Searching for New Physics with multilepton events at PADME

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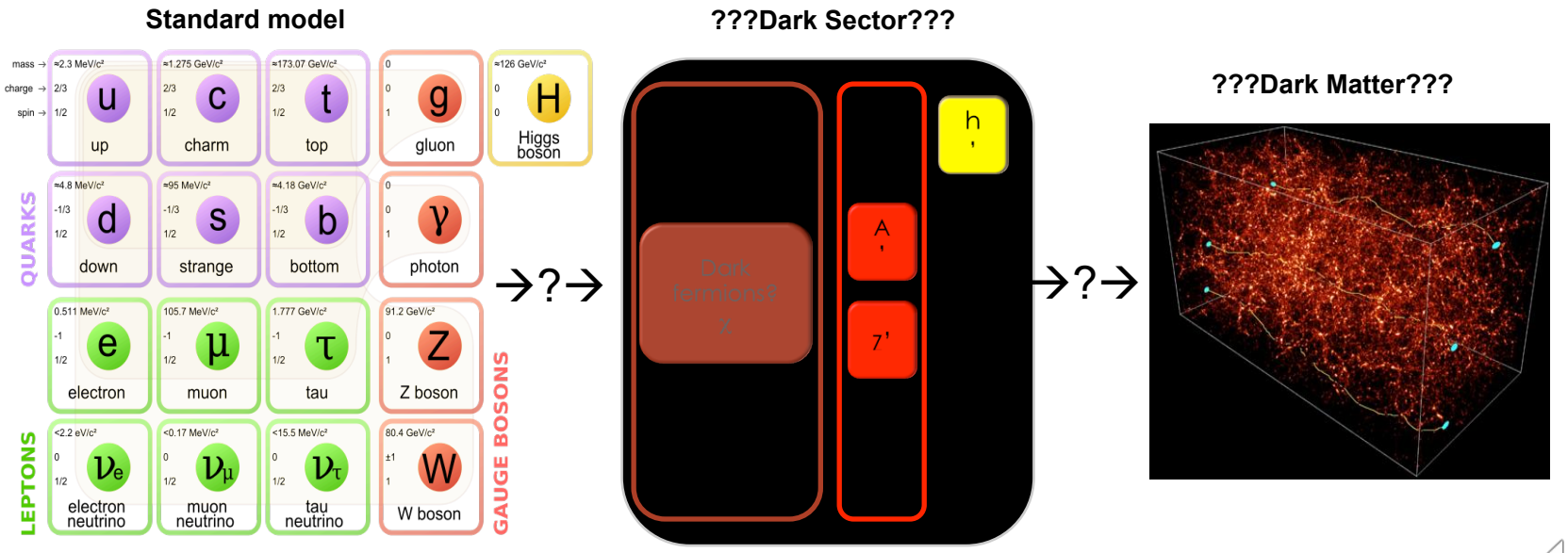
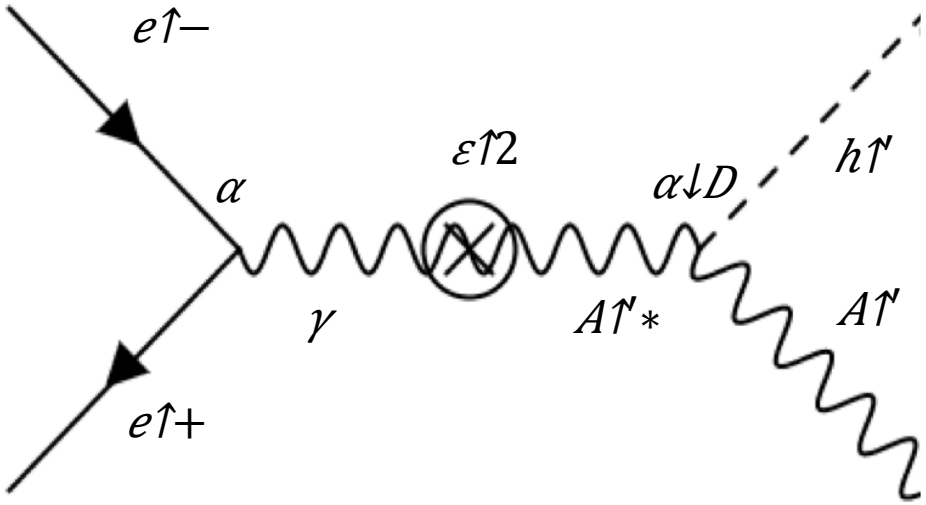
The Dark Sector and Dark Photon

- Standatd Model (SM) and Dark Matter (DM) particles could live in two separate sectors connected by a portal
- The simplest model for this theory adds a new $U(1)_D$ symmetry and therefore a new boson called Dark Photon (A')

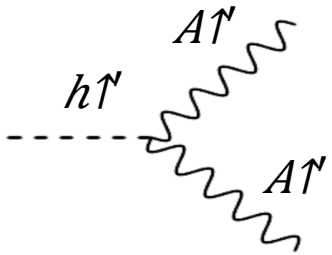


The Dark Higgs

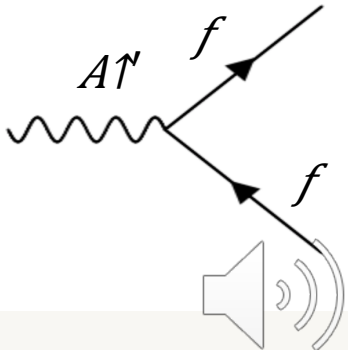
- In non-minimal models where the A' mass is generated through spontaneous symmetry breaking, an associate production of a Dark Higgs (h') is possible
- The h'-strahlung process is one of the few h' production processes and it is similar to the SM Higgs-strahlung, with a A' instead of a SM photon



- $m_{h'} > 2m_{A'}$

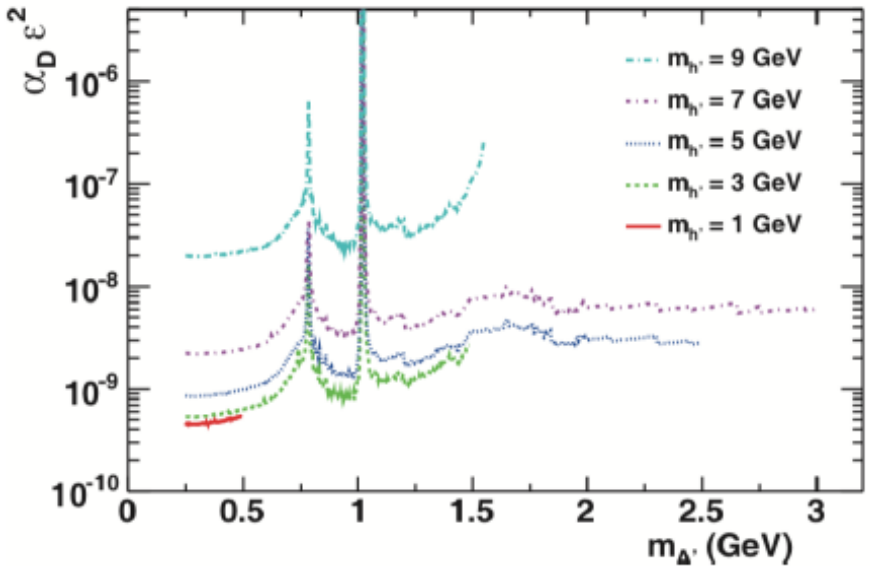


- $m_{A'} > 2m_f$



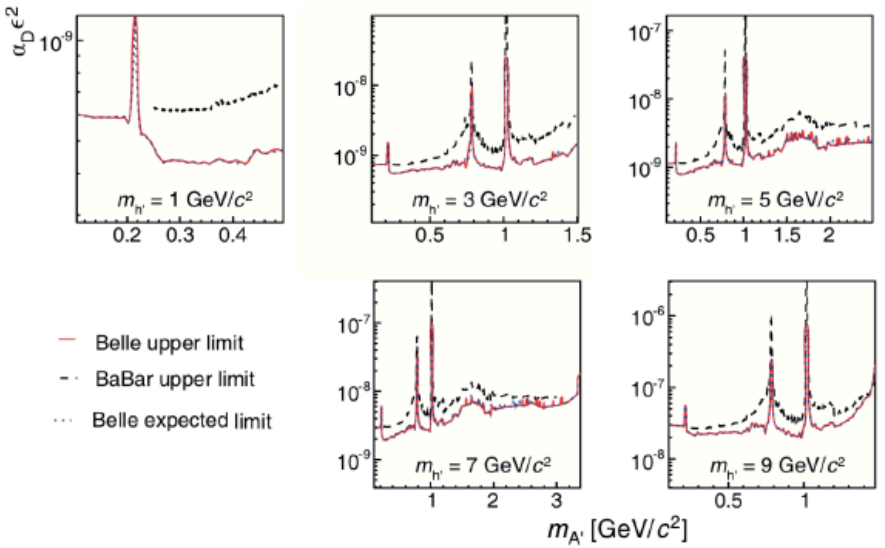
Dark Higgs searches

BaBar



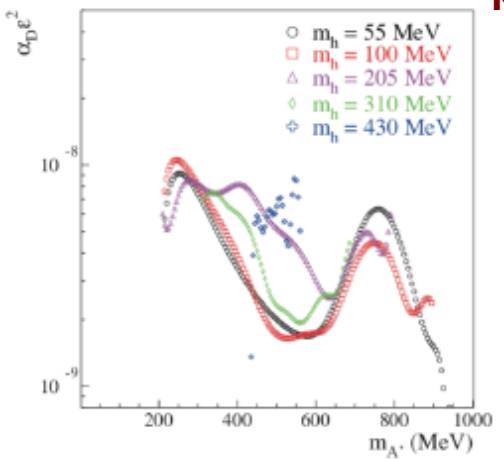
Phys. Rev. Lett., 108 (2012) 211801.

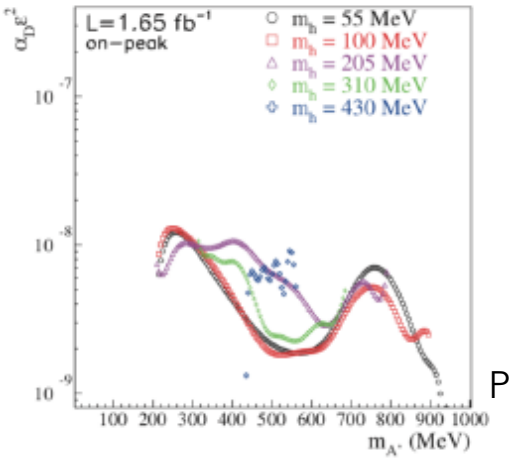
Belle



Phys. Rev. Lett., 114 (2015) 211801.

KLOE-2





Phys. Lett. B, 747 (2015) 365.

Cross sections evaluations

Paper used	Value in pb	Estimate method
Pospelov 2009	25231	Estimate
BGMS 1970	20131	$\gamma\gamma \rightarrow 4l$ = 6.5 μb
Da Silva 2012	20134	Direct integration $\gamma\gamma \rightarrow 4l$
Cheng Wu 1970	20133	$\gamma\gamma \rightarrow 4l$ using Riemann Z function

- All the estimates with Equivalent Photon Approximation (EPA) seem to point to the same value $\sigma\downarrow e\uparrow+ \; e\uparrow- \rightarrow 3(e\uparrow+ \; e\uparrow-)$ = (20133±10) pb

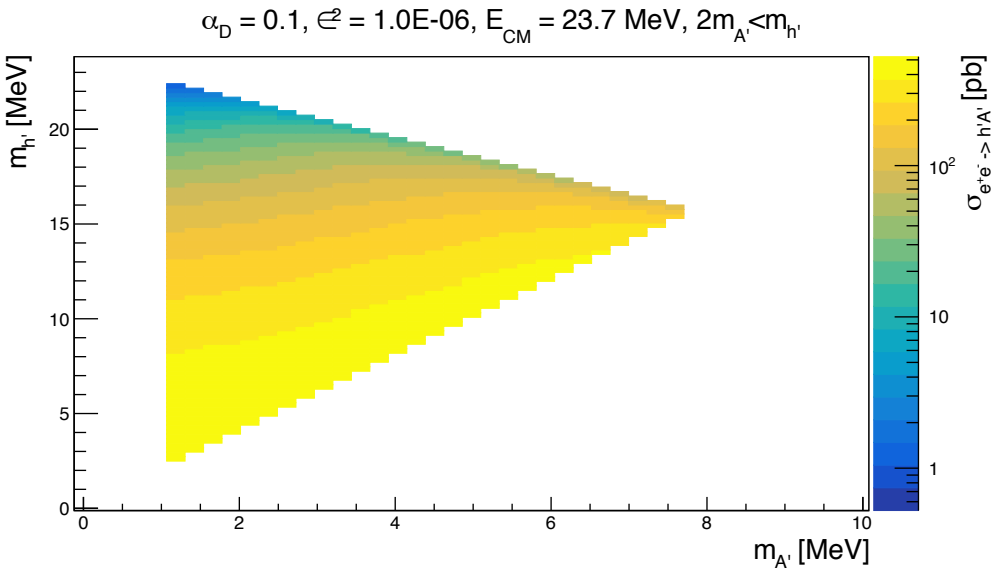
- The Dark Sector cross section can be estimated with the following e

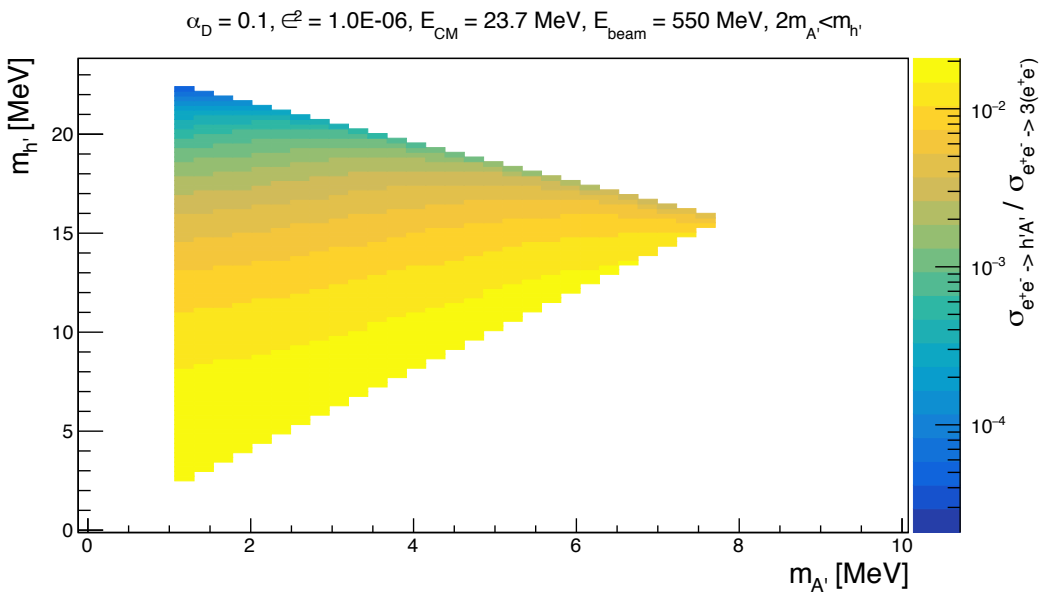
$$\sigma_{e^+e^-\rightarrow Vh'} = \frac{\pi\alpha\alpha'\kappa^2}{3s}\left(1-\frac{m_V^2}{s}\right)^{-2}\sqrt{\lambda\left(1,\frac{m_{h'}^2}{s},\frac{m_V^2}{s}\right)} \times\left[\lambda\left(1,\frac{m_{h'}^2}{s},\frac{m_V^2}{s}\right)+\frac{12m_V^2}{s}\right]$$

B. Batell, M. Pospelov, and A. Ritz, Phys. Rev. D 79, 115008 (2009).

Cross section in different mass regions

- Upper limit on the $e^+ e^- \to A' h'$ cross-section as a function of the dark photon and dark Higgs masses
- Low masses → high cross sections

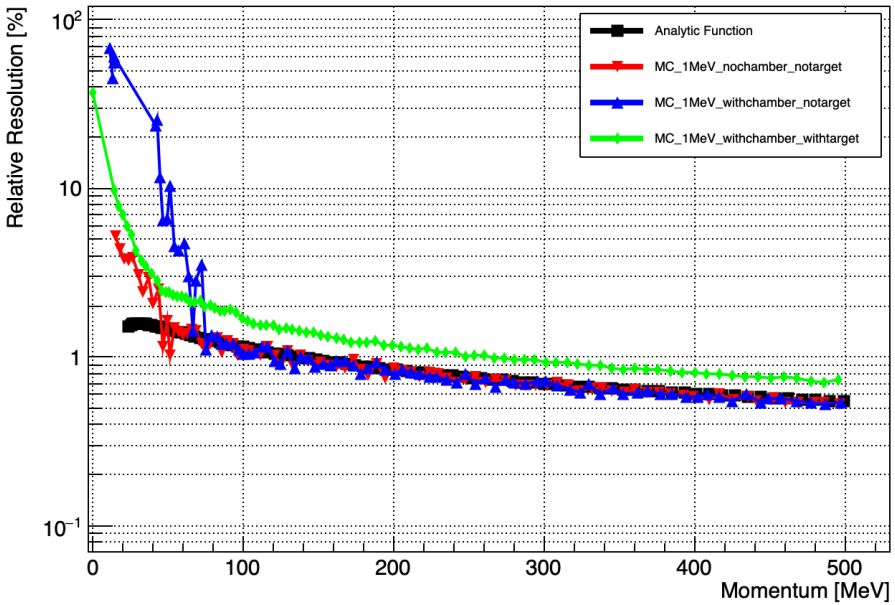




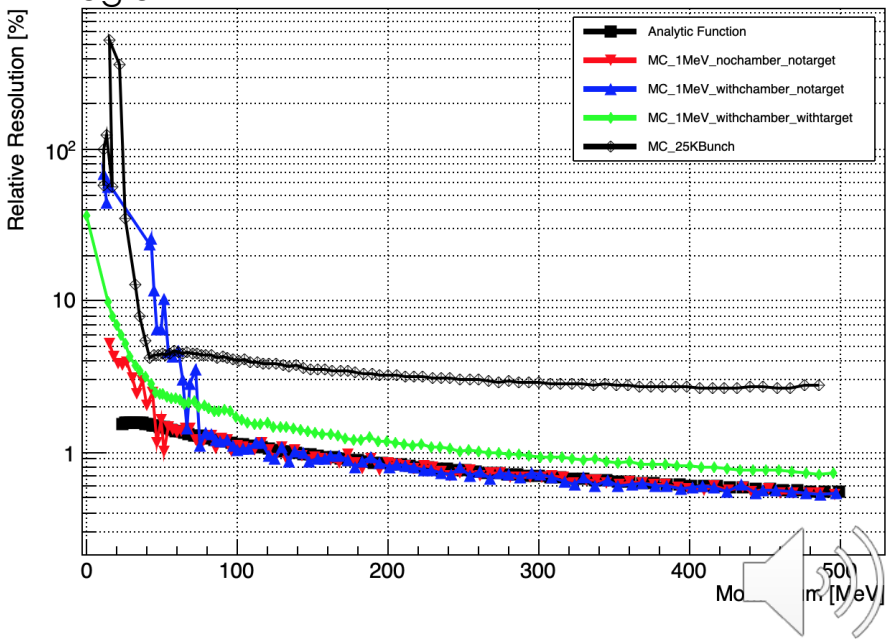
- Ratio between Dark Sector and SM cross sections as a function of the dark photon and dark Higgs masses
- Low masses→higher Dark Sector cross sections respect to the SM

Charged particles momentum reconstruction

- In **Single Particle mode** particles of different energies are sent to the active diamond target with initial direction parallel to the beam axis
- The resolution of the PADME spectrometer is very good, below 2%, for E>50 MeV
- For E<50 MeV acceptance is reduced due to the presence of the vacuum chamber
- Effect of multiple scattering slightly reduces the precision of the measeurement



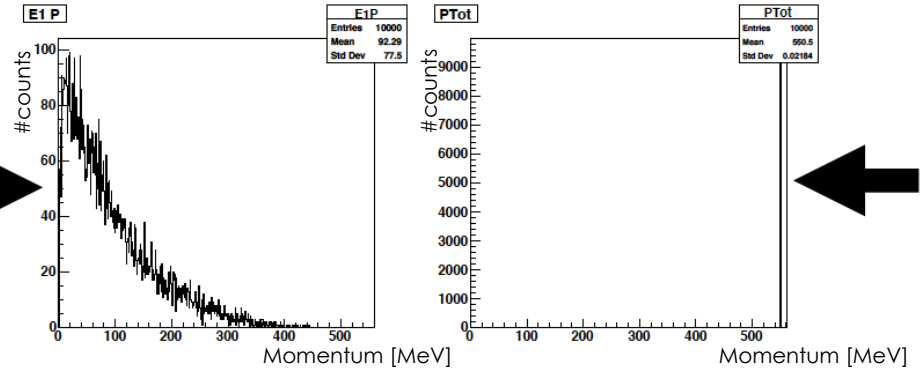
- In **Full Bunch Structure mode** only the original positron beam energy of 550 MeV is generated with energy resolution of 1%
- Lower energies are obtained only when the positron emits a hard Bremsstrahlung photon
- The ideal resolution is worsened by a factor ≈ 2, it is still lower than 5% in the whole measurable region



Acceptance: $e\uparrow+ e\uparrow- \rightarrow 3(e\uparrow+ e\uparrow-)$ Standard Model

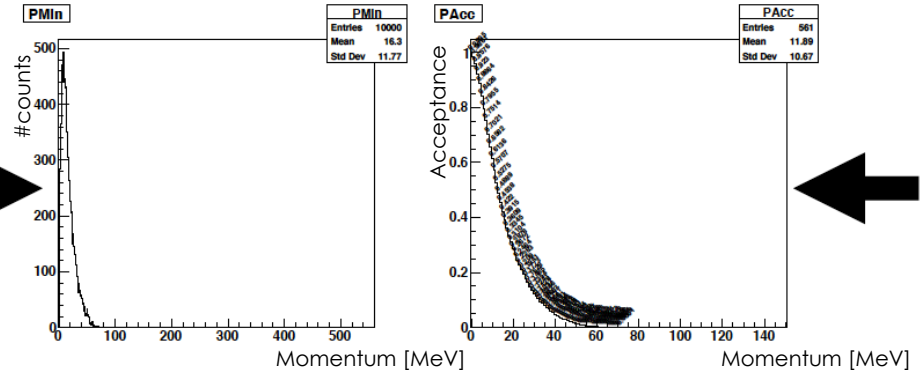
$$e^+e^- \rightarrow 3(e^+e^-)$$

Momentum distribution for a particle in the final state



Total momentum conservation

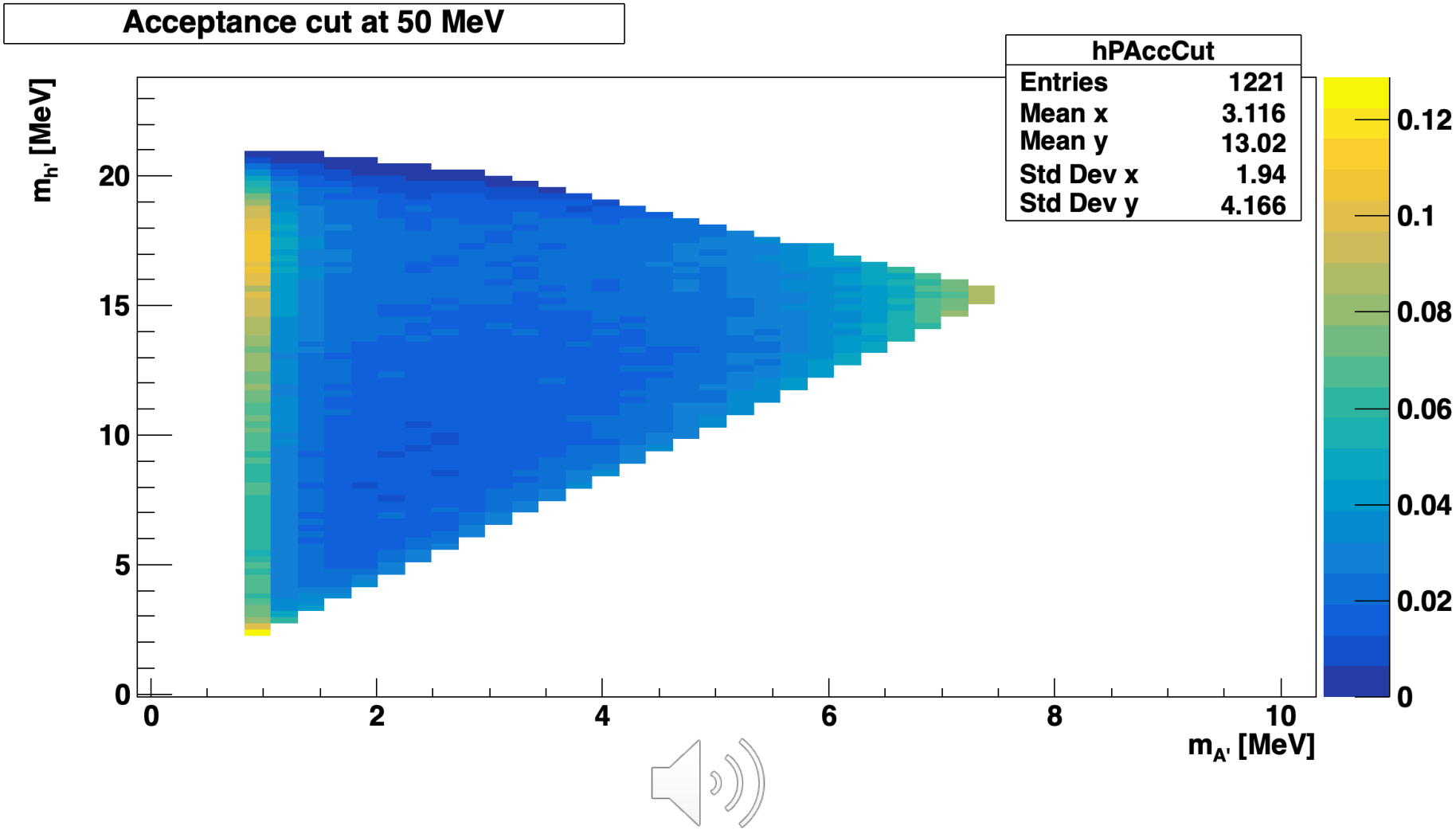
Minimun Momentum distribution for a particle in the final state



Acceptance (0.015 at 50 MeV)

- The resolution of the PADME spectrometer is very good, below 2%, for E>50 MeV
- $6e^{\pm}$ SM acceptance seem of the order of 1% for E_{min}>50 MeV

Acceptance: $e^+ e^- \rightarrow 3(e^+ e^-)$ Dark Sector



Conclusions

- Multi lepton final state are measurable at PADME
  - None of them has been measured at energies below the GeV energy
- In the current magnetic field configuration they are strongly suppressed by the acceptance of the PADME chamber
- Reducing the magnetic field will allow to collect interesting samples of these decays in scale of days of running
- Challenging is to evaluate the reconstruction efficiencies with the present level of background in the detector
- On behalf of the PADME collaboration, thank you for listening