DARK MAGIX

Dark photon searches at MAGIX

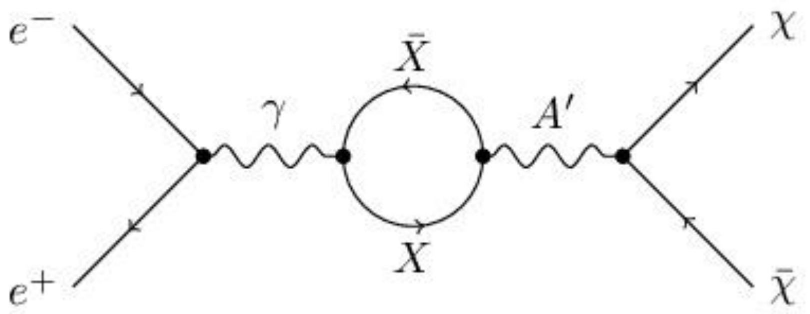
WHAT IS A DARK PHOTON

U(1) Gauge boson

- Carrier of an unknown interaction between unknown particles
- Massive (mass unknown)
- No direct coupling with any SM field

Kinetic mixing

- Same quantum numbers of the SM photon
- Transitions mediated by loops at unknown scales
- Assuming a particle of any mass charged under both fields.
- Mixing degree parameterized by $\varepsilon^2 = \frac{\alpha'}{\alpha}$
- α' is the effective SM coupling



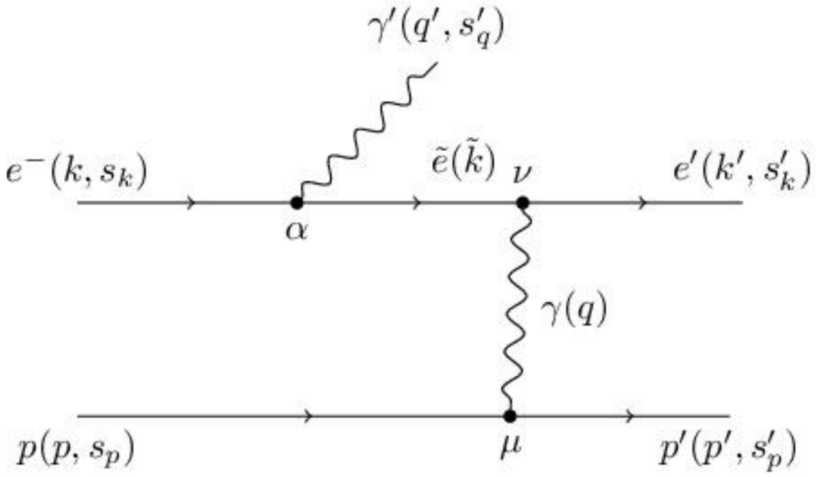
DARK PHOTON PRODUCTION

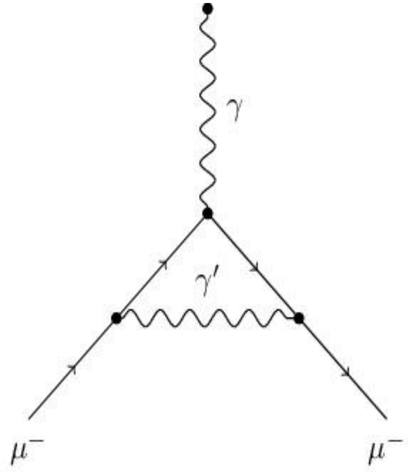
Replace the SM photon in allowed processes

- Bremsstrahlung
- Schwinger term in muon magnetic moment
- Electron pair production

Observable differences

- Kinematic differences due to the particle mass
- Cross section difference due to the additional diagrams

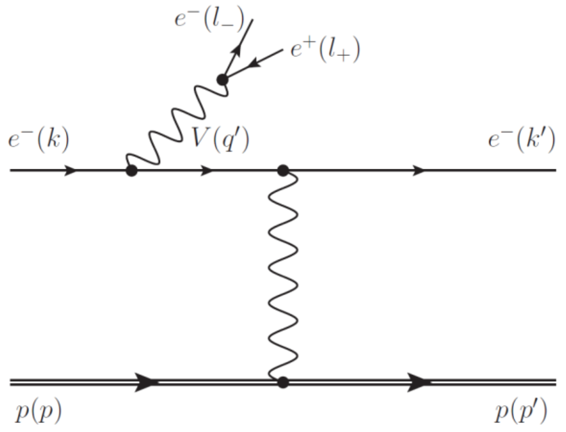




DARK PHOTON DETECTION

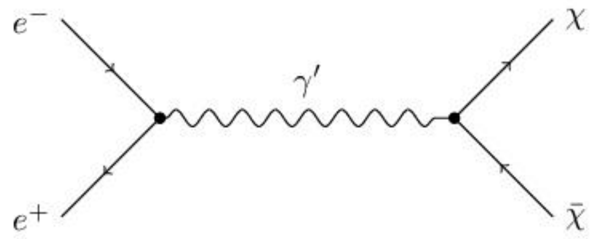
Visible decays

- Relevant branching ratio of $\gamma' \rightarrow SM$
- Possible if the dark photon is the LDP
- Fixed decay product invariant mass



Invisible decays

- The dark photon decays in the dark sector
- Likely if the dark photon is not the LDP
- Reasonable to assume a complex dark sector (it should represents up to 85% of the universal mass)



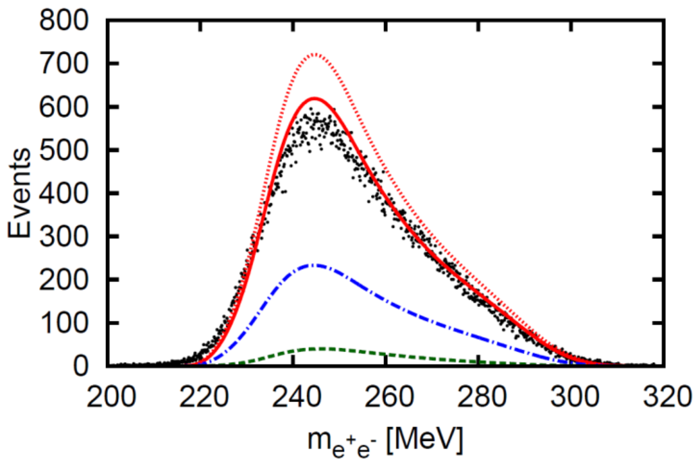
VISIBLE DECAYS

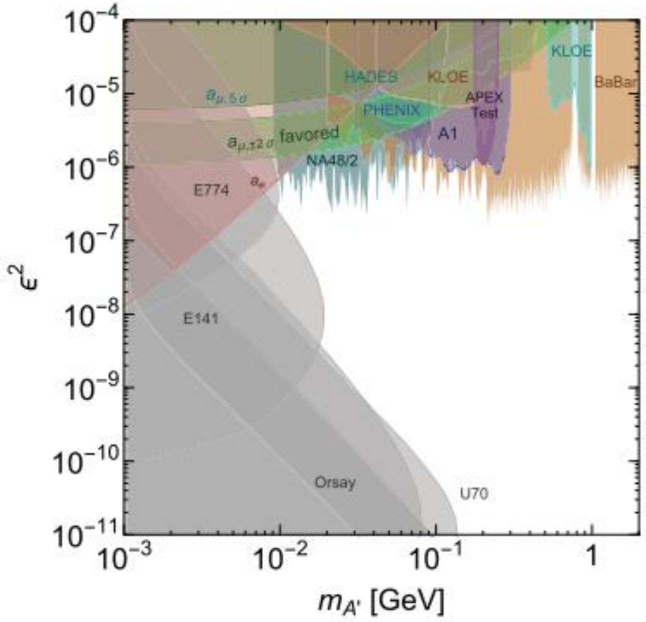
Bump hunting

- The DP decay products have a well-defined invariant mass
- Competing background are the similar SM photon processes
- Needs to locate a narrow "bump" on the continuous spectrum

Fast ongoing developments

- Many new running experiments quickly filling the holes
- Will we still be competitive in 4/5 years?





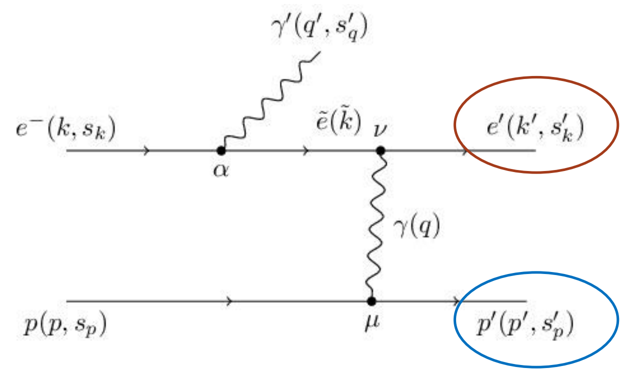
INVISIBLE DECAYS

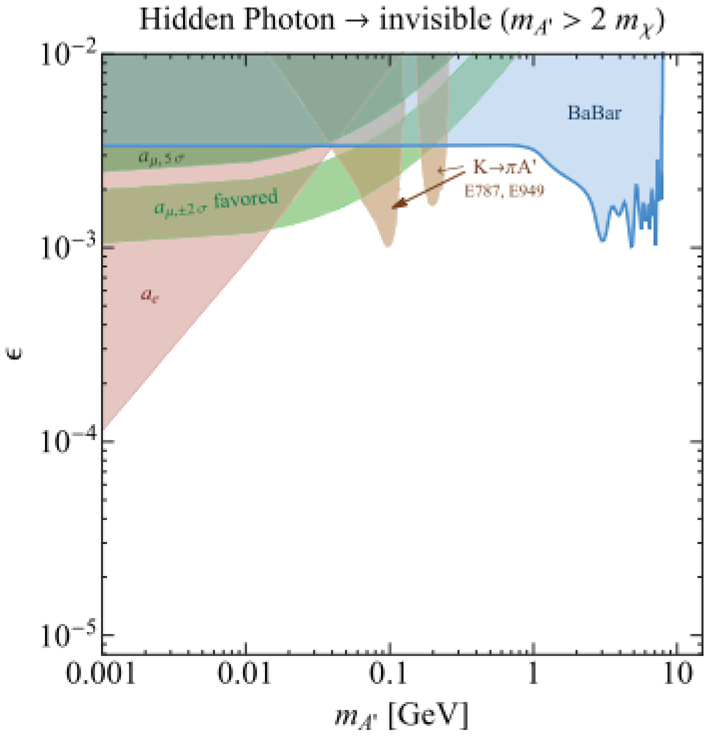
Missing mass

- Measure all the final products
- Measure the missing invariant mass
- It's challenging to tag the proton

Almost virgin territory

- Almost no constraint by current experiments
- Several competing experiments in development
- Important contributions to be made





MAGIX DP SIMULATION

GENERAL FEATURES

First benchmark of the MXWare software

- Extensible and configurable system
- More on Friday

Event generator

- Custom beam, target and detector representation
- Pseudo- or quasi-random generator
- Complete event generation for further analysis
- Fast direct histogram generation

Fast detector simulation

- The detector are represented by their phase space acceptance
- Detection efficiency parameterized in the acceptance

Bachelor thesis of F. Berressem

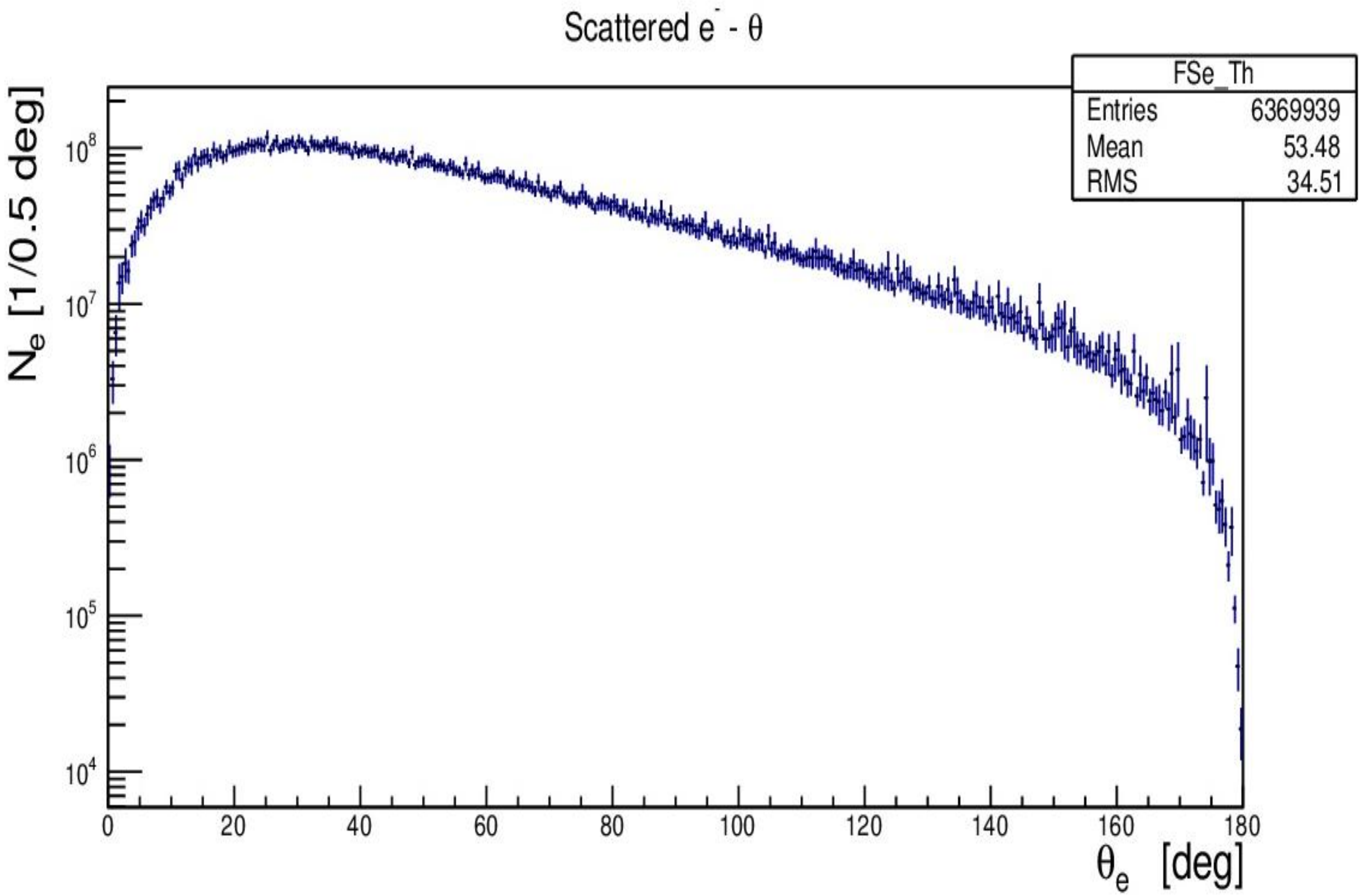
CROSS SECTION CALCULATION

Full phase space generator

- Customizable phase space constraints
  - Electron and proton angles and momenta
  - Dark photon mass
- Restrictions to reduce run time

Experimental parameters

- 105 MeV electron beam
- 10 days run time
- Luminosity $1.987\ 10^{34} cm^{-2} s^{-1}$



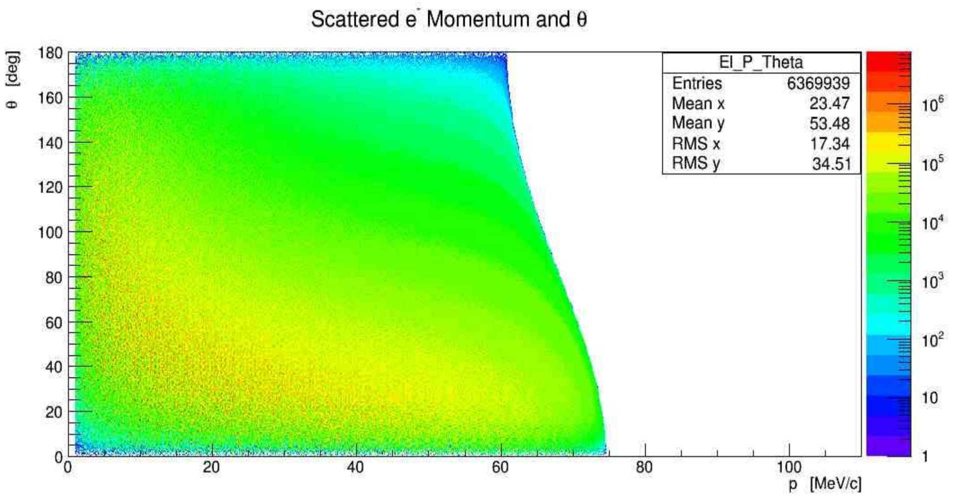
SETUP OPTIMIZATION

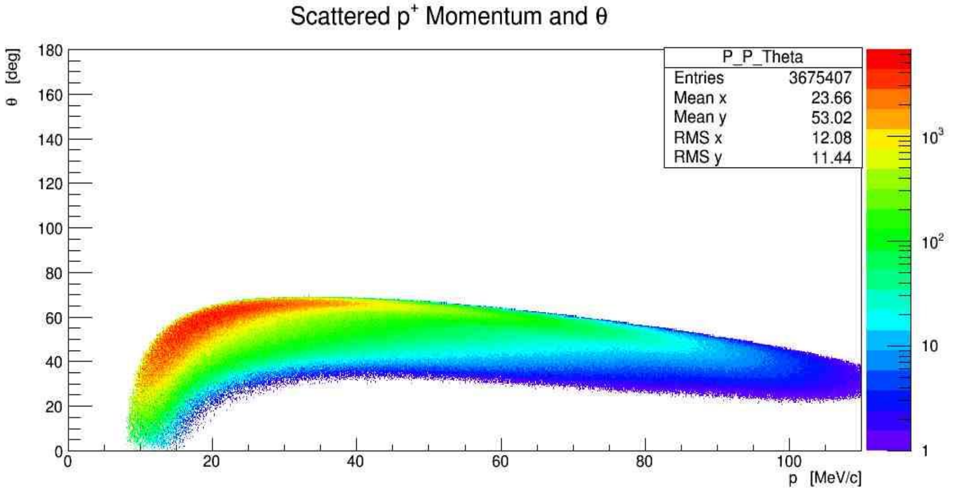
Fix dark photon mass

Optimize electron spectrometer
- Angle and momentum

Optimize proton spectrometer
- Angle and momentum

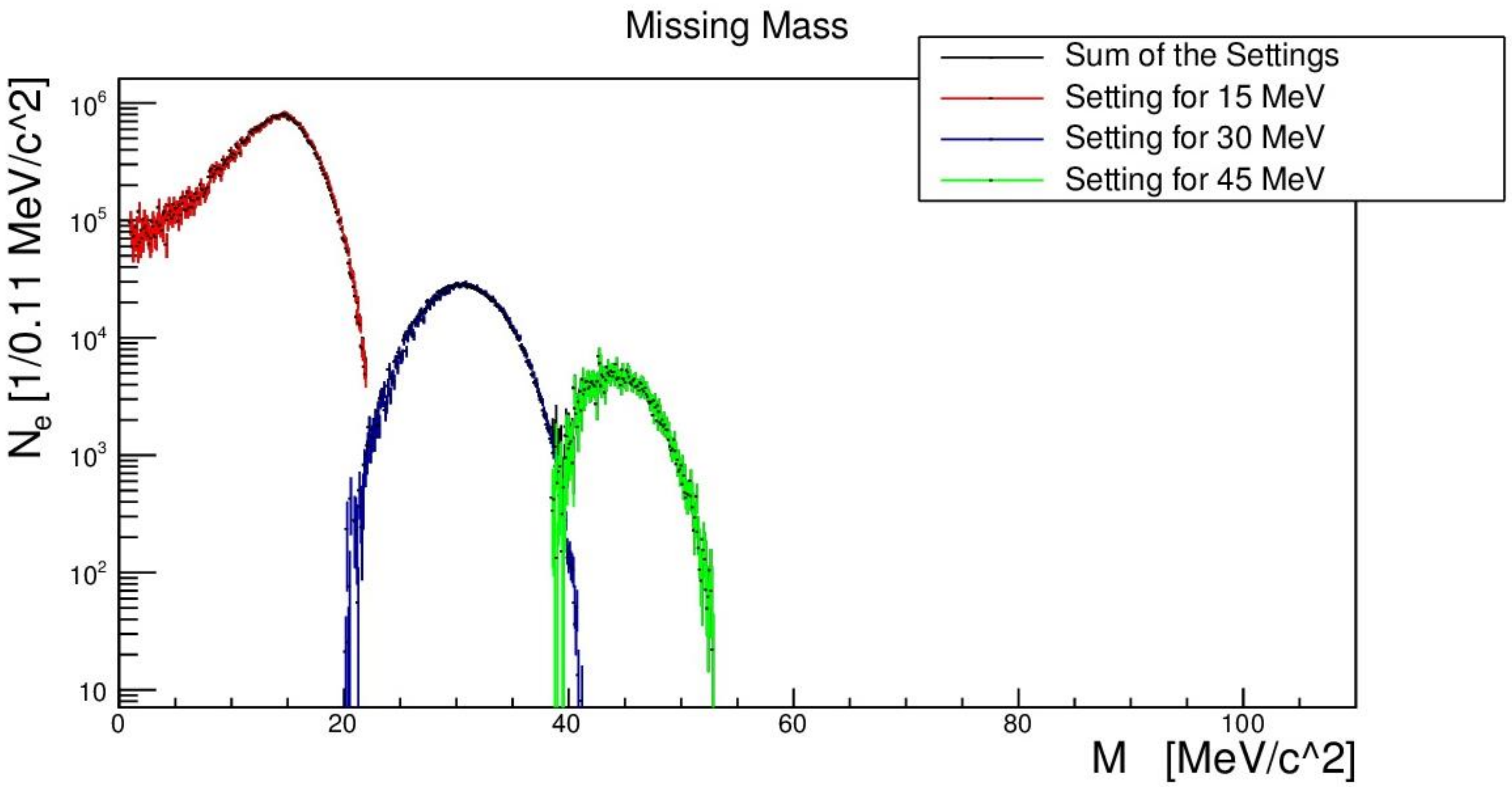
m(γ')	Electron spectrometer		Proton spectrometer		10-days event couns
	Θ [°]	P [*MeV*]	Θ [°]	P [*MeVI*	
15	14	40.87	71.03	10.02	4.68×10^6
30	18	40.74	51.03	17.36	157722
45	16	30.5	49.05	29.74	28924





RATE SIMULATION

For each defined setting	Run the simulation with random DP mass
	Calculate the rate as a function of the missing mass
Next step	Implement the background generators (Bethe-Heitler)
	Re-optimize
	Calculate sensitivities



CONCLUSIONS

NEXT DEVELOPMENTS

Implement background process simulation	Bethe-Heitler Student thesis project
Implement the visible decay generator	And the bump hunting algorithm Another possible student project
Improved detector representation	Proton detector efficiency and momentum resolution Needs a more complete detector simulation package
Adaptive Monte Carlo generator	To reduce the run time and simulation errors One of the general improvements of the simulation package
Putting all together	Compute the MAGIX sensitivities for both processes