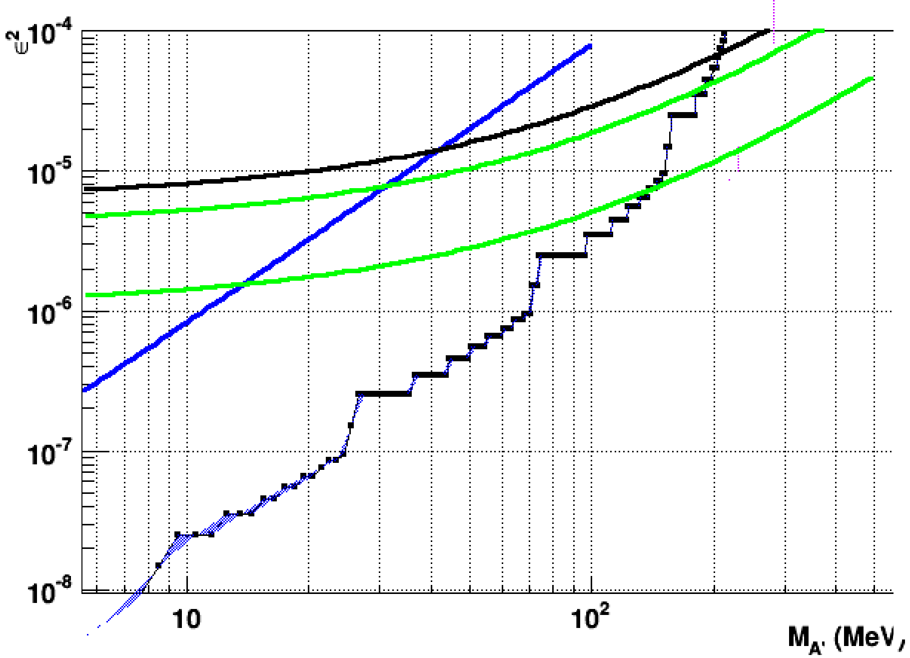


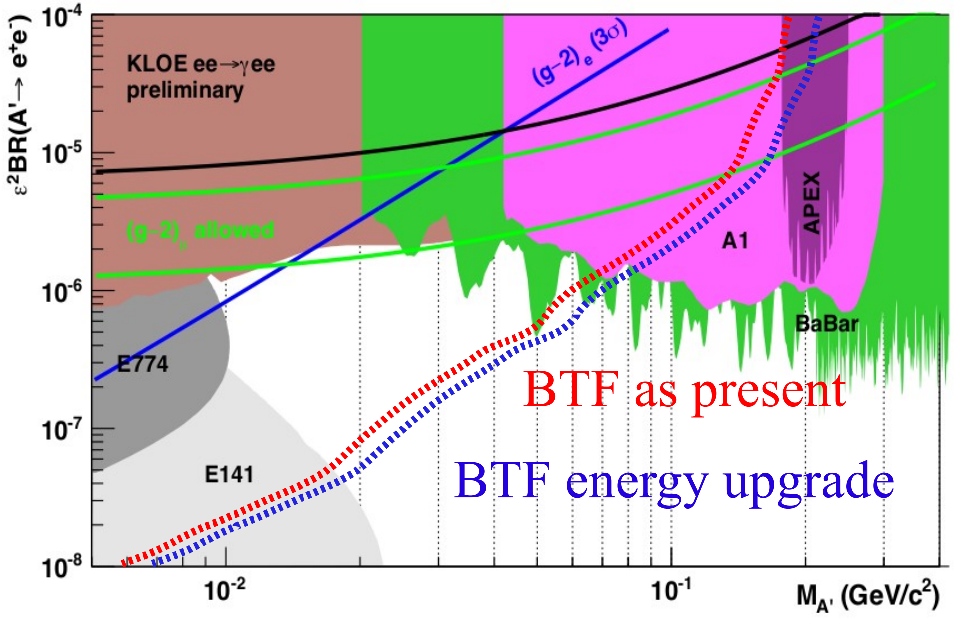
800 MeV beam, 500um target, 10^{12} EOT



Visible searches

- Upgraded BTF – Ebeam = 1200 MeV





1000 MeV beam, 500um target, 10^{12} EOT

- The visible decays searches might cover quite an interesting part of the parameter space, but the access to it might be difficult due to background
  - Perform a low intensity beam experiment with full single event reconstruction

Conclusions

- The basic idea is quite clear – detect DP decays with dileptons
- However many open questions still
  - What is the effect of the position resolution
  - What momentum resolution is needed
  - What is the optimal spectrometer design? Technology – fibers, GEM, TPC?
  - Should the spectrometer be in vacuum?
- Background estimation has not been done
  - The resolution itself is not the only factor to the achievable sensitivity
- Nominal mode of operation
  - Single event mode: beam intensity allowing low multiplicity in the spectrometer
  - High beam intensity: if the 3e background is negligible