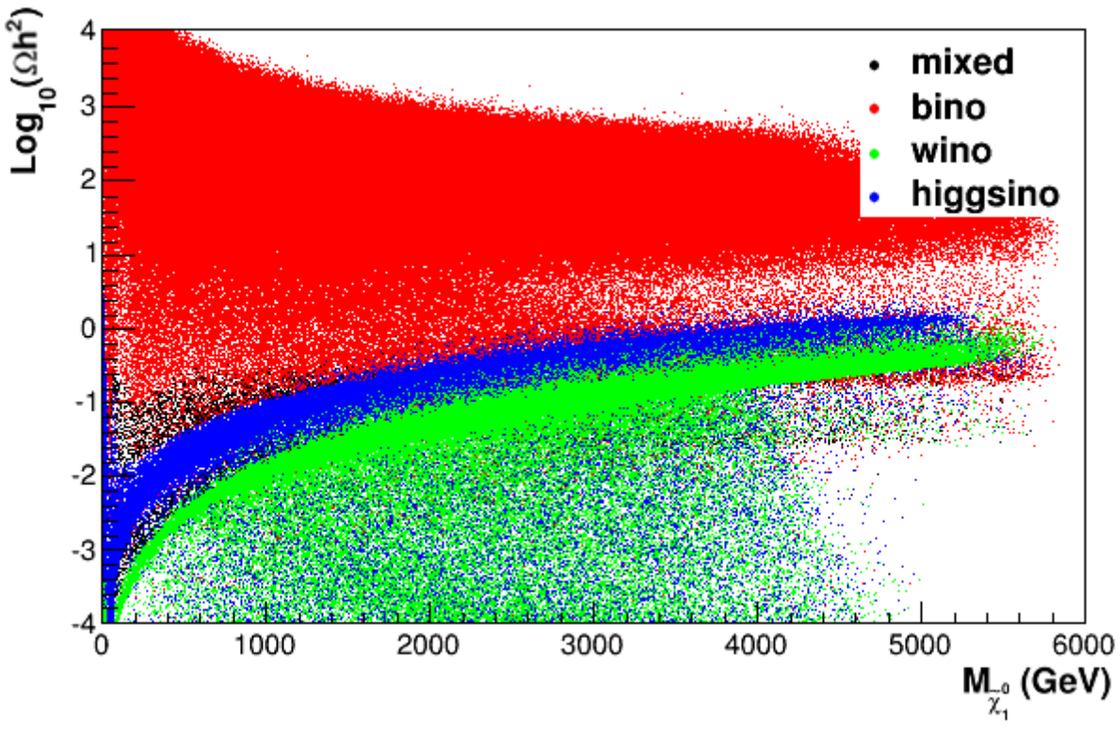
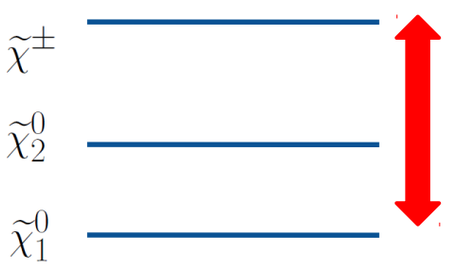
Higgsino projection study experience and beyond

Hideyuki Oide (Tokyo Tech)

Based on 1910.08065
with H. Fukuda, H. Otono, S. Shirai, N. Nagata

Brief about the model

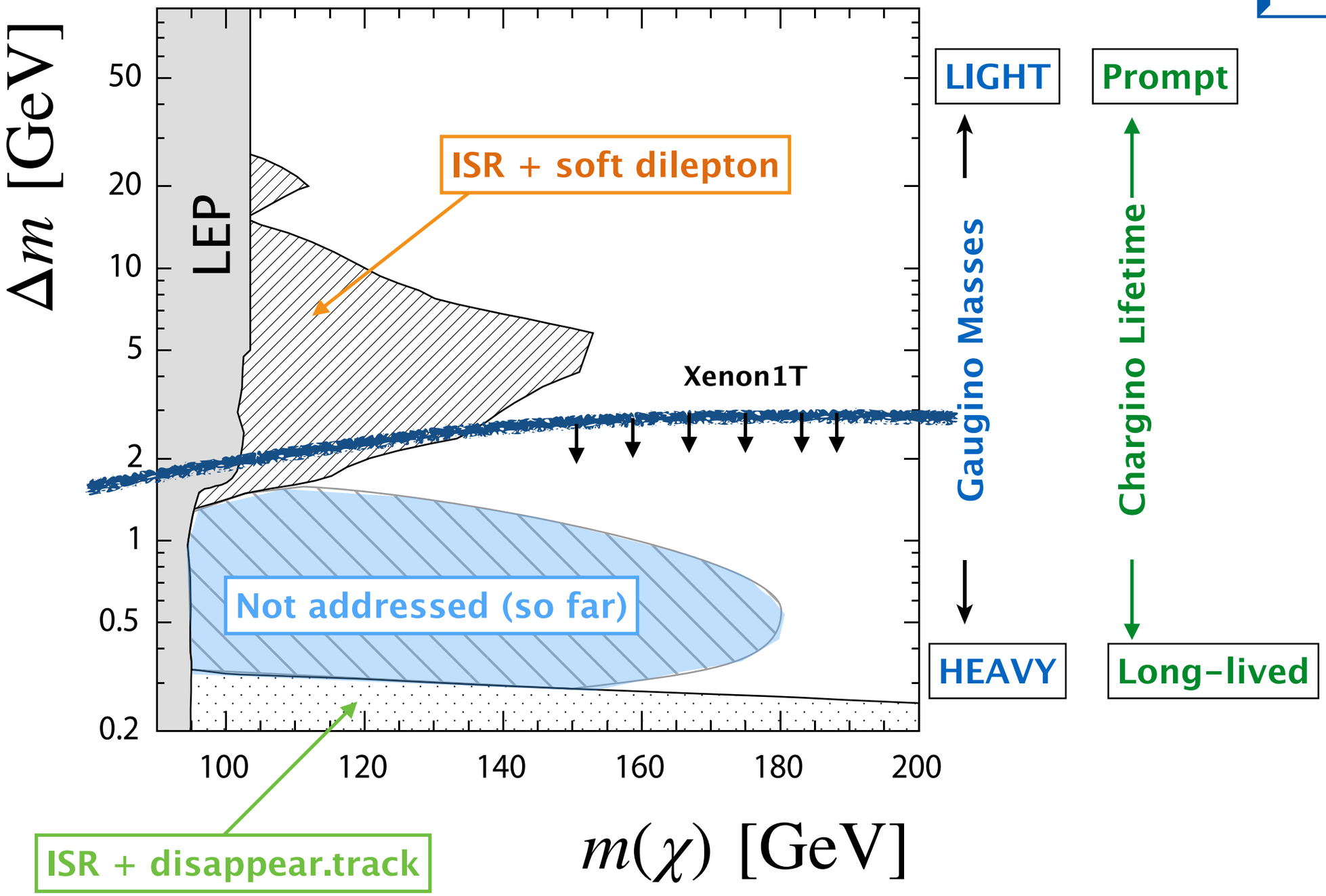




$$\Delta m \sim \frac{m_W^2}{m_{\mathrm{gaugino}}} = O(100)\ \mathrm{MeV}\left(\frac{m_{\mathrm{gaugino}}}{10\ \mathrm{TeV}}\right)^{-1}$$

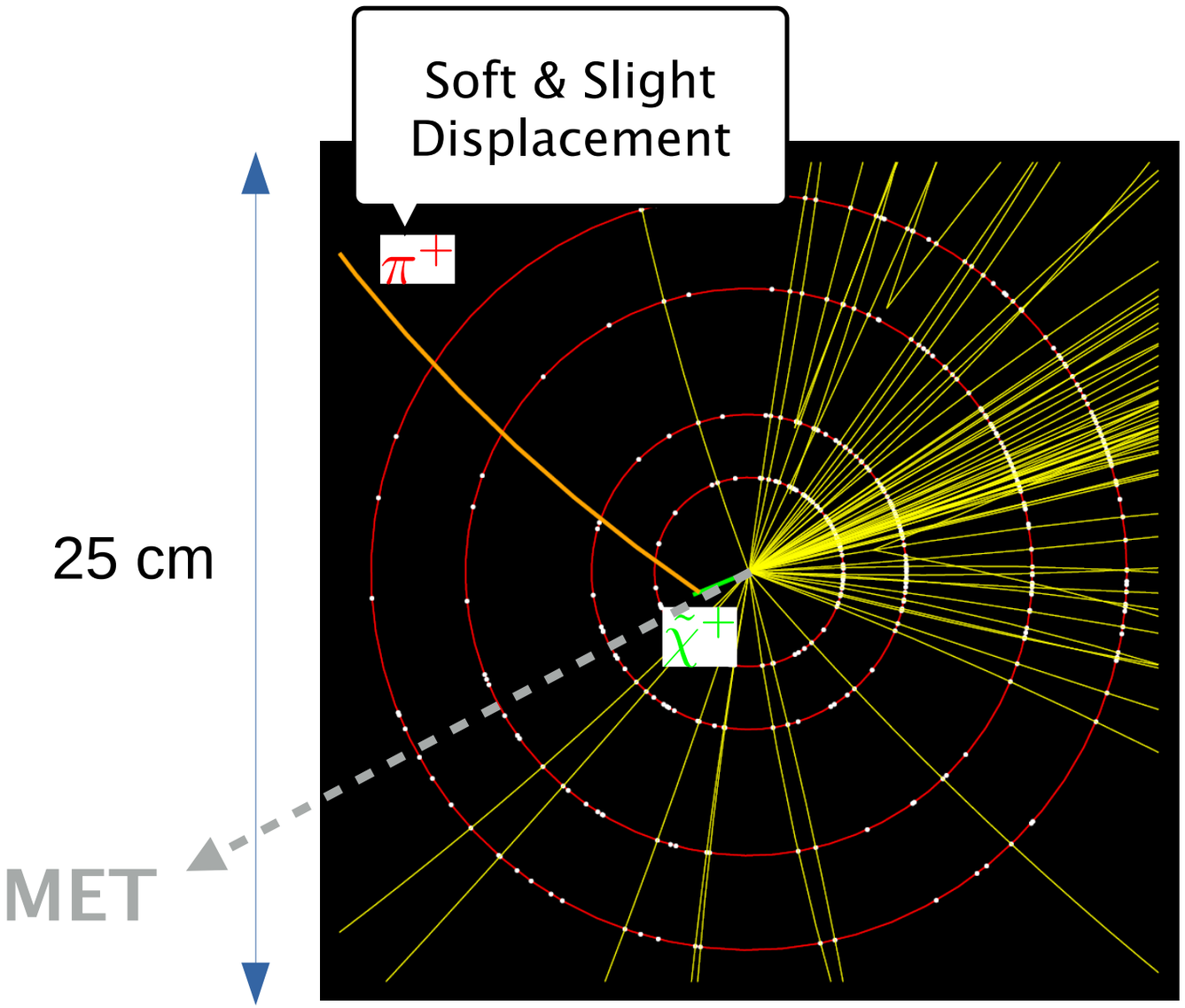
$$\Gamma^{-1}_{\chi^{\pm}\to\chi_1^0\pi^{\pm}} \simeq \frac{14\ \mathrm{mm}}{\hbar c} \times \left[\left(\frac{\Delta m_{\pm}}{340\,\mathrm{MeV}}\right)^3 \sqrt{1-\frac{m_{\pi^{\pm}}^2}{\Delta m_{\pm}^2}}\right]^{-1}.$$

- Higgsino has been catching interests as (at least fractional) DM candidate.
  - $\Omega h^2 \leq 0.12 \Leftrightarrow$ m(higgsino) $\leq$ ~1.1 TeV
- Higgsino: triplet of (N_1, N_2, $C_1^{\pm}$)
  - Generally compressed spectrum.
- Mass scale distance from higgsino to gauginos reflects in mass-splitting.
  - Smaller mass-splitting → narrower width.
- "Pure" higgsino can be slightly long-lived. ($c\tau$ ~ 0.2 ns)
- Beyond LEP, so far "soft di-lepton" and "disappearing track" searches have been devised in LHC searches.



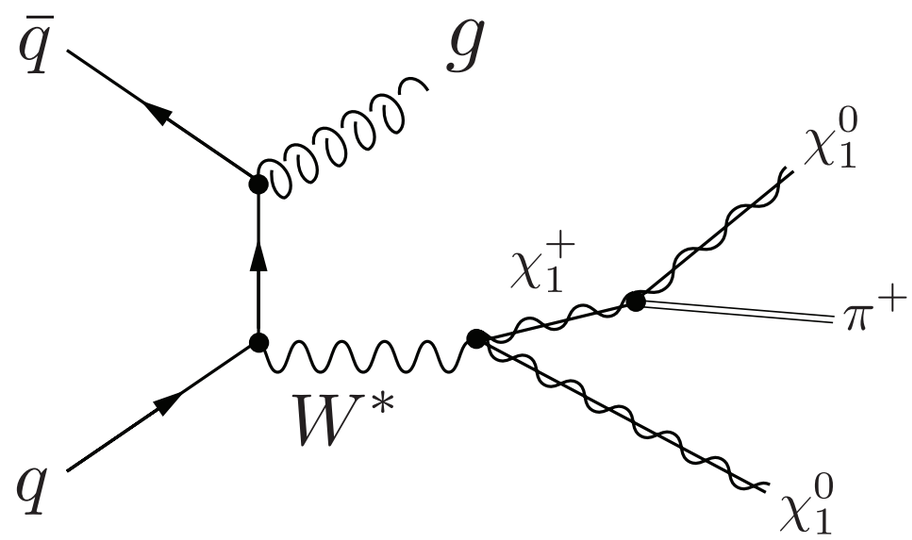
- The “pure higgsino” model is already excluded by the direct detection.
- Direct detection elastic scattering can constrain larger Δm ranges.
- Perhaps “almost pure higgsino” would be an interesting region, but it’s not addressed so far.

Event topology



Signal

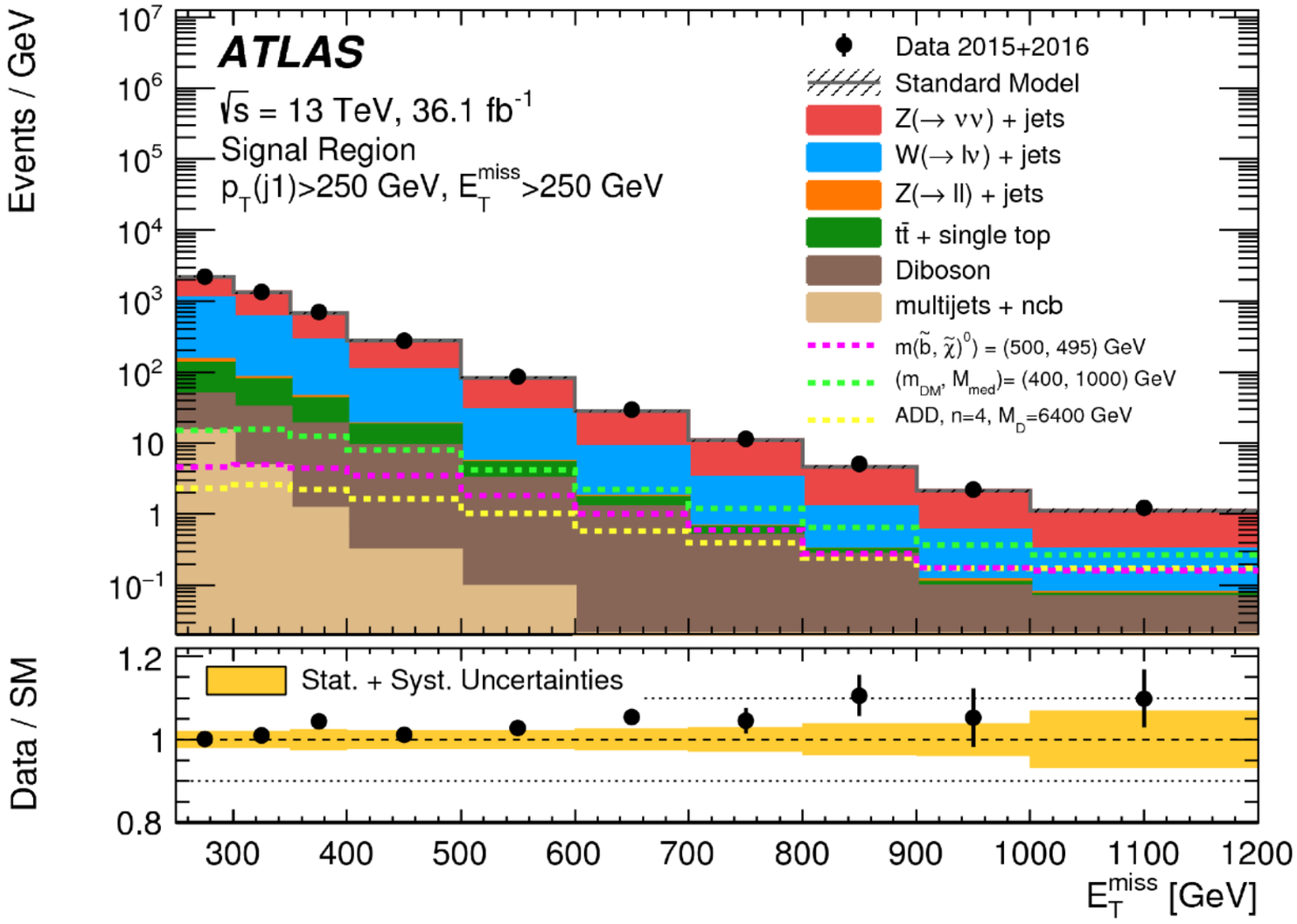
ISR



- One non-trivial question was how it'd be possible to predict the backgrounds to soft-displaced tracks.

Detector response, background modeling

ATLAS-EXOT-2016-27

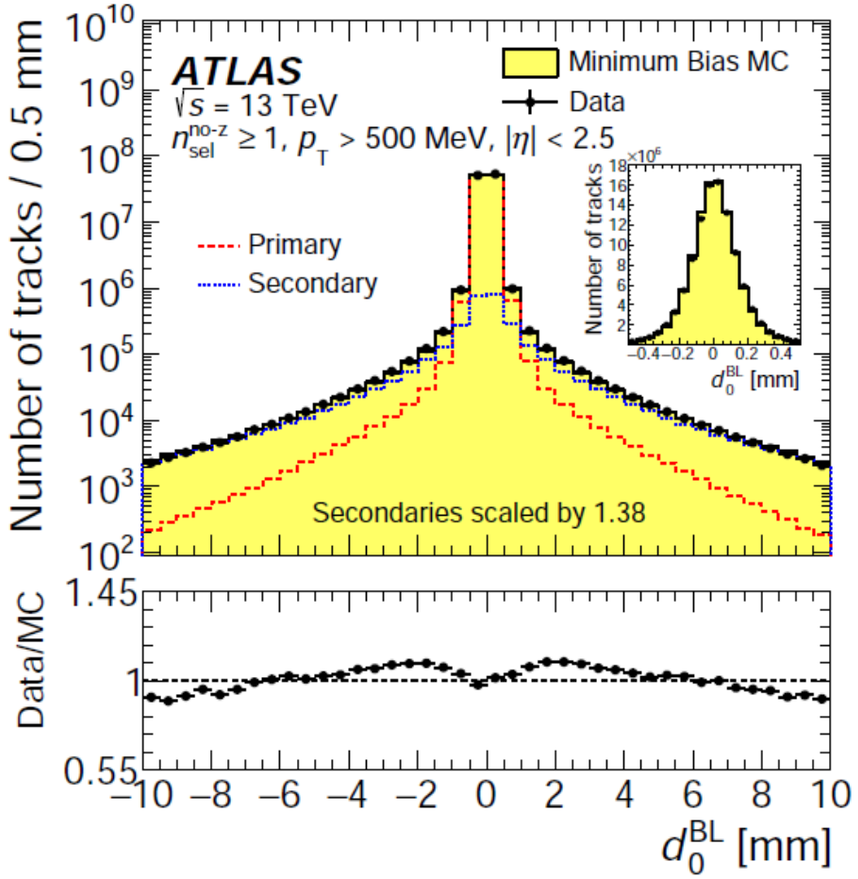


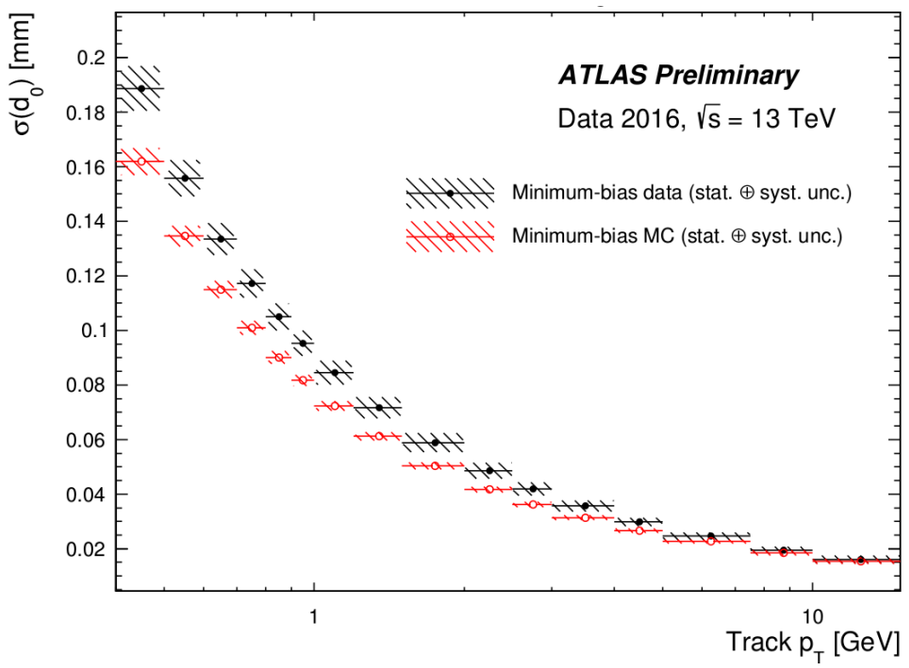
- Event selection is based on the mono-jet search, to see the additional sensitivity gain by soft track requirements.
- The Delphes simulation yield was scaled to match with the ATLAS mono-jet result.

Track response

- For soft-tracking performance, it is important to emulate:
  - Tracking resolution, efficiency
  - Track IP resolution shape
  - Secondary particles contamination

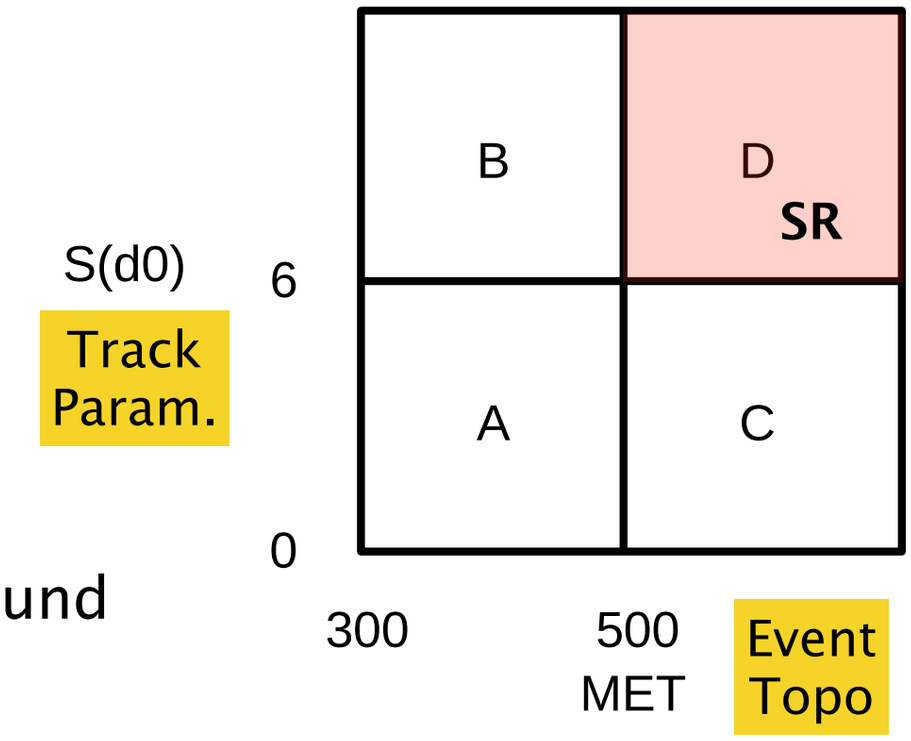
- Parameterization based on MinBias measurements
  - expect quasi-accurate description of the discrimination using IP significance.
  - Secondary track components are inclusively taken into account as a part of impact parameter distribution.





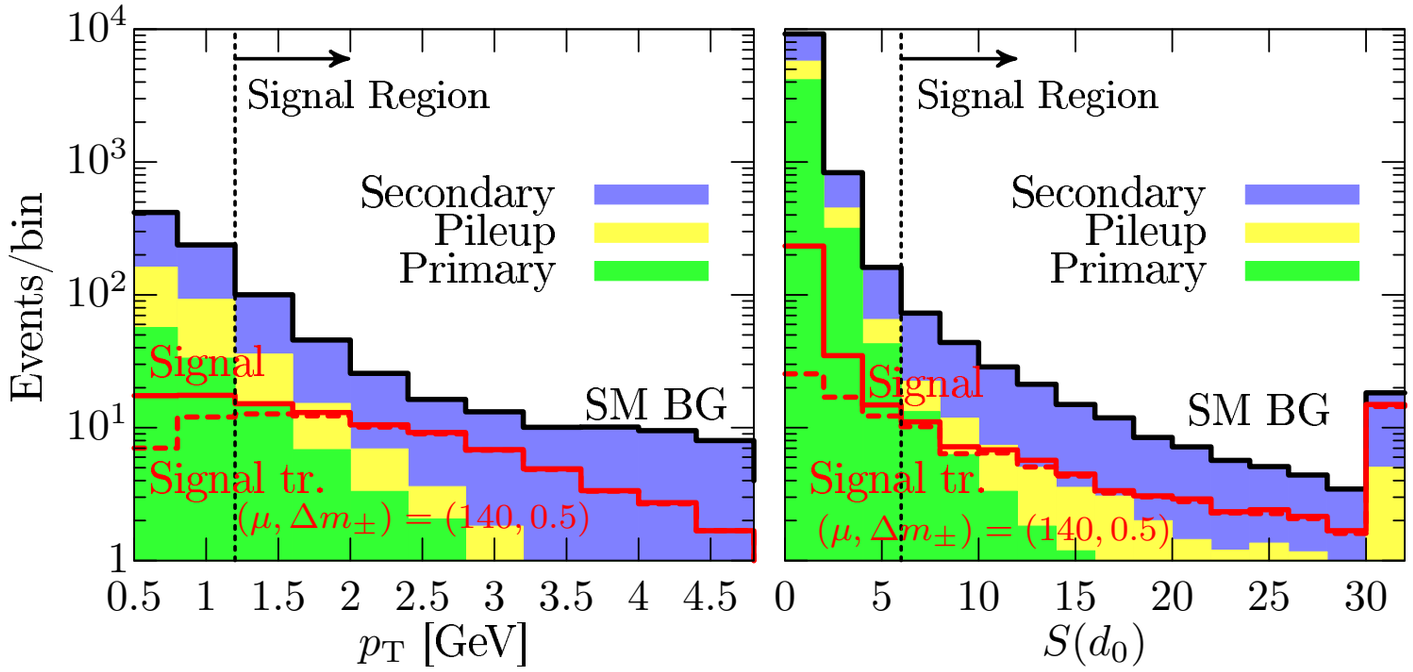
Demo analysis

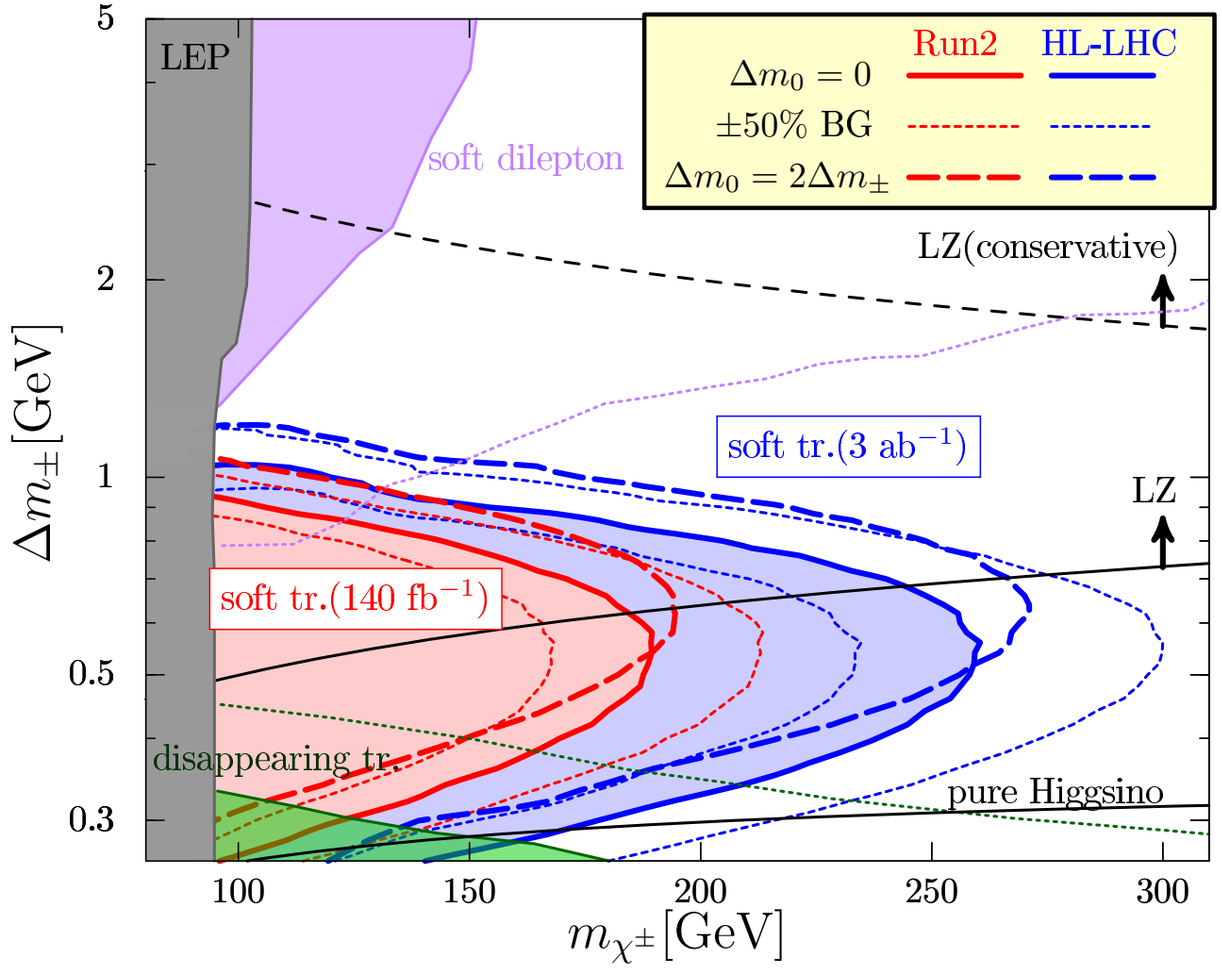
- Not aiming at full optimization of the signal selection
  - it was important to illustrate the effectiveness of the search idea to urge the LHC experiments to look into this possibility.
- The background estimation can be only semi-quantitative anyways
  - soft tracks (1-5 GeV) mostly originate from soft-QCD and MC simulations are not super reliable.
- Simple cut-based signal selections:
  - 1 GeV < pT < 5 GeV; higher pT range than this suffers soft taus from Z+jets.
  - Isolated from other tracks of the event;
  - Somewhat aligned with respect to MET;
  - Transverse IP significance $S(d_0) > 6$ sigma.



- Illustrated a simple "data-driven"-inspired background estimation approach using the ABCD method.
  - To show there is at least one possibility of background estimation.
  - Making use of independence between the event topology and soft track parameters.
  - Picked up two variables: MET and $S(d_0)$.

Results


Signal Region
Secondary
Pileup
Primary
Signal
SM BG
Signal tr.
$(\mu, \Delta m_{\pm}) = (140, 0.5)$
Events/bin
p_{T} [GeV]
$S(d_0)$


Run2
HL-LHC
$\Delta m_0 = 0$
$\pm 50\%$ BG
$\Delta m_0 = 2\Delta m_{\pm}$
LEP
soft dilepton
LZ(conservative)
soft tr.(3 ab^{-1})
LZ
soft tr.(140 fb^{-1})
disappearing tr.
pure Higgsino
$\Delta m_{\pm}$[GeV]
$m_{\chi^{\pm}}$[GeV]

Implications of experience

- Nice to have a teamwork of pheno + experimental folks!
  - Complementary expertises (of course!)
  - We were actually not focusing on the Higgsino model from the first place – was studying some other course then realized that discussion could profit here.
- A hybrid of a simple detector response (Delphes) and a specialized add-on for the LLP part (soft displaced track) was effective in this projection exercise.
  - Not so trivial for other signal models, e.g. for reconstruction of displaced vertices.
- Potential extension of the study in:
  - Signature involving multiple displaced soft tracks?
  - To higher energy: 33 TeV, 100 TeV.
    Making use of VBF instead of ISR?
- No particular plans extending this course for the Snowmass (yet)