Searching for dark matter with the ATLAS detector using unconventional signatures

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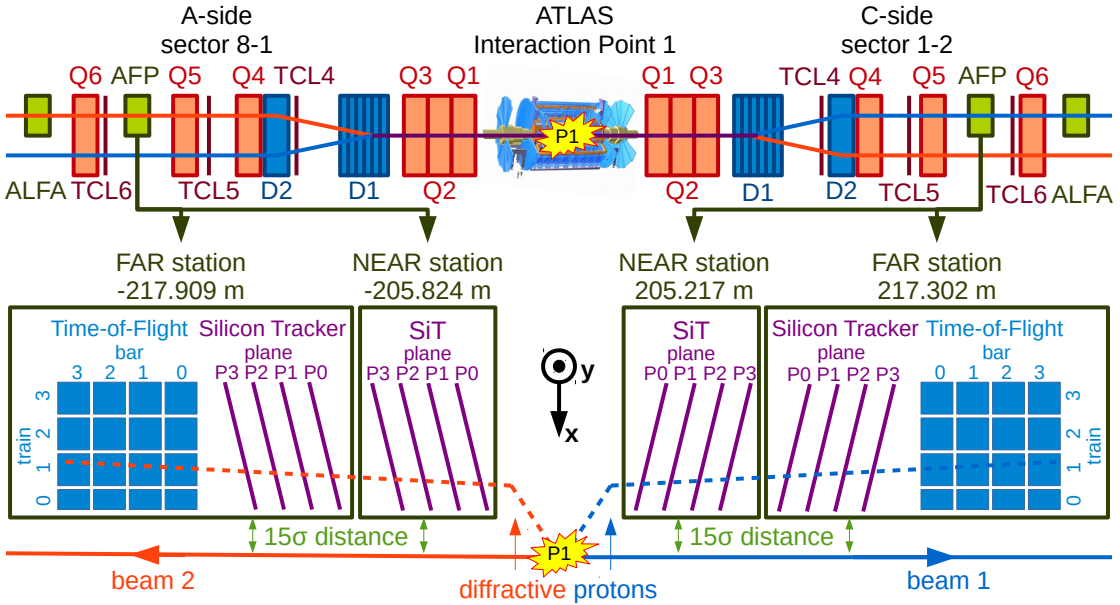
AFP

The ATLAS Forward Proton Detector

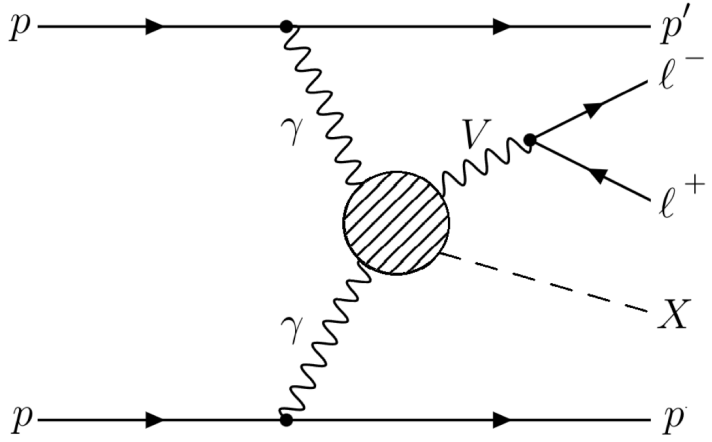
Located at ~210 m from the IP



- **Silicon Tracker (SiT)**: Proton tracks reconstruction
- **Time-of-Flight (ToF)**: Calculate if protons come from a common vertex ⇒ Check if it is consistent with primary vertex

Channel Signature

- **Elastic** production of V+X
- **V** decays into **leptons**: it can be a SM or BSM particle
- **X** is a **generic** particle: there is no need to infer its properties
- **Model independent** search
- AFP information is used for the **missing mass method**
- Takes into consideration the **visible particle** properties



$$m_X^2 = (E_{\gamma\gamma} - E_{ll})^2 - (\overrightarrow{p_{\gamma\gamma}} - \overrightarrow{p_{ll}})^2$$

AFP

Central detector

AFP V+X

Event Selection

- So far this analysis has used real p-p collisions **data collected in 2017** at $\sqrt{s} = 13$ TeV (Periods **C, E, F, H, I, K**)
- Corresponds to ~ 44 fb^{-1} of raw data, 14.6 fb^{-1} after the **AFP Good Run List** (GRL) is applied

GRL (afp_grl_2017)	
HLT_mu26_ivarmedium OR HLT_2mu14	HLT_e26_ltight_nod0_ivarloose OR HLT_e60_lhmedium_nod0 OR HLT_e140_lhloose_nod0 OR HLR_2e17_lhvloose_nod0_L12EM15VHI OR HLT_2e24_lhvloose_nod0
At least 2 muons passing: ▪ Opposite sign ▪ Muon selection: Medium ▪ Muon isolation: WP Loose ▪ $p_T(l_1, l_2) > 15$GeV ▪ $\lvert\eta(l_1, l_2)\rvert < 2.4$	At least 2 electrons passing: ▪ Opposite sign ▪ Electron selection: LooseAndBLayer ▪ Electron isolation: Loose_VarRad ▪ $p_T(l_1, l_2) > 18$ GeV ▪ $\lvert\eta(l_1, l_2)\rvert < 2.47$
Exactly 1 proton per AFP side	

AFP V+X

MC Background vs Data

Background estimation: hybrid method

- Sherpa 2.2.11 Z+jets samples (recommended by PMG) overlayed with pile-up protons from data

Real data

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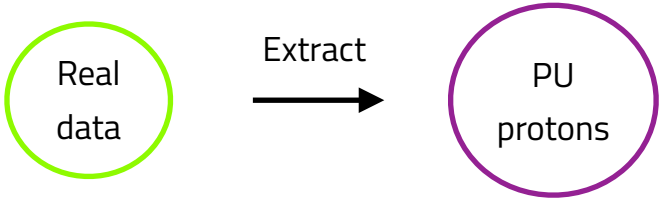

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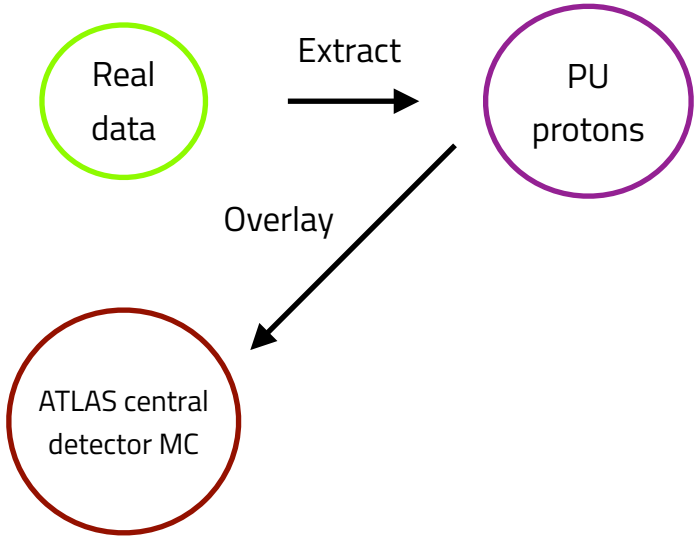

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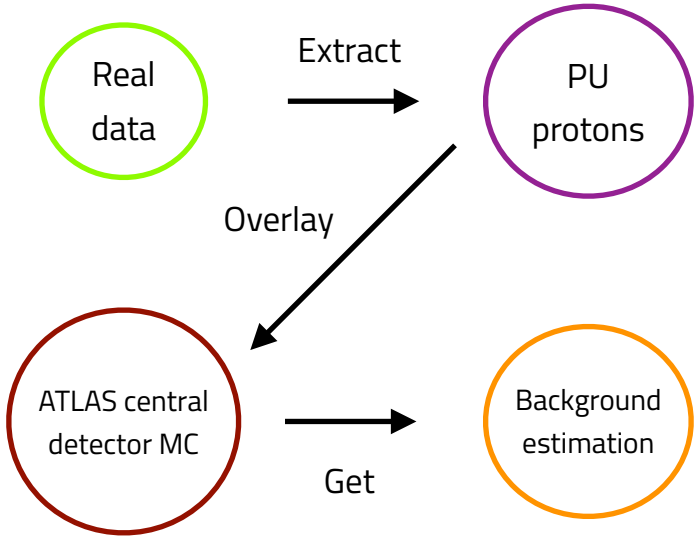

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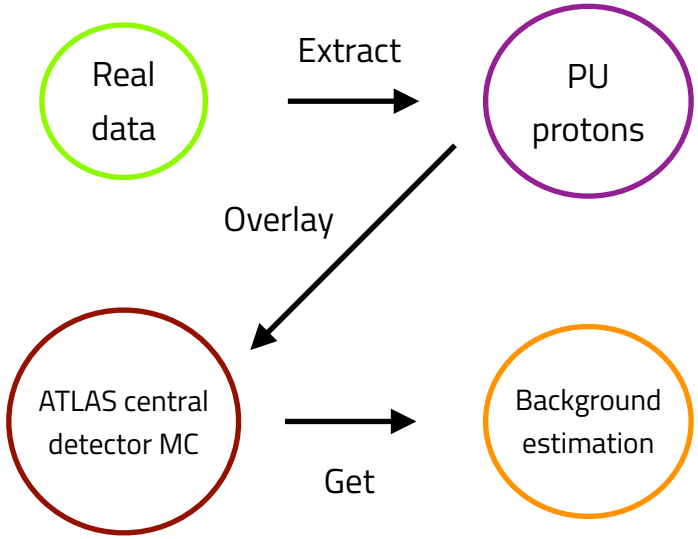
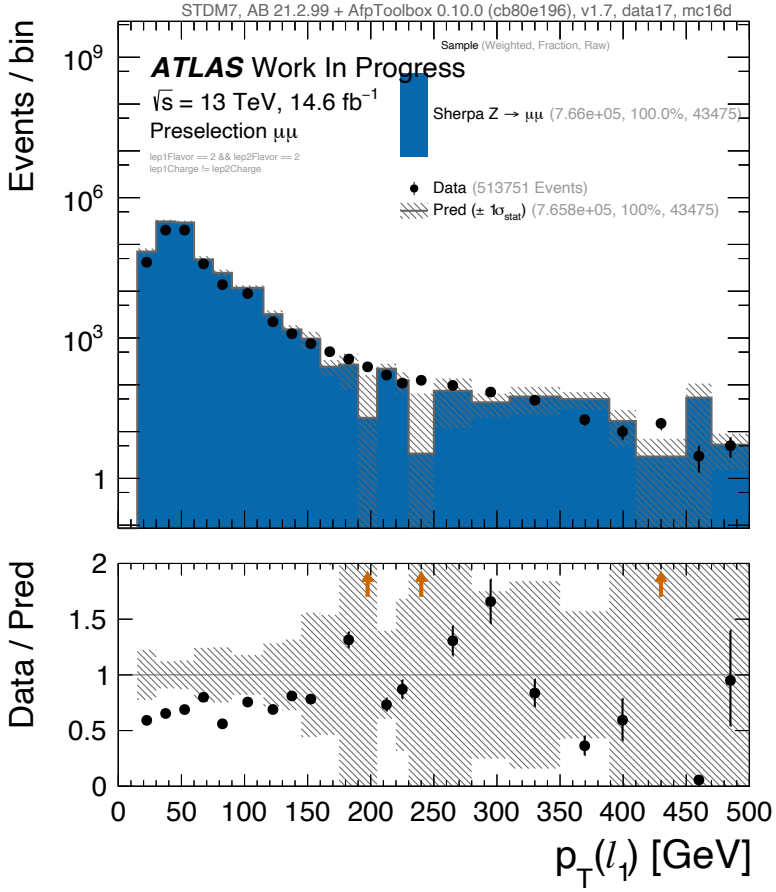
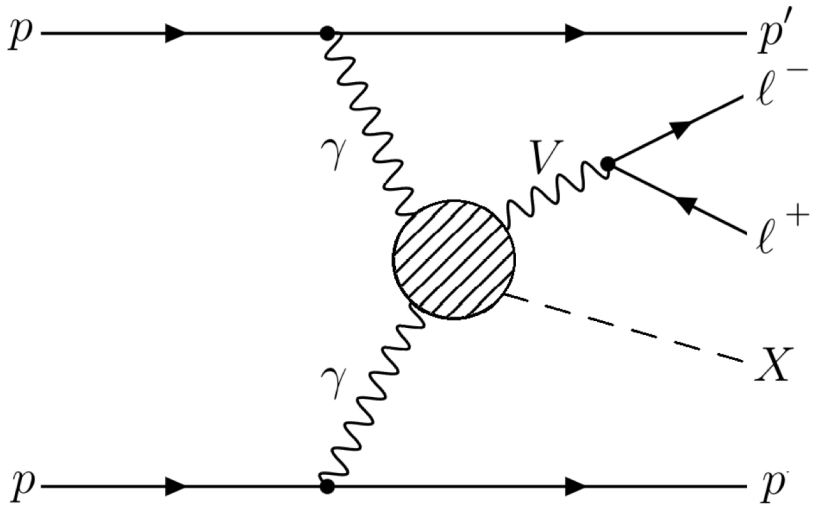




AFP V+X

Signal Generation: SuperChic and MadGraph

- The analysis strategy does not require any signal model choice. However, for results interpretation a specific signal should be chosen



$$\xi = 1 - \frac{E_p}{E_{beam}} \qquad M_{pp} = \sqrt{s\xi_1\xi_2}$$

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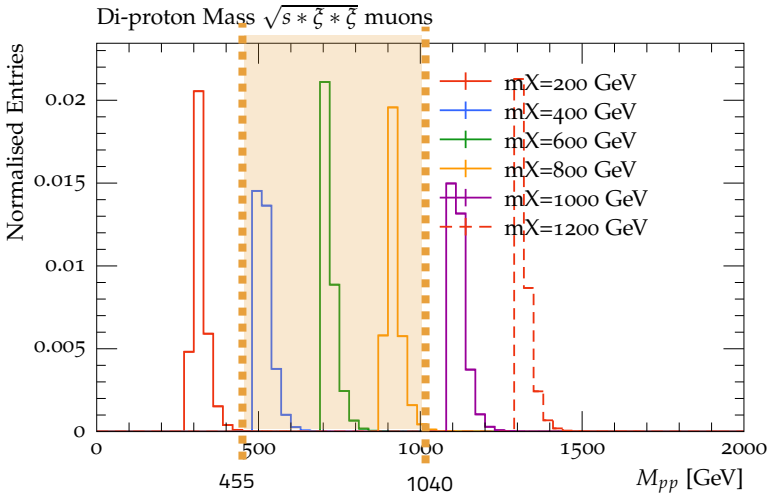

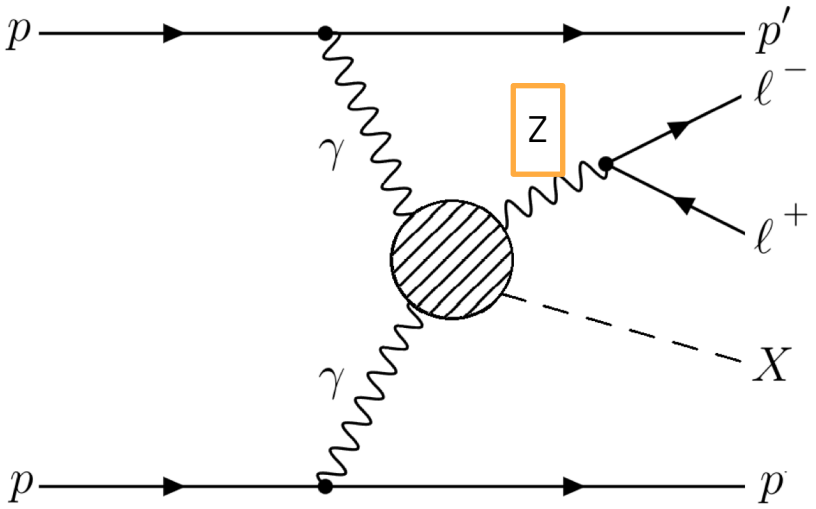

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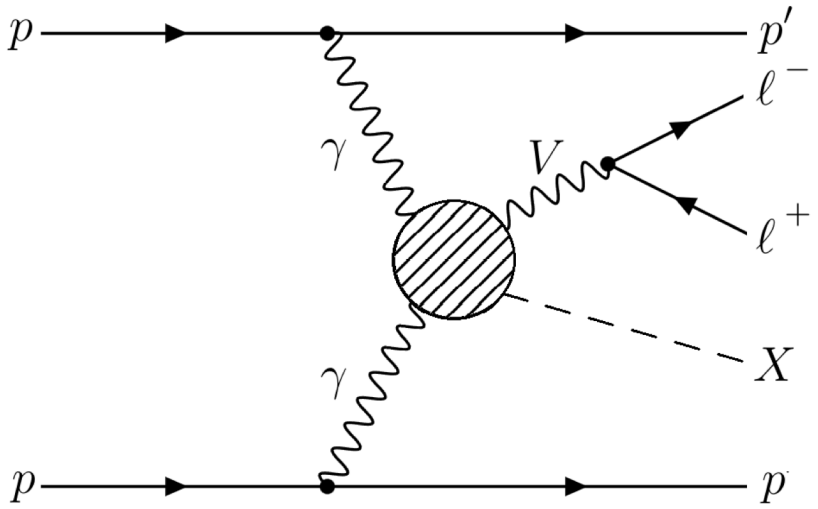

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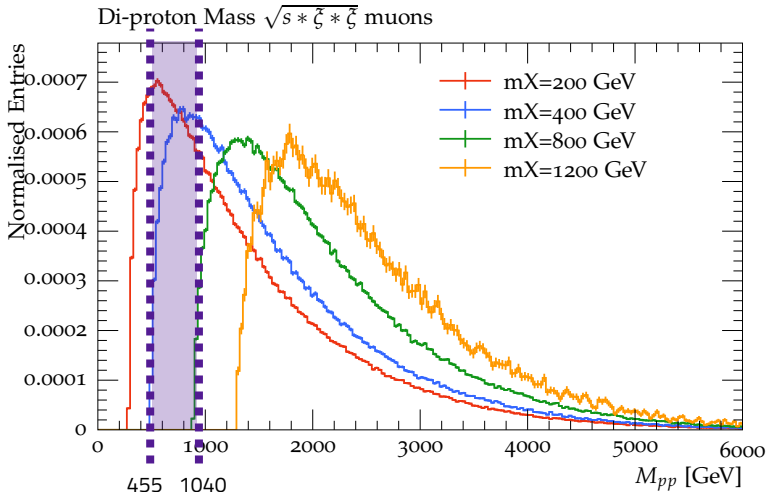

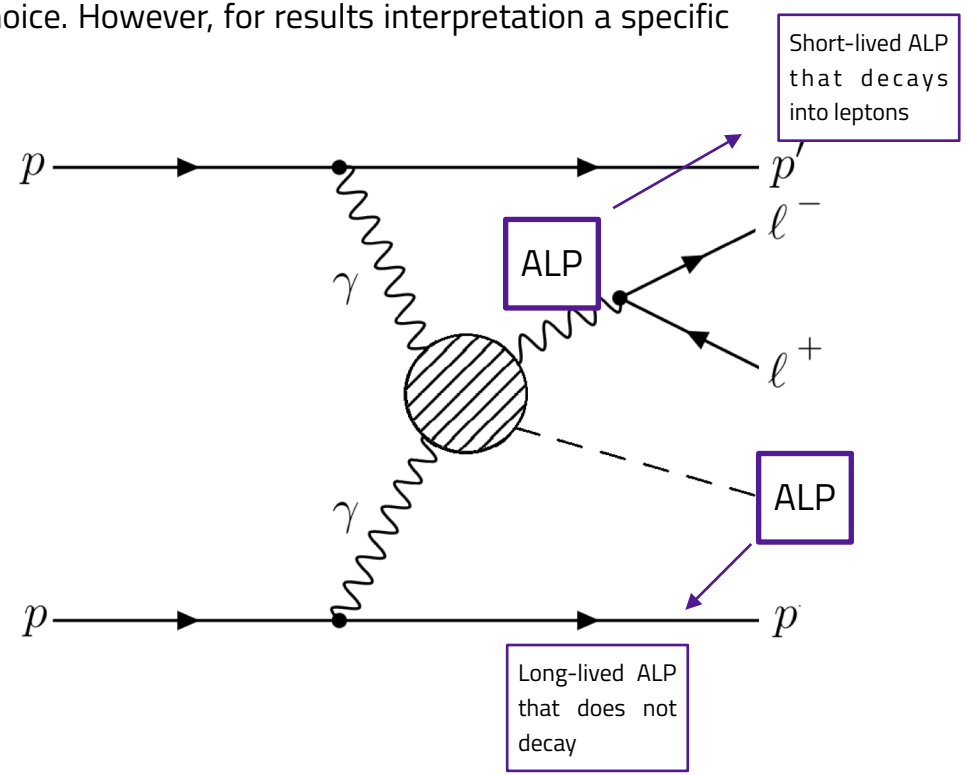

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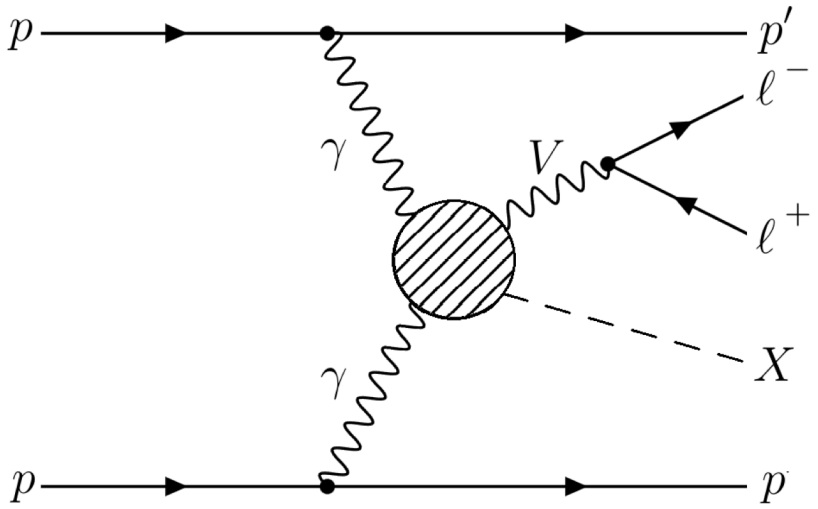

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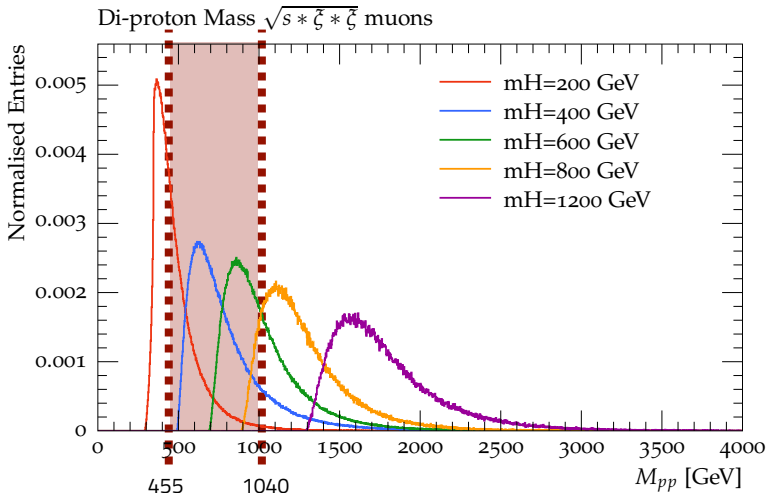

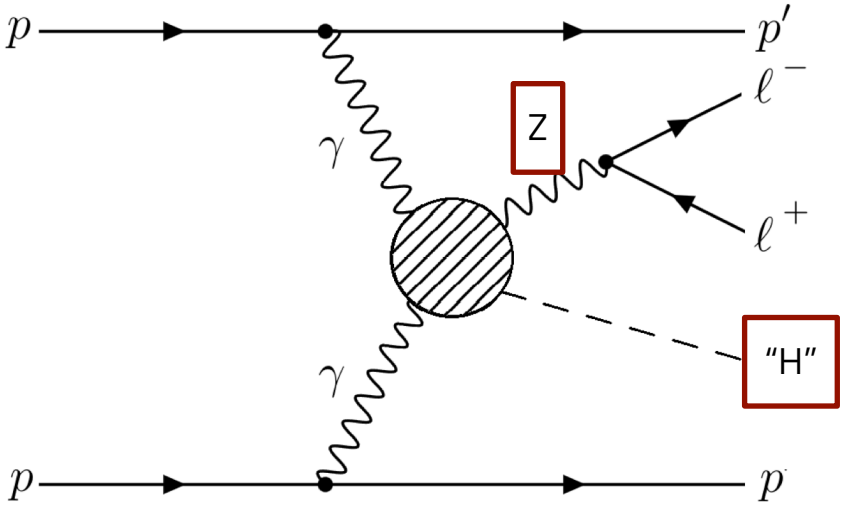

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Summary

Next Steps

V+X analysis using double-tag AFP events:

- Chain for the ntuple production, selection and plotting is ready
- Full signal MC already generated with ATLAS official production

- **Next steps**:
  - Working on TRexFitter configuration file for the limit calculation
  - Finalise the analysis and have it approved in ATLAS
  - Finish the writing of the thesis

Thank you!

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Backup

Background estimation

Data-driven Estimate

- Event shifting of i = 2, 3, …, N is used to estimate the background. E.g. event 1 will be mixed with protons from event 3
- Multiple orthogonal samples were used to improve statistics

Real data i=0

Hybrid Method

- Sherpa 2.2.11 Z+jets samples (recommended by PMG) overlayed with pile-up protons from data

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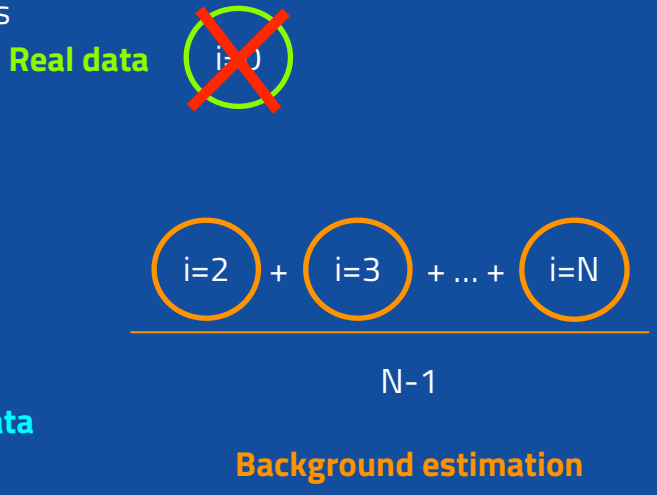

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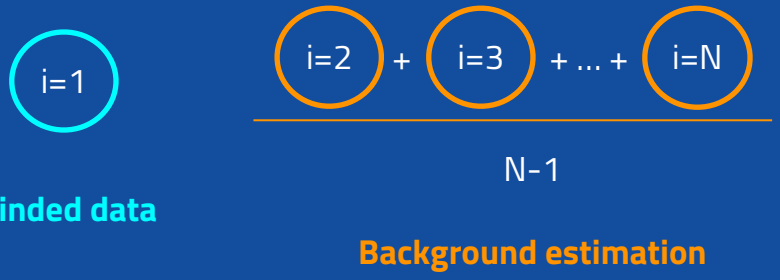

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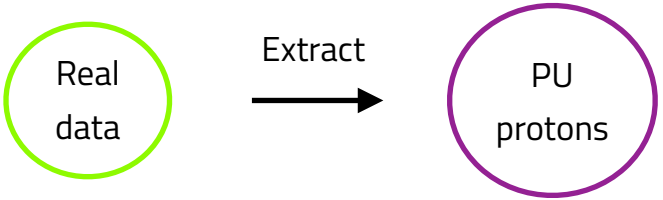

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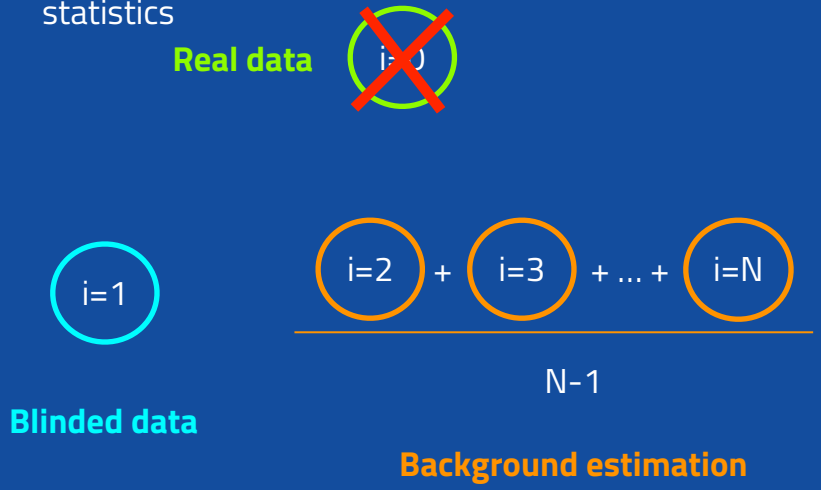

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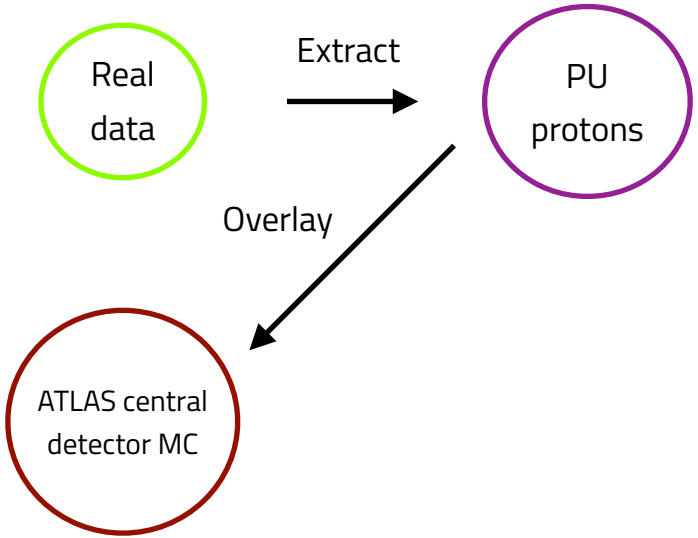

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Real data i=0

i=1

Blinded data

$$\frac{i=2 + i=3 + \ldots + i=N}{N-1}$$

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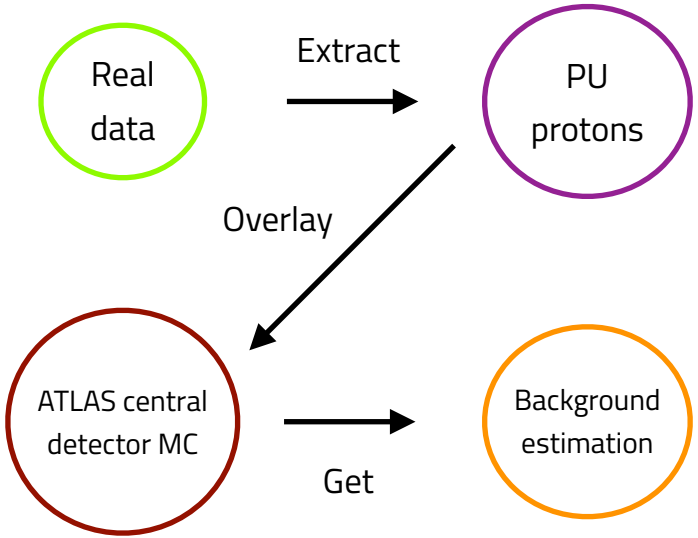

AFP V+X

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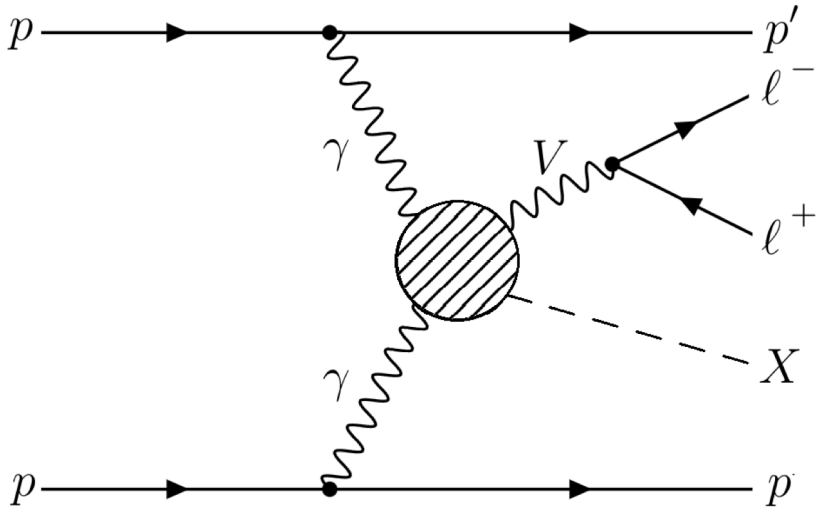

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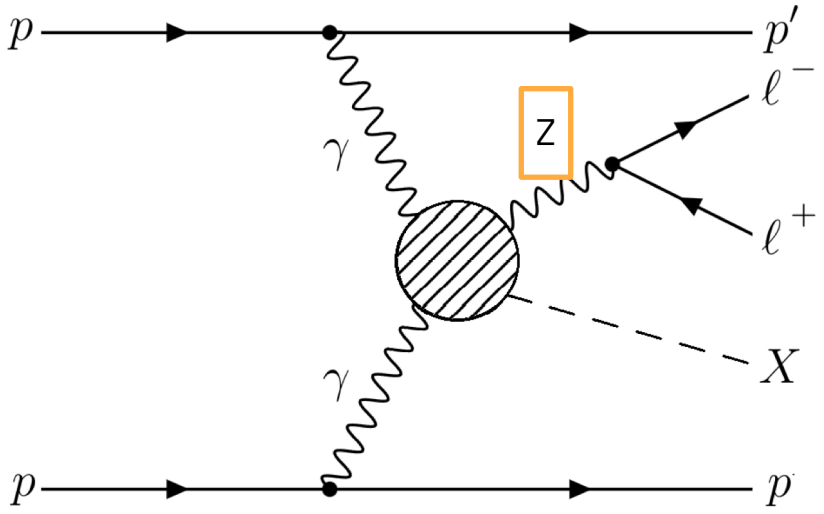
X Mass (GeV)
200
400
600
800
1000
1200



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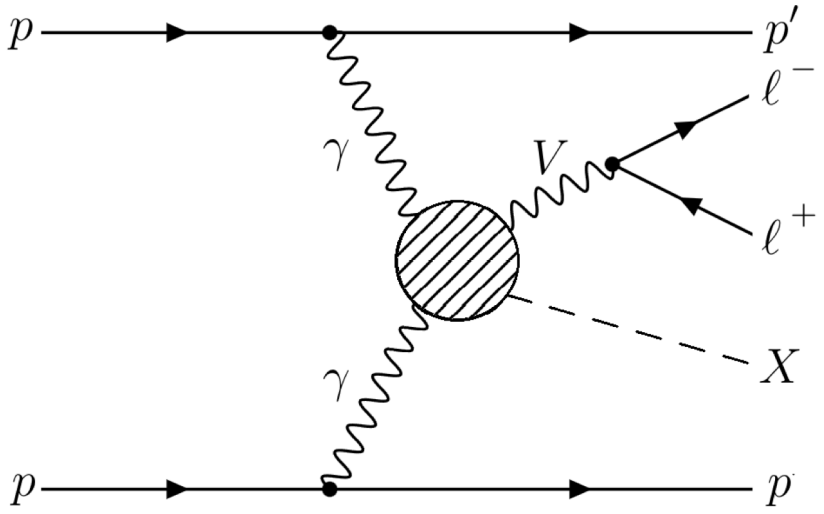

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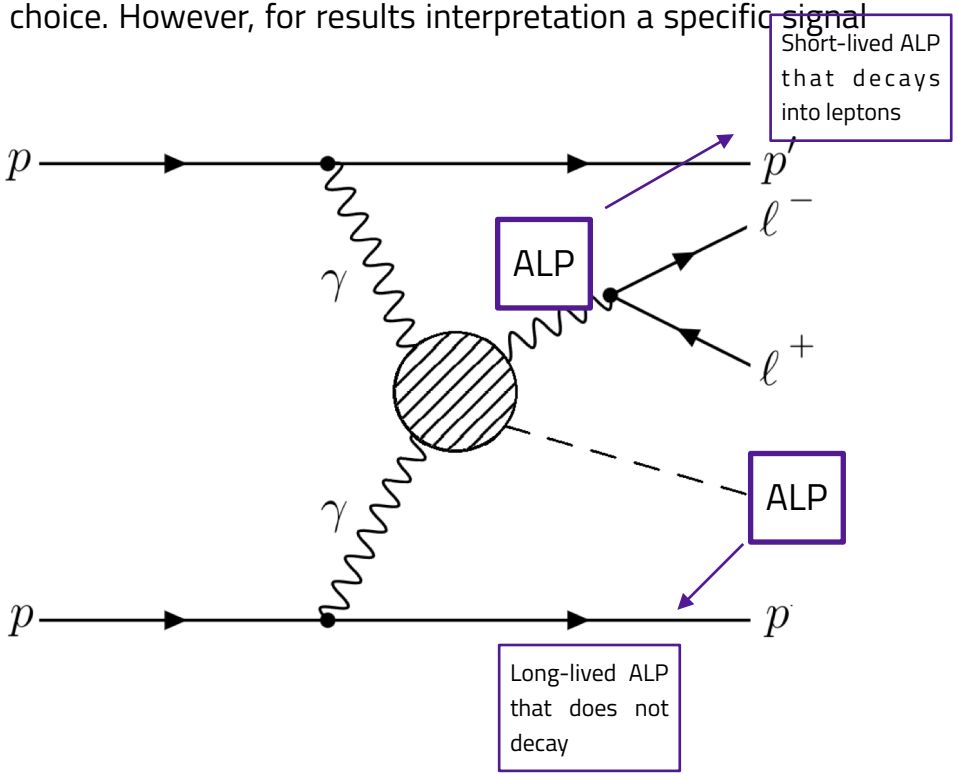
Short-lived ALP mass (GeV)	Long-lived ALP mass (GeV)	Couplings
10	800	1
91	200	1
	400	1
	800	1
	800	0.1
	1200	1
200	800	1



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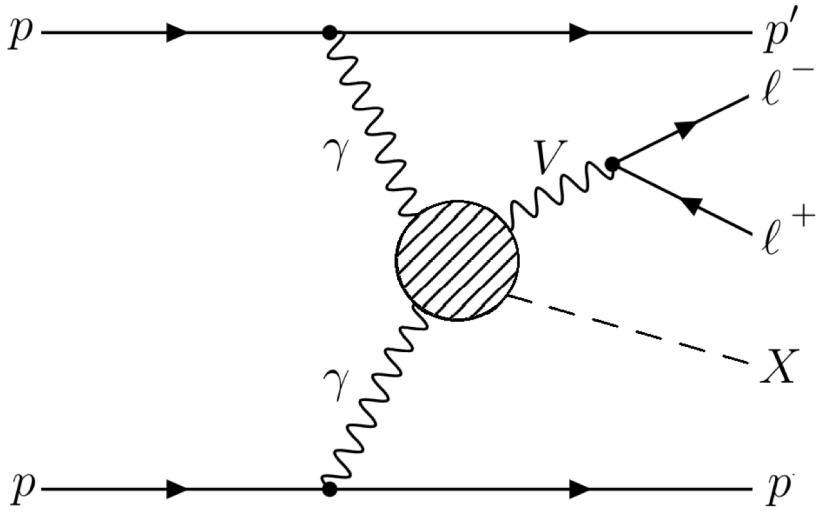

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Higgs Mass (GeV)
200
400
600
800
1200