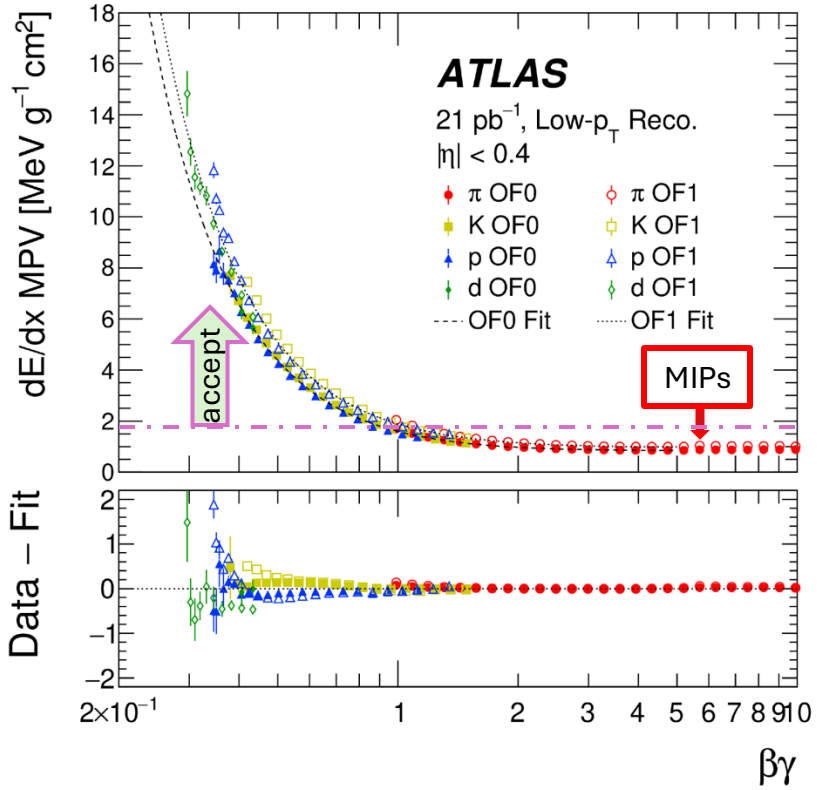
Collider cross talk seminar on dE/dx

The ATLAS contribution

The story and the experimental method

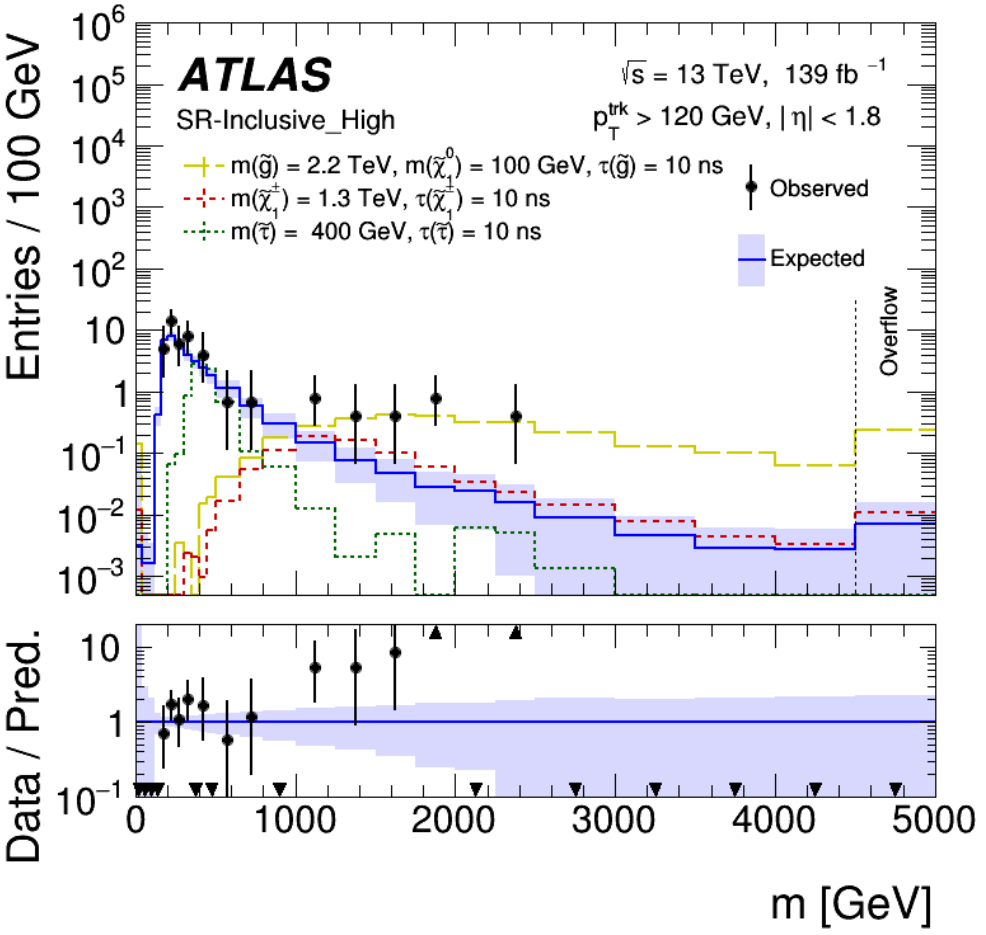
- Six (7TeV, 8TeV, 13TeV: 3.2 fb^{-1}, 36.1fb^{-1}, 139.9 fb^{-1}, 140fb^{-1}) measurements since 2013, all MET-triggered and searching for high-p_T isolated charged particles, massive and long-lived.
- Strategy based on m=p/$\beta\gamma$, with $\beta\gamma$ measured via dE/dx (Bethe-Bloch fit for $\beta\gamma$<1, $\beta\gamma$ range [0.3-1]), dEdx is measured using pixel detector with a truncated mean (typ. reject 1 dE/dx measurement out of 4) and calibrated with low-p SM particles.
- Then generate data-driven background and check if data shows any significant excess in any predefined mass windows (size of windows increases with mass following σ(p))



- The method is valid for any high-mass charged particle with unit charge and τ>3ns (track measured in pixel and part of SCT, i.e. r>45cm, only pixel contributes to dE/dx), the interpretation is done in a SUSY environment (staus, charginos and R-hadrons).

The results up to 2023

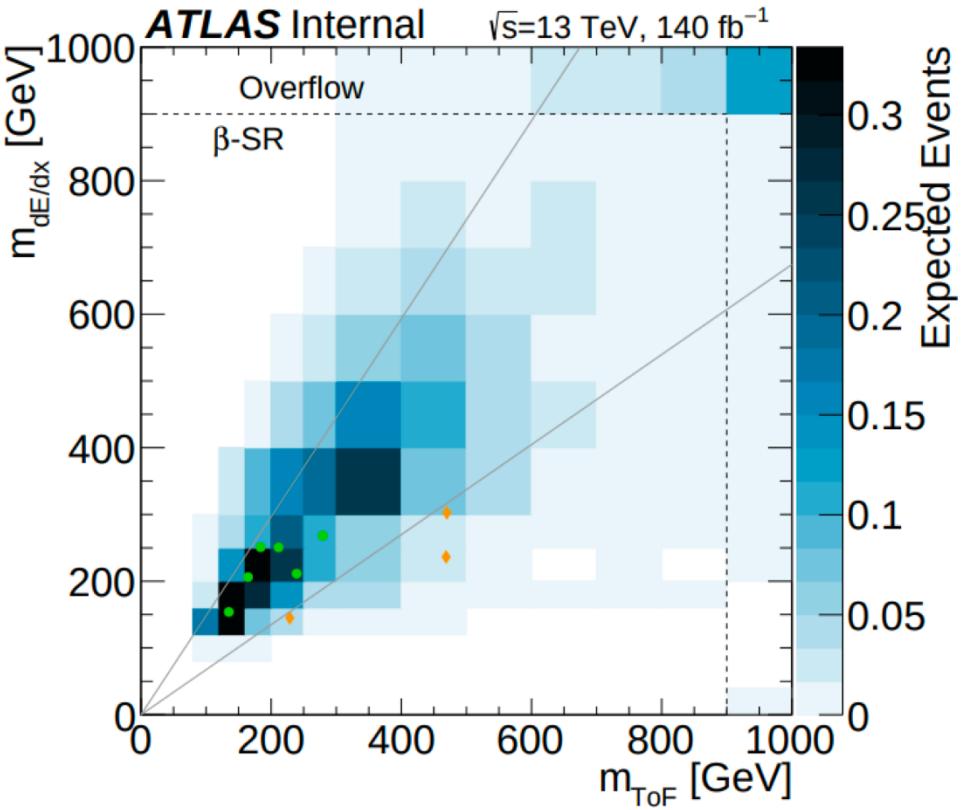
- The experimental method has been refined over the years reflecting a better understanding of the pixel detector operation under irradiation, the addition of the innermost pixel layer (IBL) and the use of larger integrated luminosities.
- The analysis group has increased [5p&1lab→ 30p&7labs] reflecting the increasing interest in LLPs
- The last publication (JHEP06(2023)158) showed a 3.3σ global excess at m~1.3TeV, this was not confirmed as due to a "slow" particle by a ToF measurement (still not perfectly calibrated).



The evolution of the strategy

- Even if the background generation has been confirmed by many studies and checks, it remains true that our mass measurement is based on the far tails of the ionization distribution.
- It was then decided that the use (and correlation) of two independent mass measurements would have added robustness to the results (impact of fluctuations minimized).
- We then:
  - Measured two $\beta\gamma$ (then two masses) on one track with high dEdx and long ToF (β-driven analysis)
  - Measured two $\beta\gamma$ on two opposite-sign tracks both with high dEdx (two-track analysis)

  and check compatibility inside a mass-compatibility cone (cone because σ_p/p increases with p).

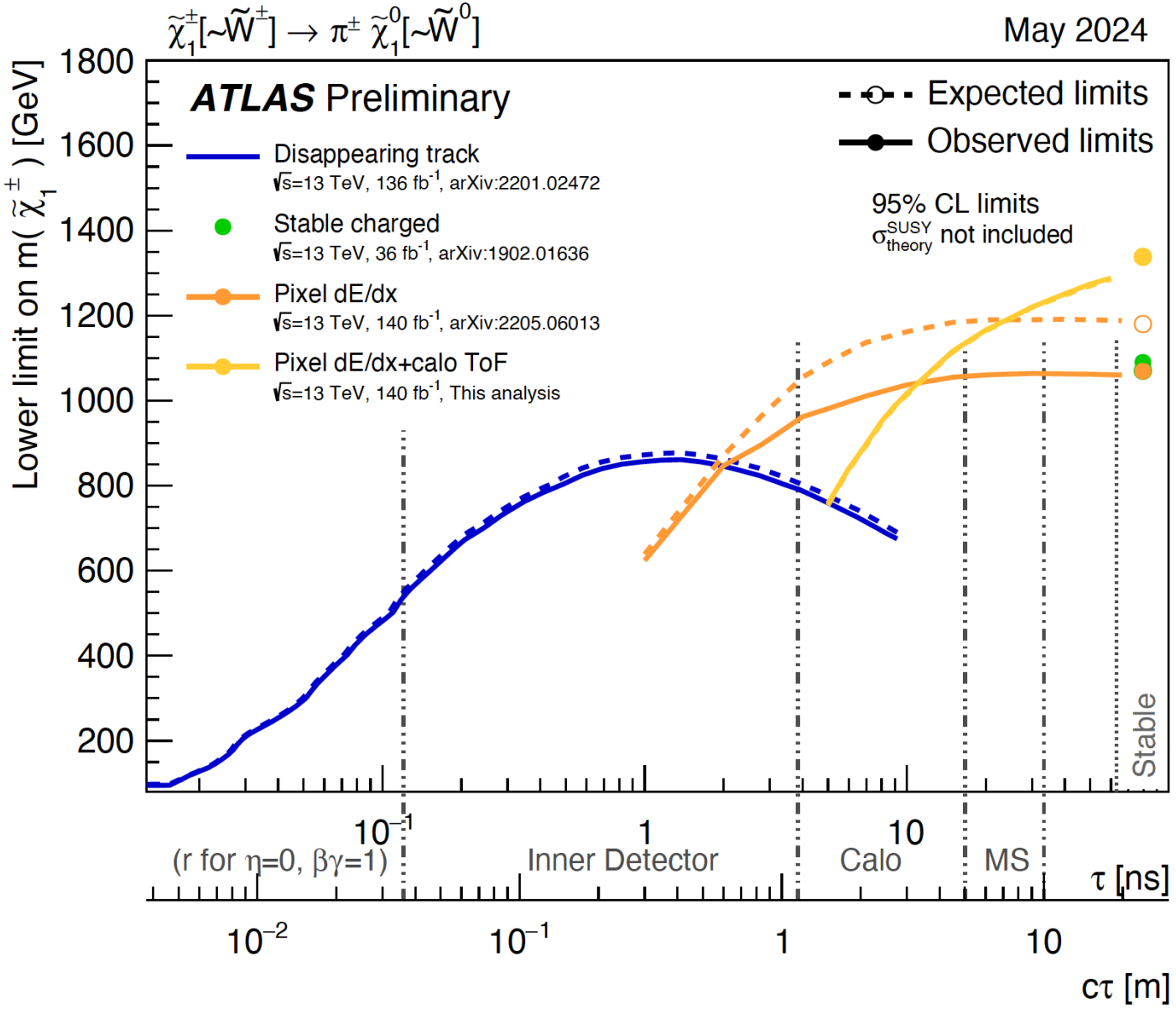


Expected background and observed data distributions in the $m_{dE/dx} - m_{ToF}$ plane

Data (6 events) are in reasonable agreement with background expectations (3.7 events). No data with m>300 GeV

The 2024 results

- Results are public for the β-driven analysis only.
- No excess observed, just improvement in mass limits for LLPs (here the chargino case).

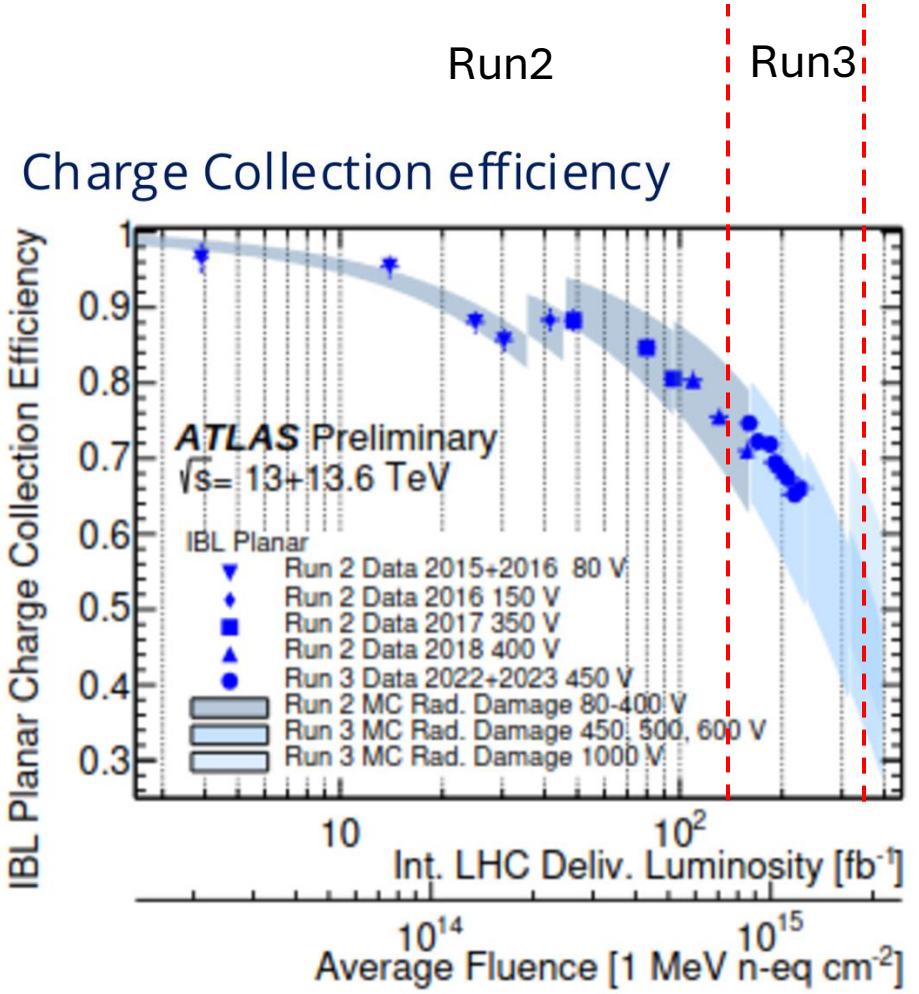


The Run3 plans

- Pursue the multiple mass measurement strategy, including the possibility of exploring excesses due to Q>1 (in the region 1<Q<3)
- We plan to significantly increase the signal acceptance widening the trigger acceptance.
- We have to afford new experimental challenges related to the degradation of the pixel detector caused by the radiation damage, which acts differently on the different pixel layers (innermost has 7 times more damage than outermost).
- This implies equalization of cluster dEdx before the calculation of the track dEdx (otherwise we apply a bias: e.g. the truncated mean would preferentially exclude the less radiation damaged sensors)

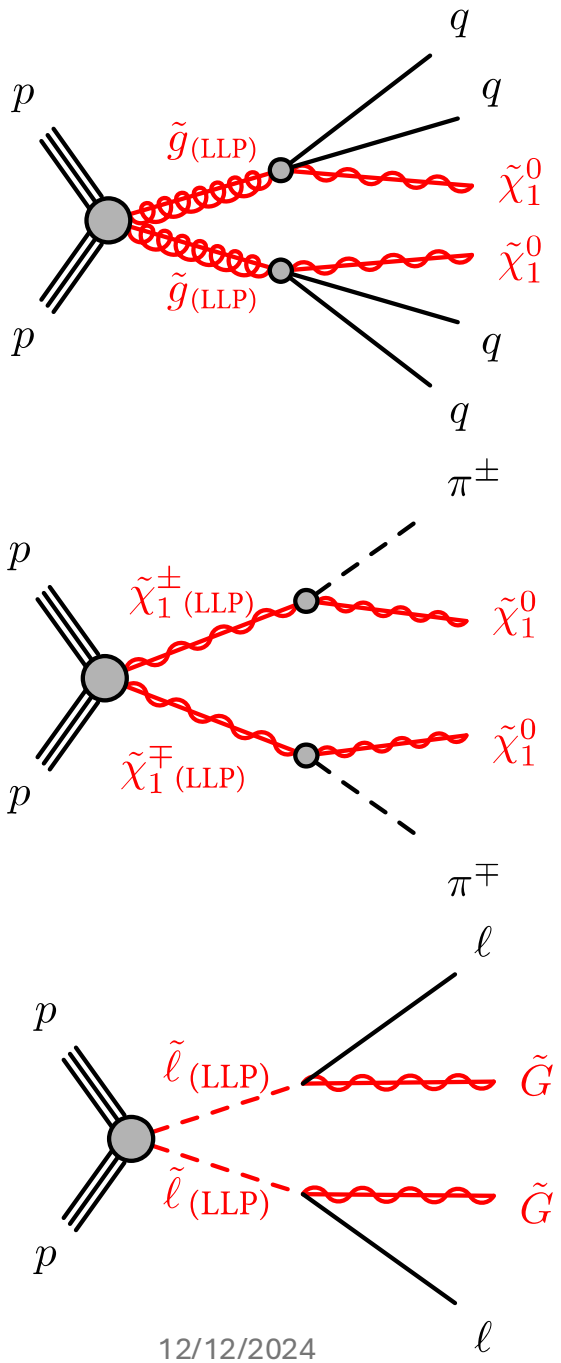
...more on the Run3 plans

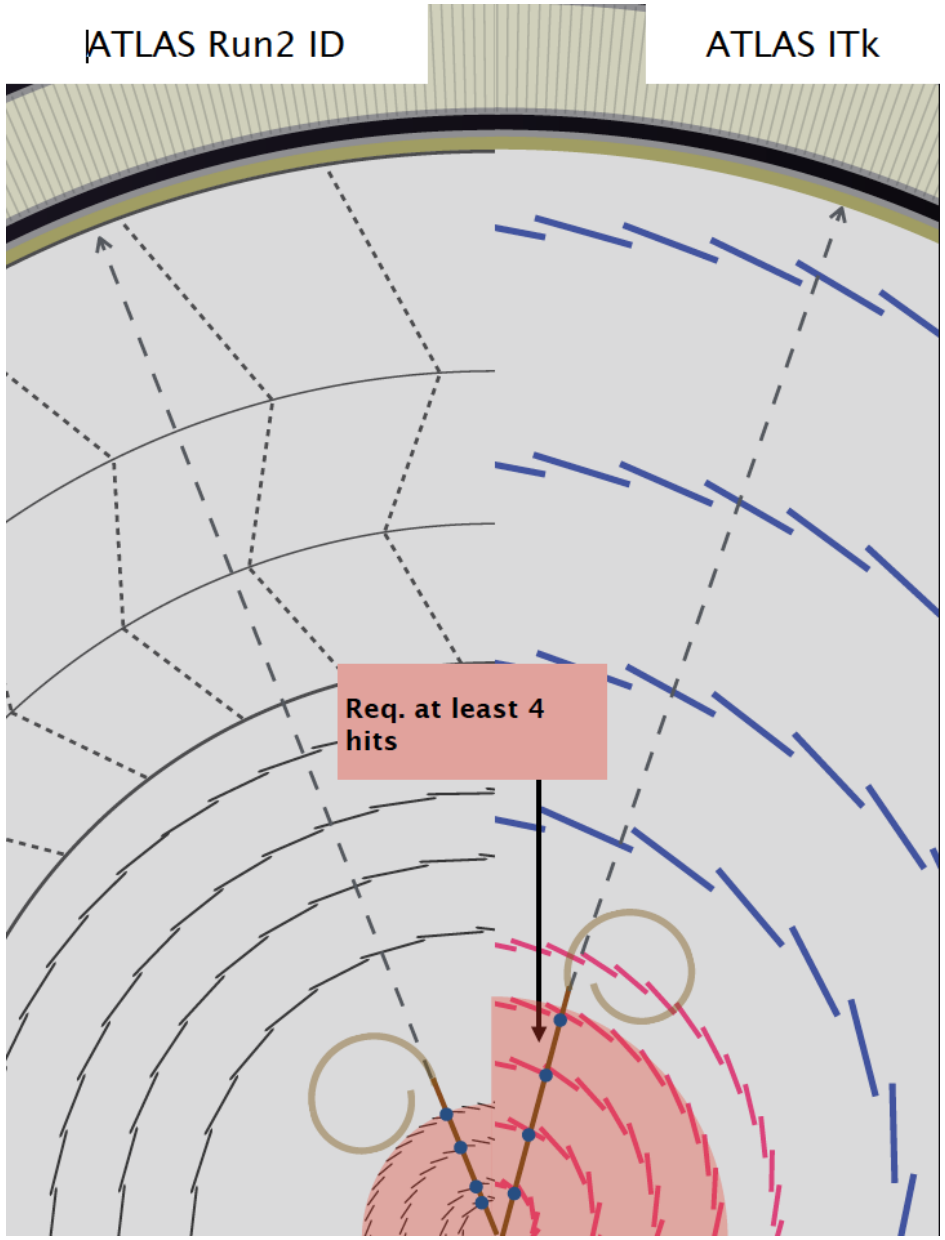
- This requires to access the raw data format (currently only track dEdx is transferred to the analysis format).
- This will allow us to also extract further information useful for the analysis.
- In general we have to treat variables (specific ionization and ToF) which are not on the ATLAS main thrust and then require effort by the analysis team. But this is also fun...



IBL: innermost (then more radiation damaged) pixel detector

backup

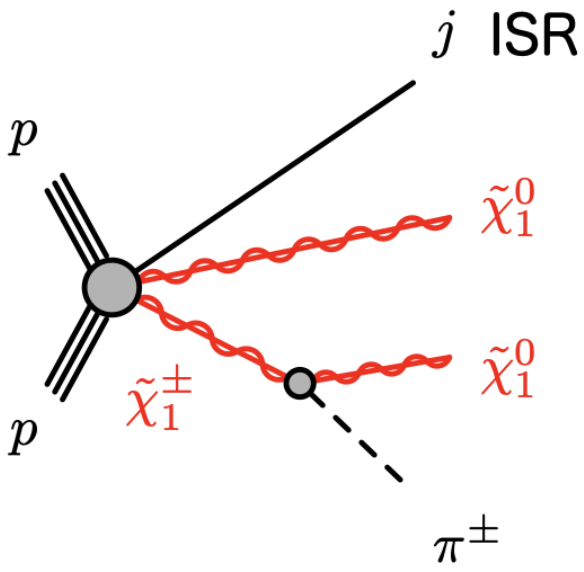




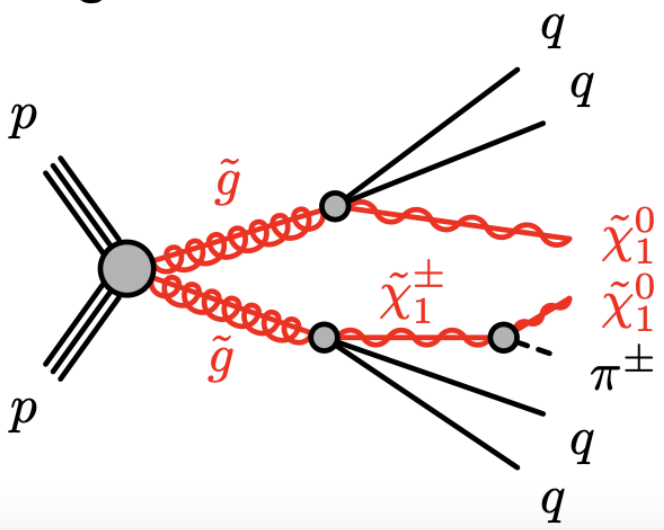
Cut	N(Events)	Eff.	Rel. Eff.
mini-xAOD	50310121	1.000	1.000
GRL	50310121	1.000	1.000
Event Cleaning	50265190	0.999	0.999
Jet Cleaning	49666647	0.987	0.988
Trigger	49666647	0.987	1.000
Primary Vertex	49666647	0.987	1.000
Offline $E_{\mathrm{T}}^{\mathrm{miss}}$	2696480	0.054	0.054
Track in PV	2696480	0.054	1.000
$p_{\mathrm{T}} > 50$ GeV	2696480	0.054	1.000
$\mathrm{d}E/\mathrm{d}x$ Used Hits	2451467	0.049	0.909
IBL/B-Layer Hits	2411925	0.048	0.984
Shared/Split Hits	2291630	0.046	0.950
SCT Hits	2187593	0.043	0.955
Track Isolation	1560198	0.031	0.713
$p_{\mathrm{T}} > 120$ GeV	390642	0.008	0.250
Track p uncertainty	385291	0.008	0.986
Central track	339695	0.007	0.882
$m_{\mathrm{T}} > 130$ GeV	86794	0.002	0.256
Electron veto	36462	0.001	0.420
Hadron veto	25440	0.001	0.698

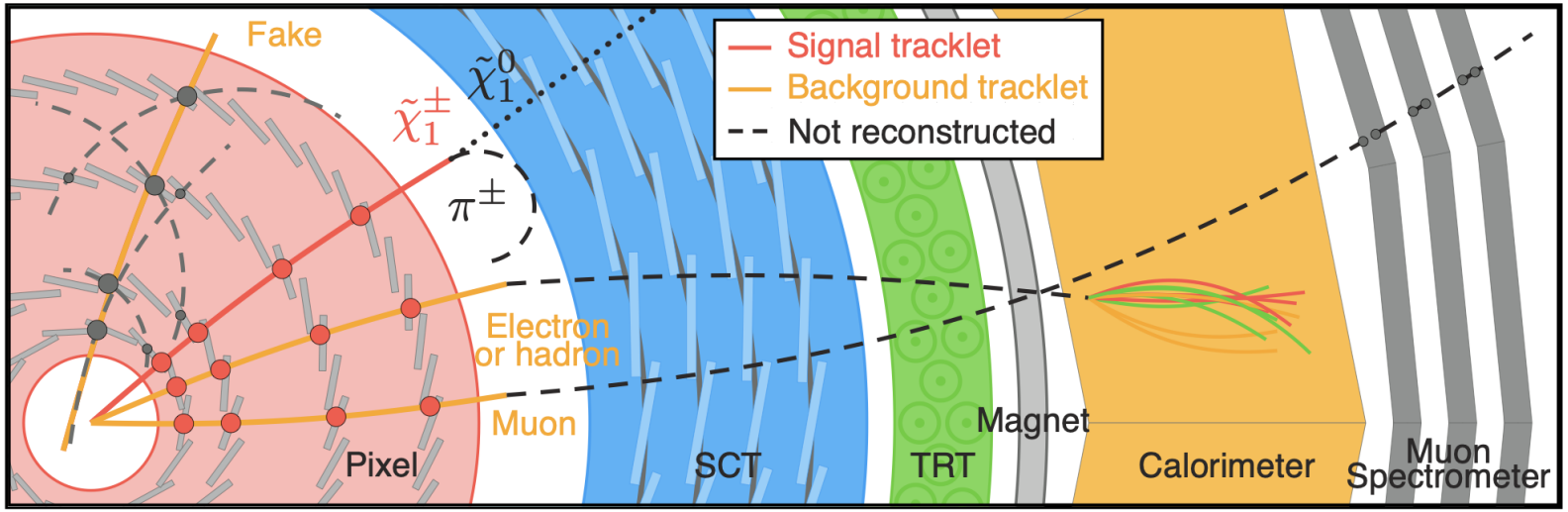
Signal Region	N(Events)	Fraction
SR-Mu-IBL0_Low	22049	0.867
SR-Trk-IBL0_Low	3058	0.120
SR-Mu-IBL0_High	22049	0.867
SR-Trk-IBL0_High	3058	0.120
SR-Mu-IBL1	286	0.011
SR-Trk-IBL1	48	0.002
SR-Inclusive_Low	25441	1.000
SR-Inclusive_High	25441	1.000

Electroweak(EWK) Production



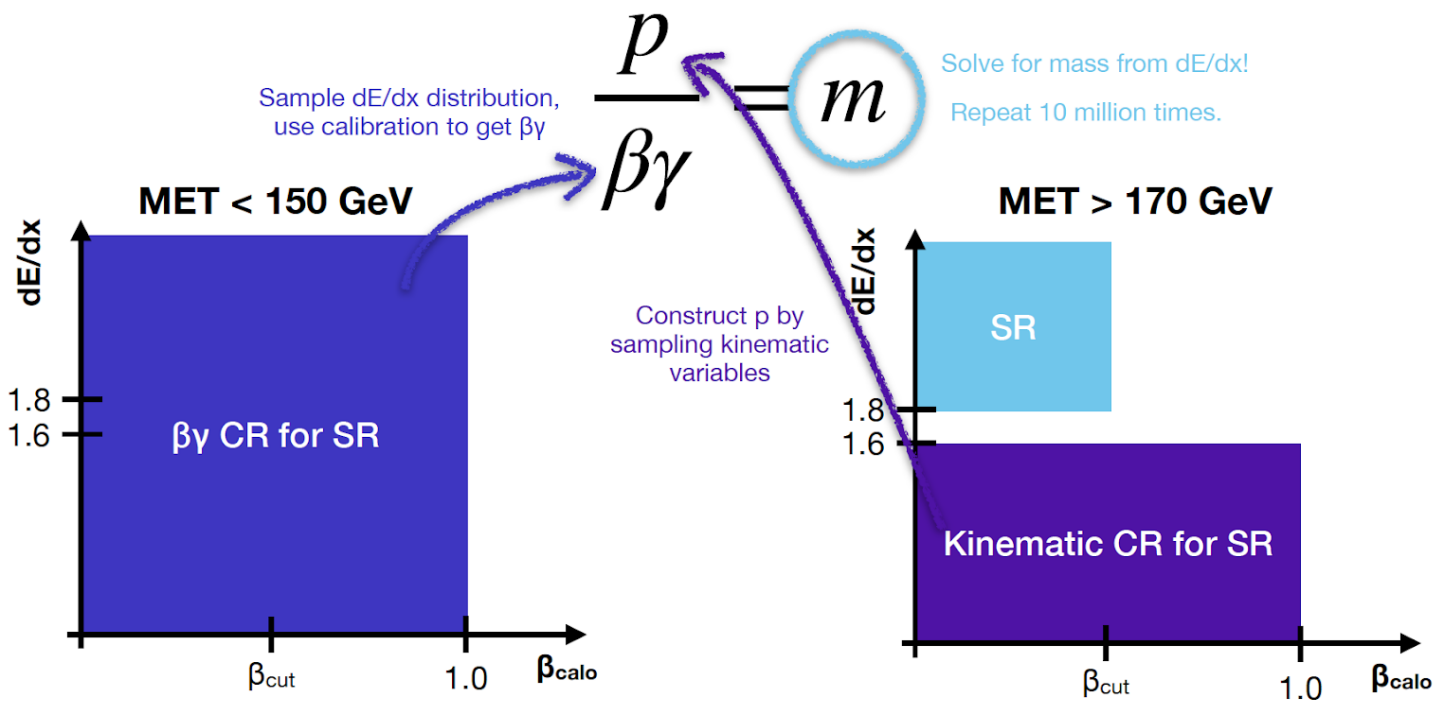
Strong Production



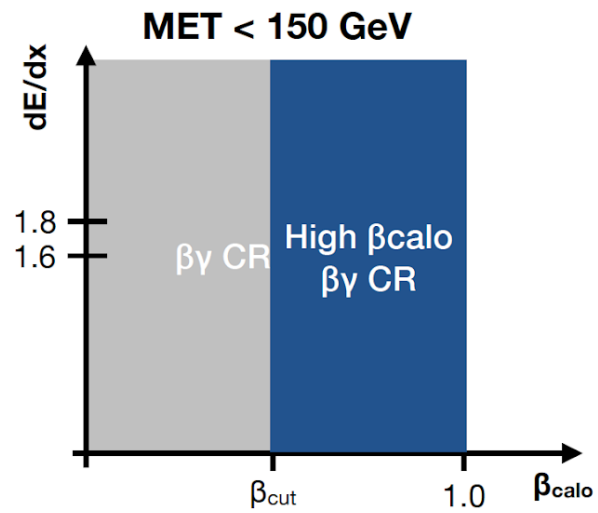


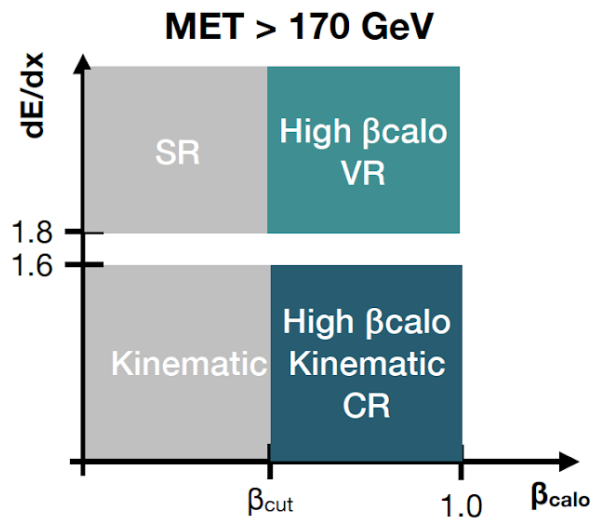
Estimating Mass from dE/dx

- Draw dE/dx, momentum from CRs to construct mass distribution in SR



High βcalo Validation Region





Low dE/dx Validation Region