SEARCHING FOR DARK PHOTON WITH THE PADME EXPERIMENT

C. TARUGGI ON BEHALF OF THE PADME COLLABORATION

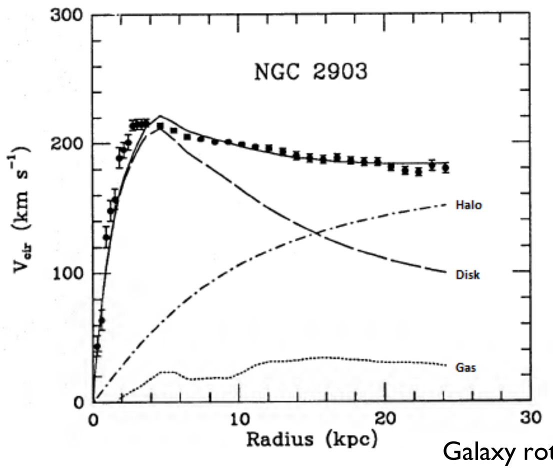
MATTER & GRAVITATION

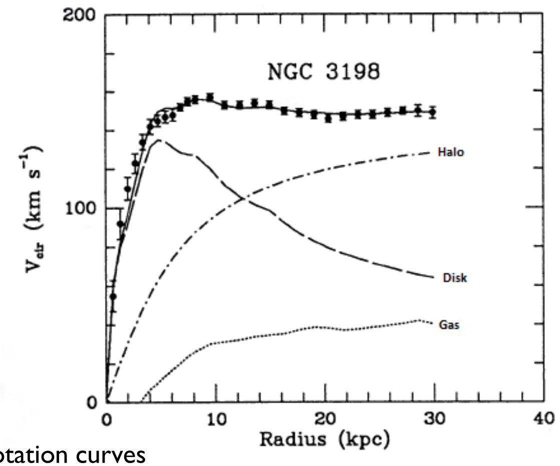
What does the Universe tell us?

Visible matter cannot explain the behaviour of many cosmological phenomena (galaxy rotation curves, gravitational lensing, CMB distribution…). We can:

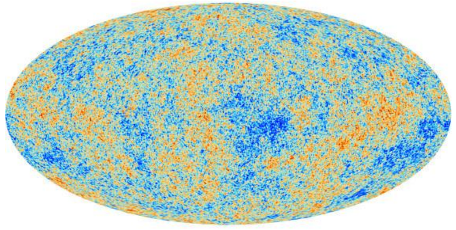
1. modify gravitational laws
2. suppose the existence of another kind of matter, not producing radiation

Following the second hypothesis, how can we detect such an «invisible» matter? Does it interact with Standard Model (SM) particles, and how?

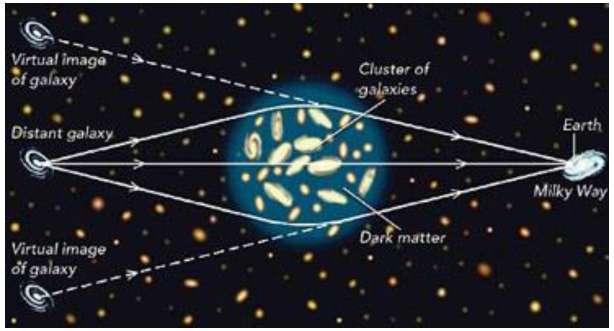




Galaxy rotation curves

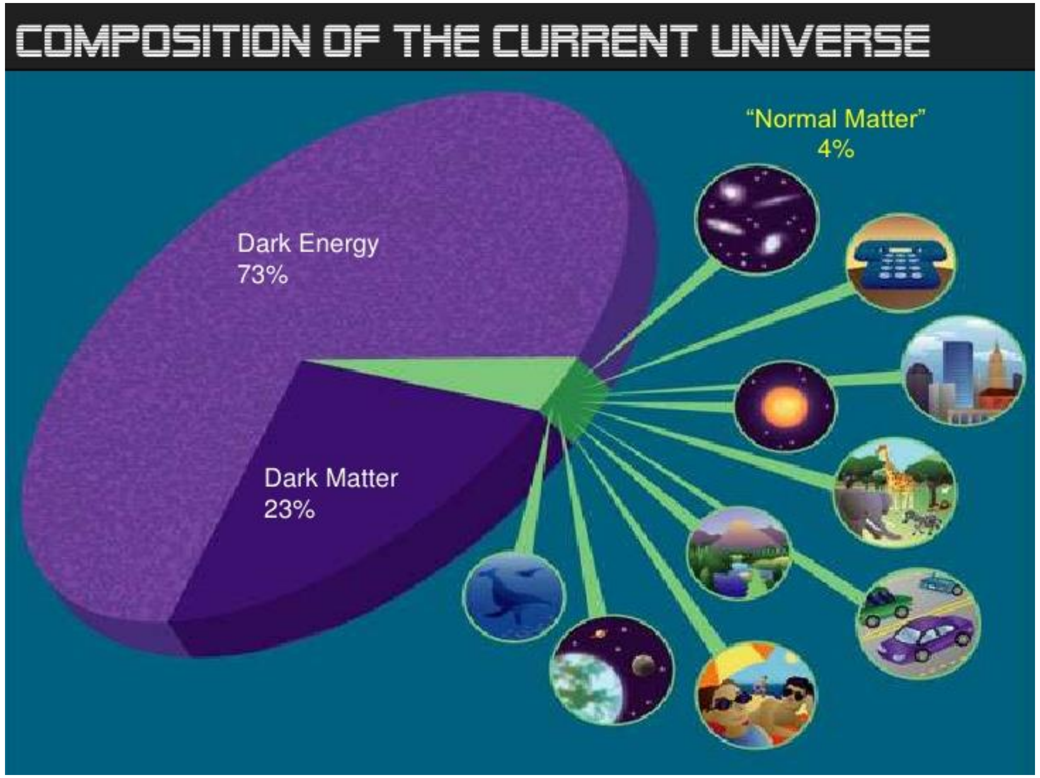


CMB map



Gravitational lensing

INTRODUCING DARK MATTER



If gravitation law is right, current observations tell us that we know only ~ 4% of the Universe.

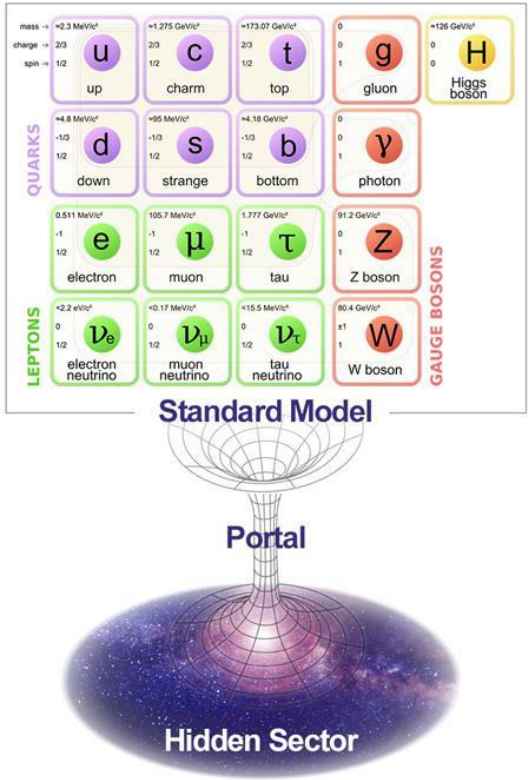
We suppose that dark matter (DM) is about 23% of the total, and that interacts *at least* gravitationally with SM particles, but very weakly! DM could belong to the SM particles group (e.g. WIMP), but could also be something else.

What if DM and SM particles interact through another force?

This could explain why detection of DM is so difficult: DM could live in a different world with respect to SM particles, and these two worlds could be connected by a fifth interaction.

DARK SECTOR

DM could live in the so called *dark sector*. We can introduce a new interaction that connects ordinary matter with the dark sector: SM particles could be neutral under this interaction. A mediator particle is associated to the interaction. Depending on the model, the mediator can be a fermion, a boson, a vector, etc.



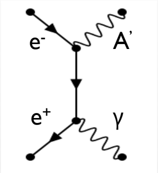
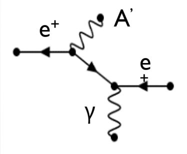
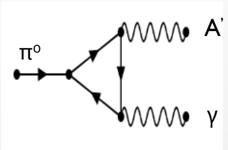
→ Dark sector theories could also be used to explain other physical phenomena other than DM, for example the muon g-2 anomaly and the ^{8}Be anomaly.

The simplest dark sector model introduces a U(1) symmetry, whose mediator is a vector boson A': in analogy with the standard photon, we call it *dark photon (DP)*.

DARK PHOTON: PRODUCTION AND DECAY

According to the dark sector model one considers, there are different ways dark photon can be produced and decay.

Here we consider production from e^+e^- interaction.

Production		
ANNIHILATION	***BREMSSTRAHLUNG***	**MESON DECAY(*)**
		

Decays	
VISIBLE (SM PARTICLES)	**INVISIBLE** (DM PARTICLES)
If DM particles with $m_{MO} \leq m_{A'}/2$ do **NOT** exist	If DM particles with $m_{MO} \leq m_{A'}/2$ **DO** exist

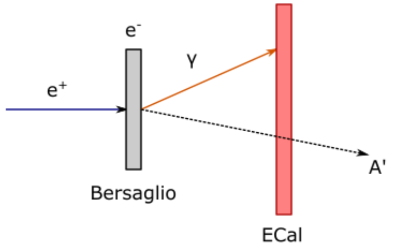
Searching for visible or invisible decays lead to different dark photon properties (e.g. mass and coupling), meaning that different exclusion plots are obtained.

DETECTION OF DARK PHOTON IN PADME

Production of DP: annihilation

$e^+e^- \rightarrow \gamma A'$

- Annihilation between e^+ beam on atomic e^- of the target
- Invisible decay
- Closed kinematic of the process



The process signal is given by a single γ in the calorimeter. The beam properties and the kinematic are known, so that it is possible to evaluate A' mass.

Search technique: missing mass

Defined as

$$m^2_{miss} = (\mathbf{P}_{beam} + \mathbf{P}_e - \mathbf{P}_\gamma)^2$$

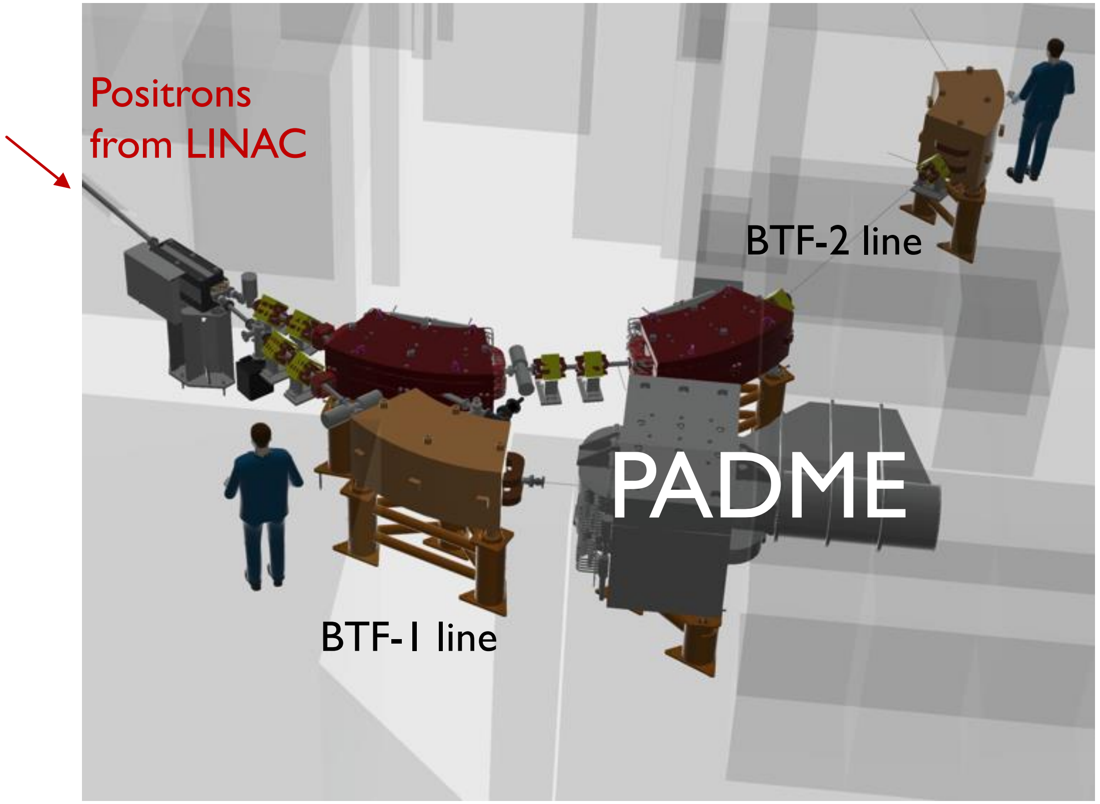
Independent from the properties of A'. It allows to measure:

- A' mass, as a peak in the missing mass spectrum
- the coupling with SM particles, through the production rate

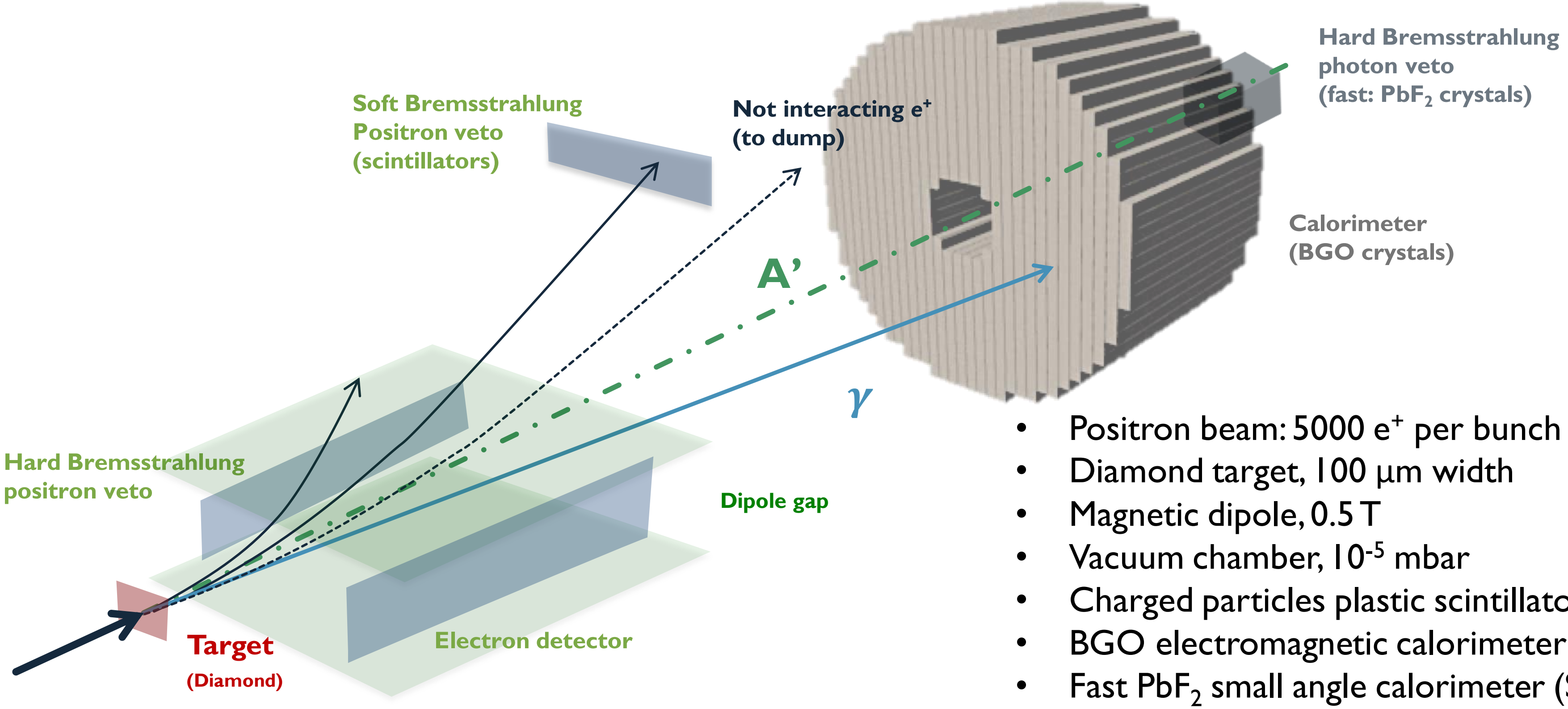
THE BEAM TEST FACILITY

PADME will be placed in the LNF Beam Test Facility (BTF).

	electrons	positrons
Maximum beam energy (E_{beam})	750 MeV	550 MeV
Linac energy spread	0.5%	1%
Typical Charge	2 nC	0.85 nC
Bunch length	1.5 – 40 ns	
LINAC repetition rate	1-50 Hz	1-50 Hz
Typical emittance	1 mm mrad	~1.5 mm mrad
Beam spot size	<1 mm	
Beam divergence	1-1.5 mrad	



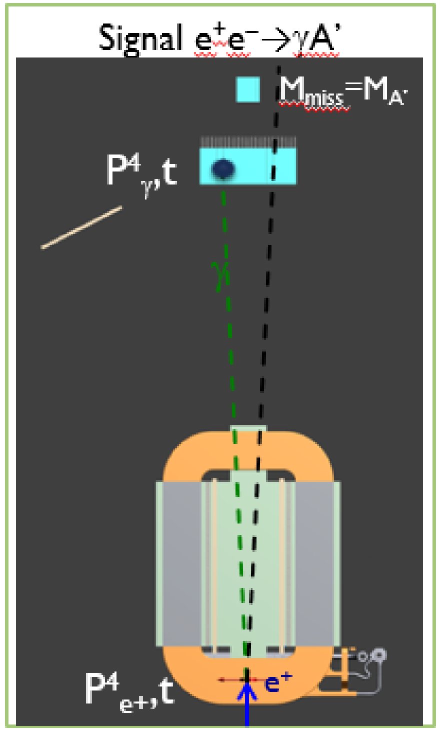
MAIN FEATURES OF PADME



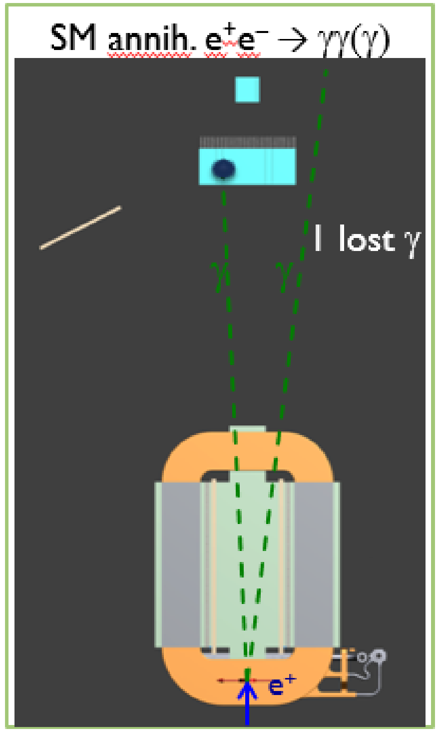
- Positron beam: 5000 e^+ per bunch
- Diamond target, 100 μm width
- Magnetic dipole, 0.5 T
- Vacuum chamber, 10^{-5} mbar
- Charged particles plastic scintillators veto system
- BGO electromagnetic calorimeter (ECAL)
- Fast PbF_2 small angle calorimeter (SAC)
- **Aim for the missing mass resolution of ECAL: 4-5 MeV/c^2**

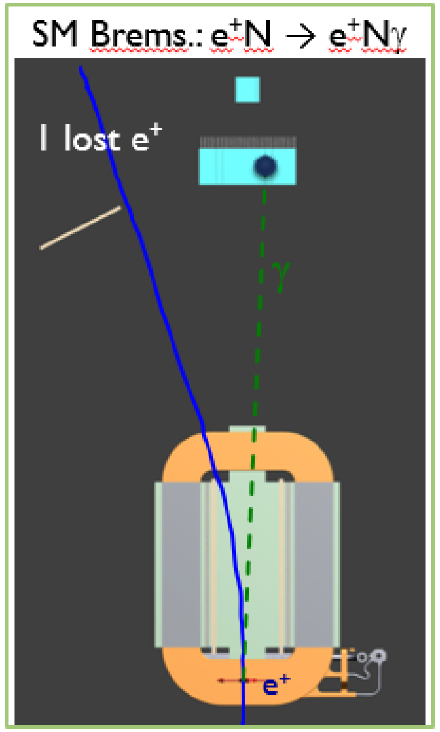
SIGNAL AND BACKGROUNDS

Signal:
1 γ in ECAL

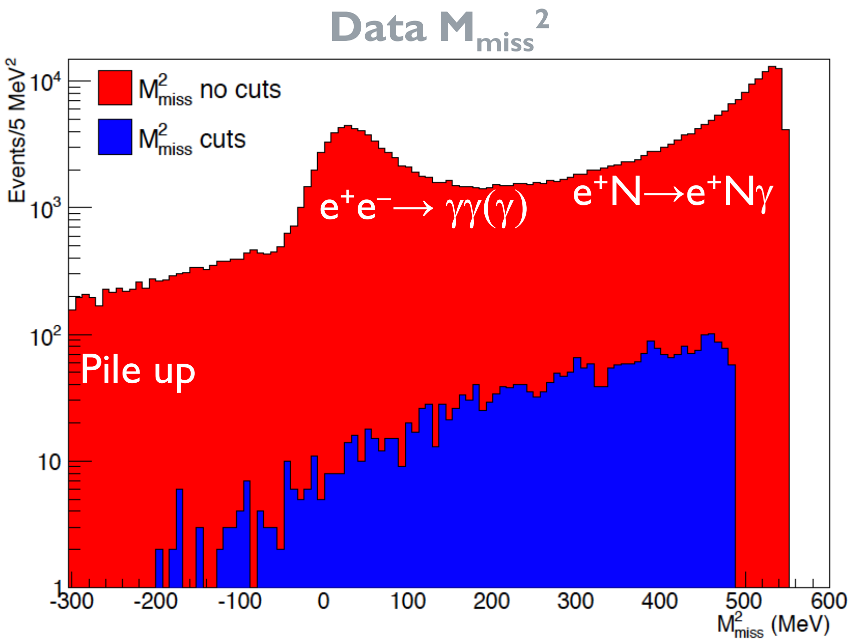


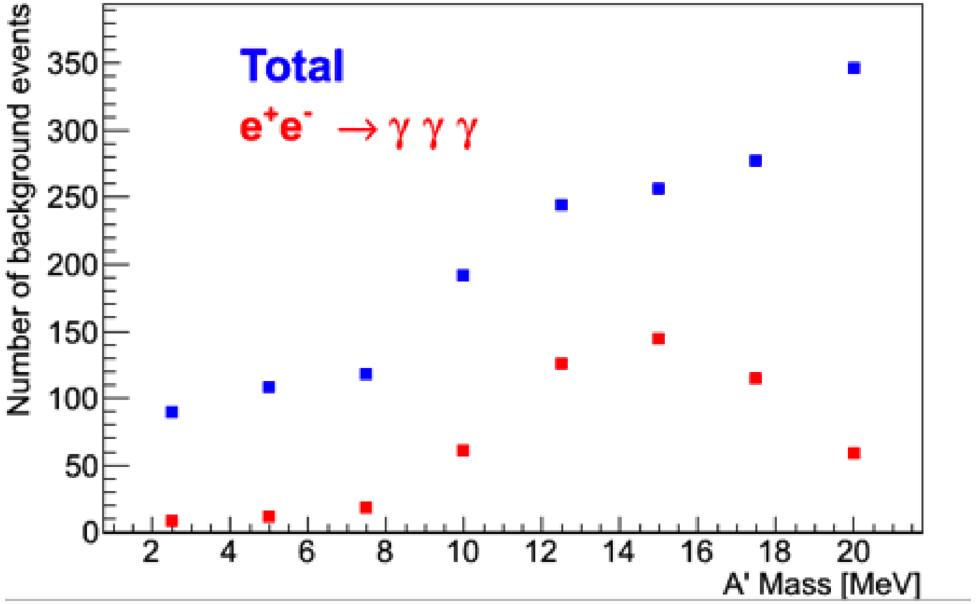
Backgrounds





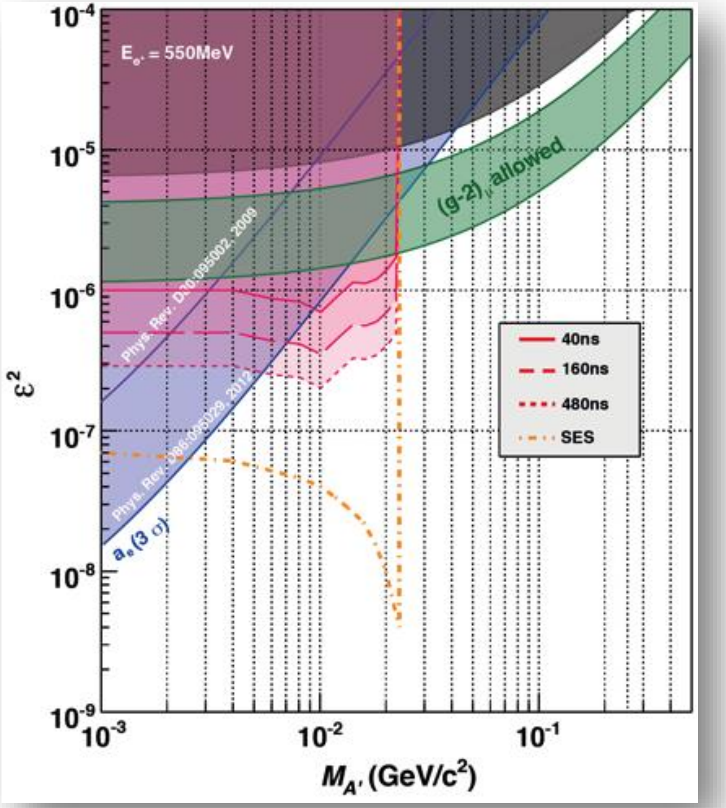
BACKGROUND ESTIMATE





- Main background contribution given by: $e^+e^- \to \gamma\gamma$, $e^+e^- \to \gamma\gamma(\gamma)$, $e^+N \to e^+N\,\gamma$, pile up
- Background from pile up is important, but rejected by the maximum cluster energy cut and M_{Miss2}.

SENSITIVITY STUDIES



- Sensitivity studies have been performed using a GEANT4 simulation
- $2.5 \cdot 10^{10}$ 550 MeV e^+ on target events extrapolated to 10^{13}
- PADME can explore in a ***model-independent way*** the band up to $\mathbf{M^2_{A'} = 2m_eE_{e+}}$ (red band in the plot)
- E_{e+}=550 MeV → $M_{A'}$ < 23.7 MeV/c^2

CONCLUSIONS

- The PADME experiment will search for dark photon, as one of the possible mediator of a fifth interaction that connects our world to the so called dark sector, where DM lives
- PADME will study the invisible decay of DP, using the annihilation process $e^+e^- \rightarrow A'\gamma$
- The experiment will search for a DP with mass up to 23.7 MeV (beam energy = 550 MeV)
- The data taking will start in June 2018 at LNF
  - We expect to collect ~1×10^{13} positrons on target by the end of 2018
  - The main components of the experiment are ready
  - Expect a second physics run in 2019 at LNF