Constructing an Inclusive Lepton Early Warning System

Christopher Willis
Michigan State University

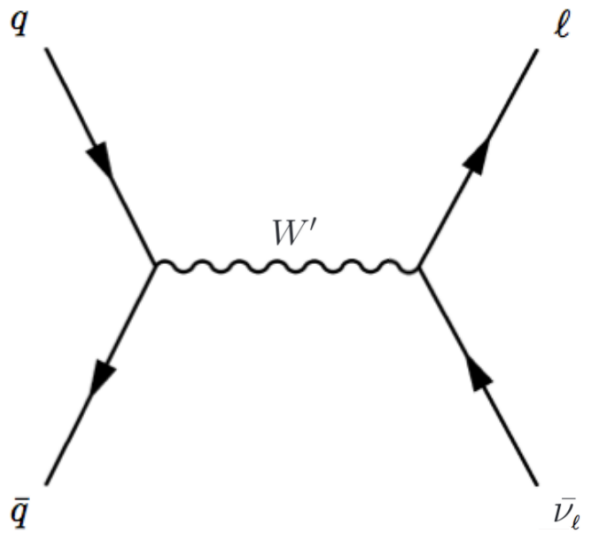
DPF Conference 2015
Thursday August 6, Ann Arbor MI

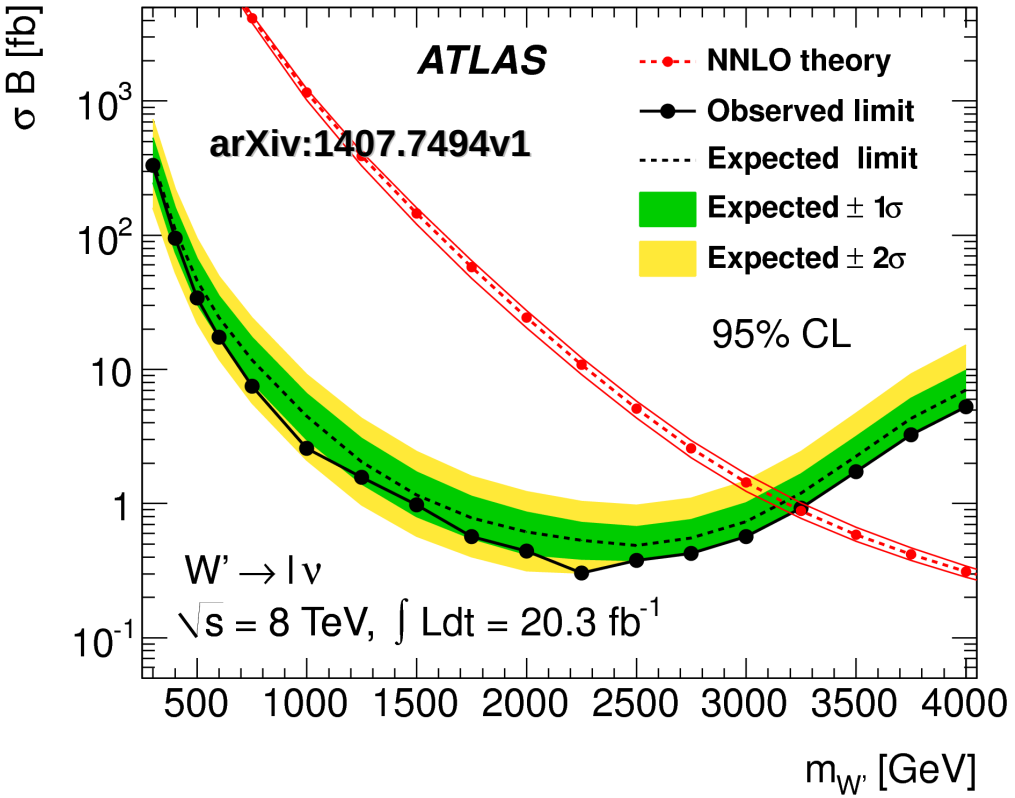
Introduction

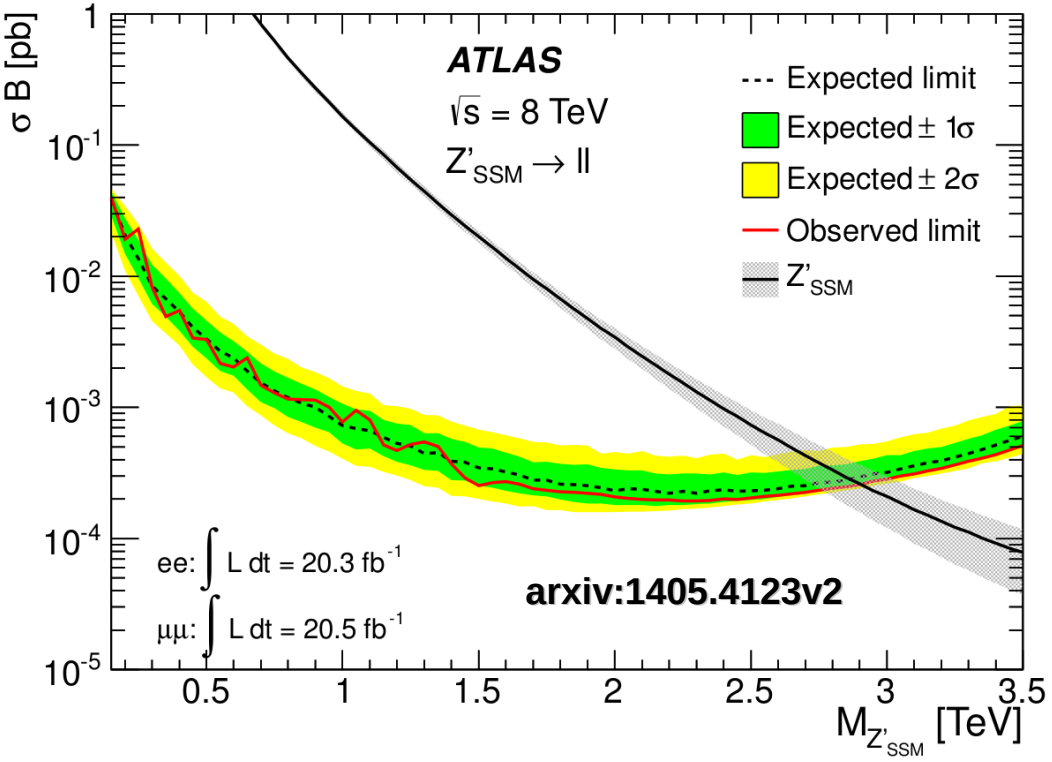
1) The Need
   - Philosophy and Motivation
2) The Idea
   - Building an Inclusive lepton analysis
   - Fitting Run-I Data
3) Proving it can work
   - Tests in the Electron and Muon Channels
4) Conclusion

The Need for an EWS

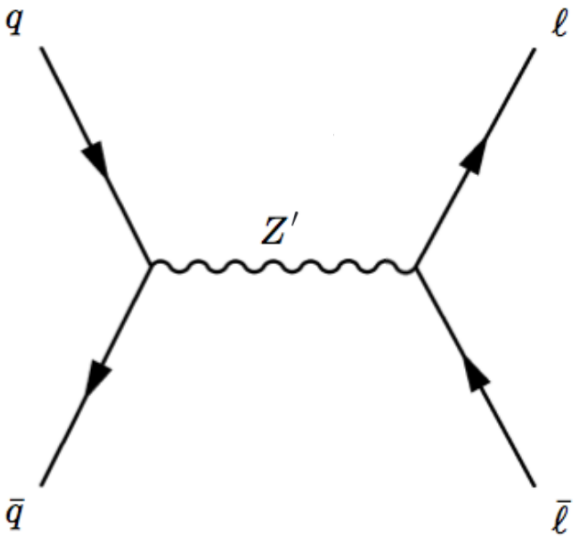
W' Production Diagram





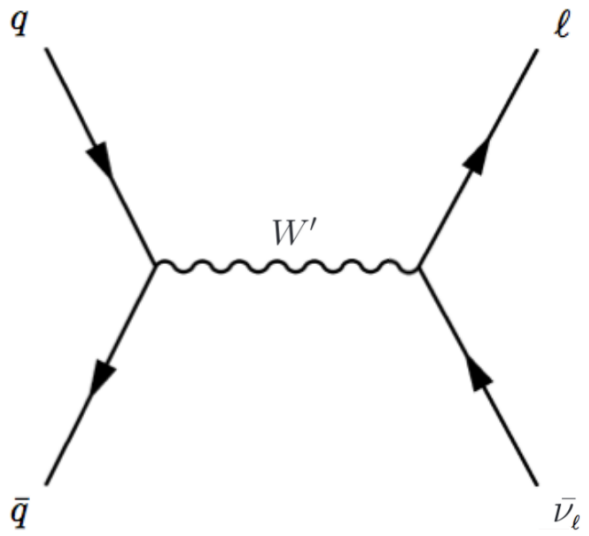


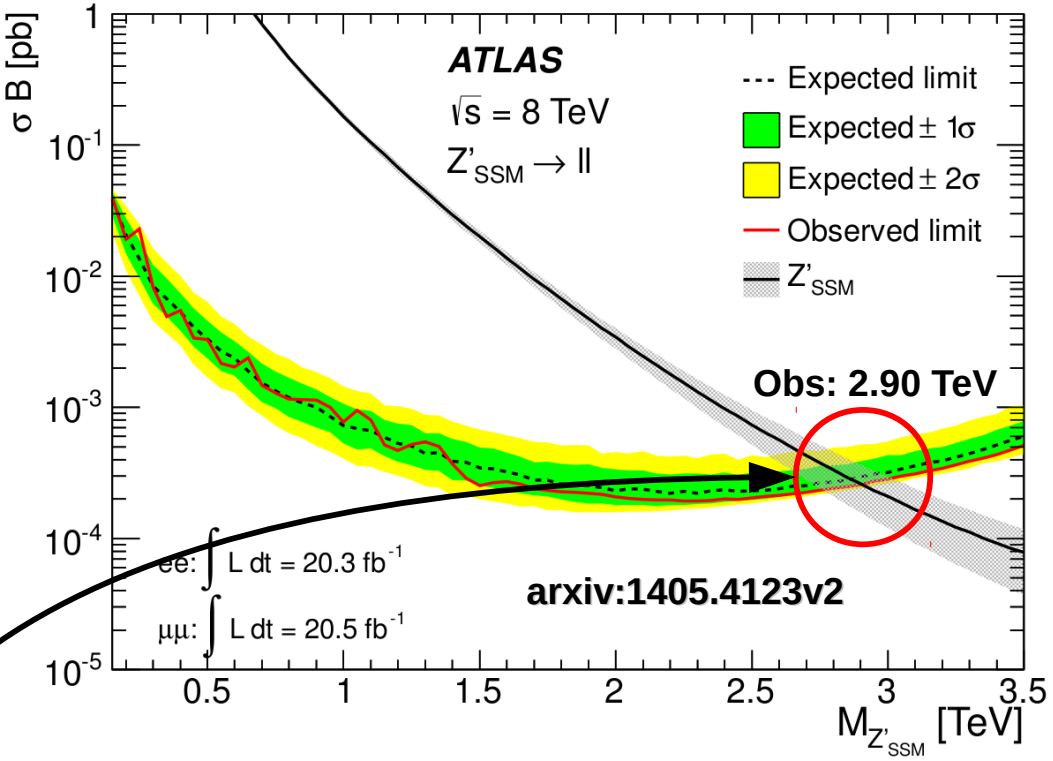
Z' Production Diagram

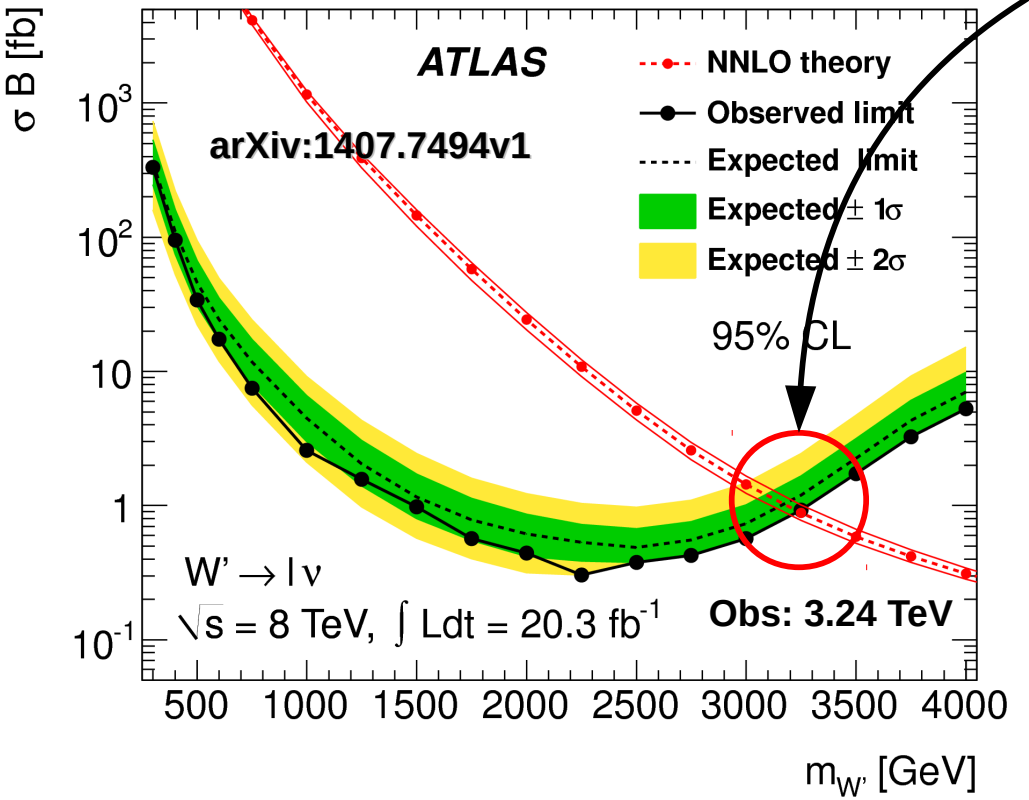


The Need for an EWS

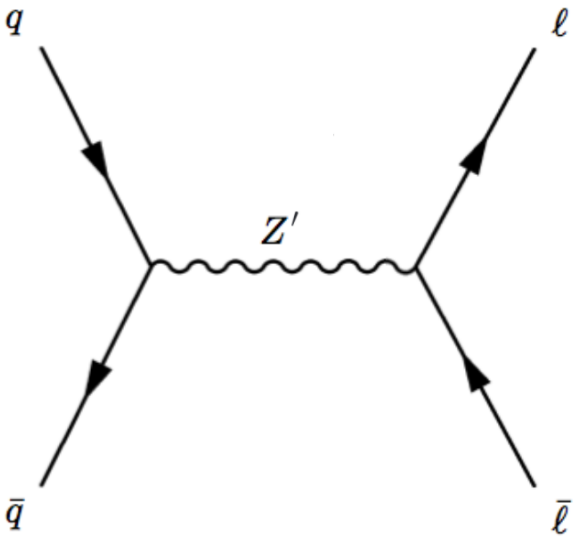
W' Production Diagram

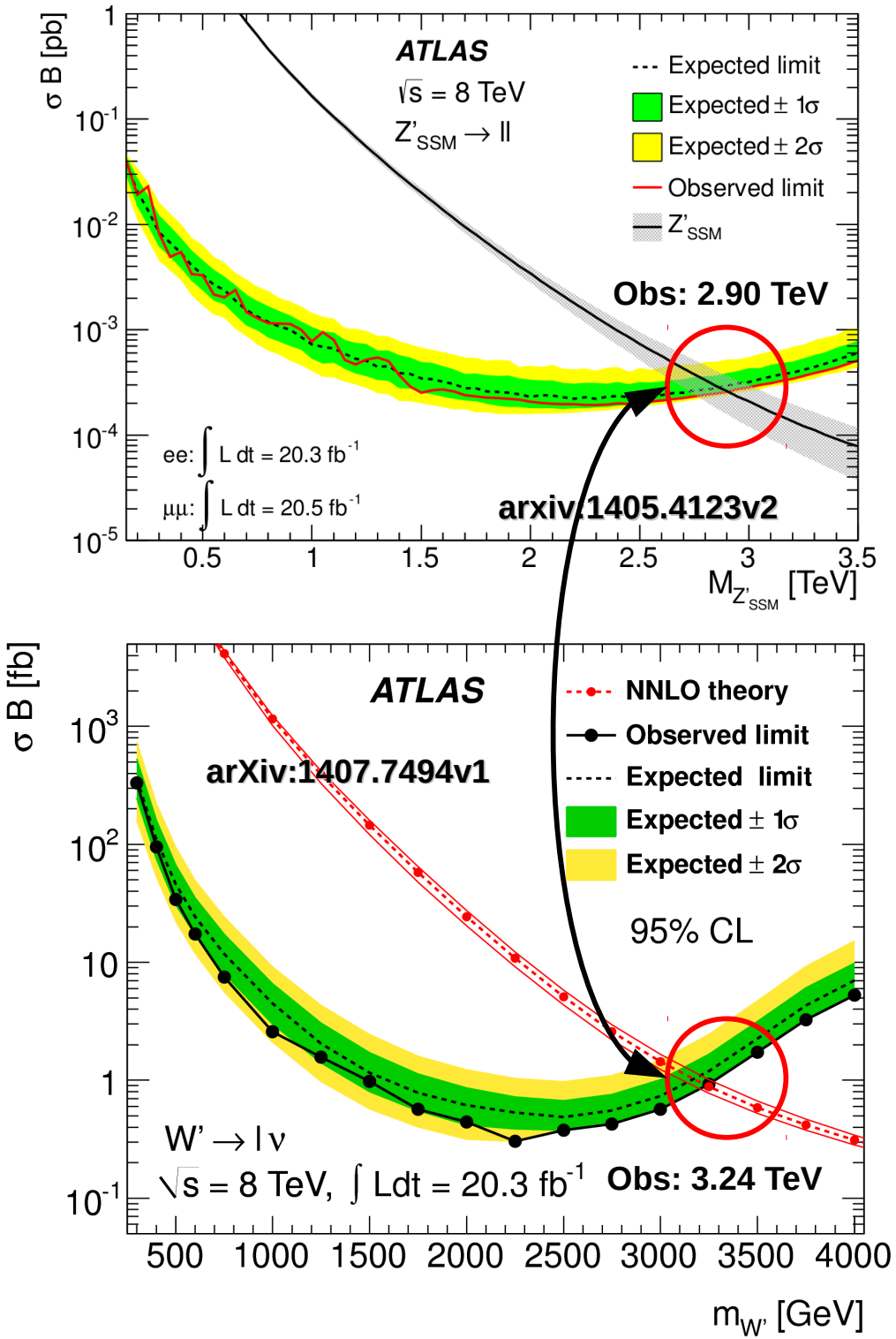






Z' Production Diagram



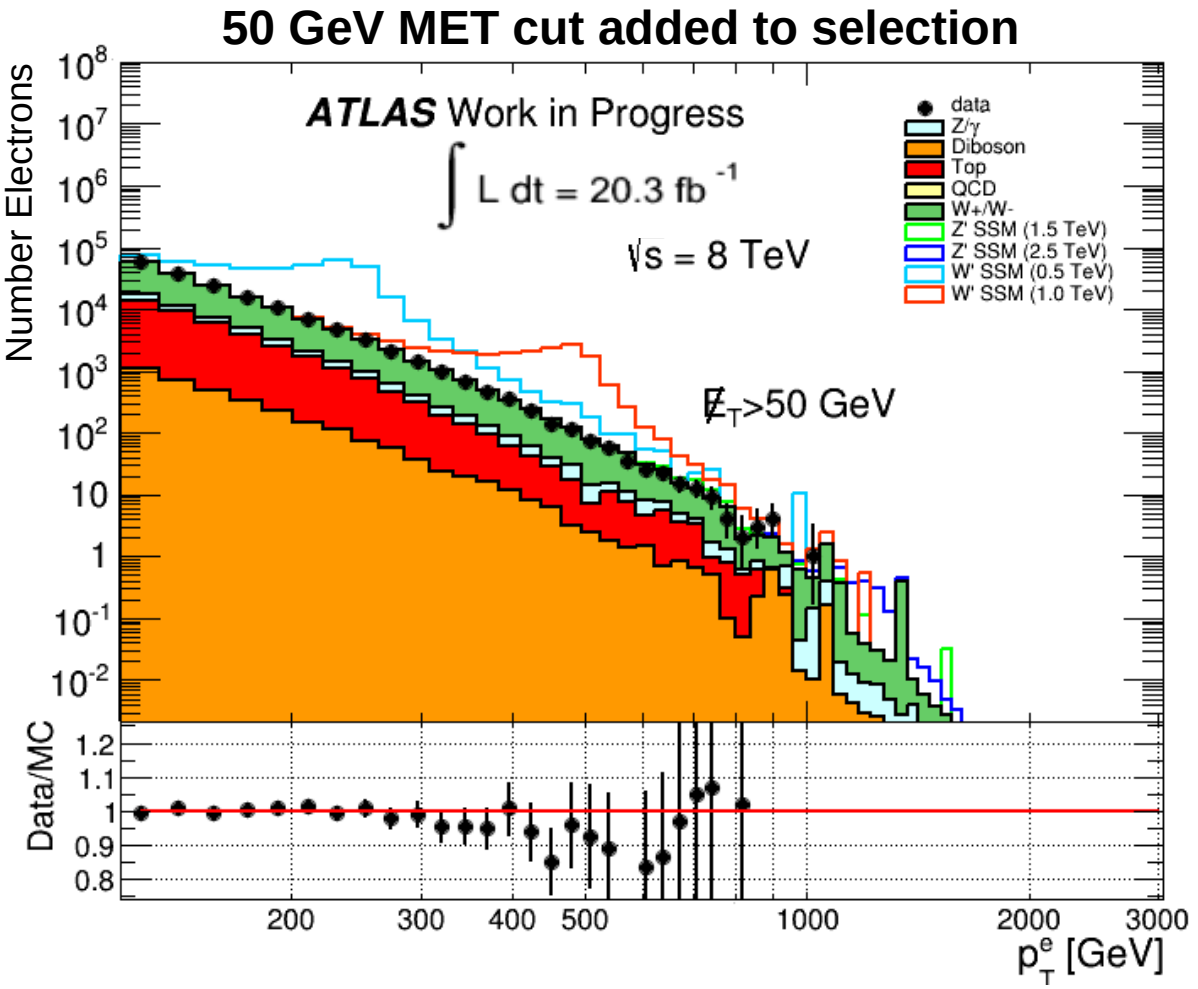


The EWS Idea

- Be as unbiased as possible
- Use lepton pT
- Compare data to fitted background
- Refit as new data become available

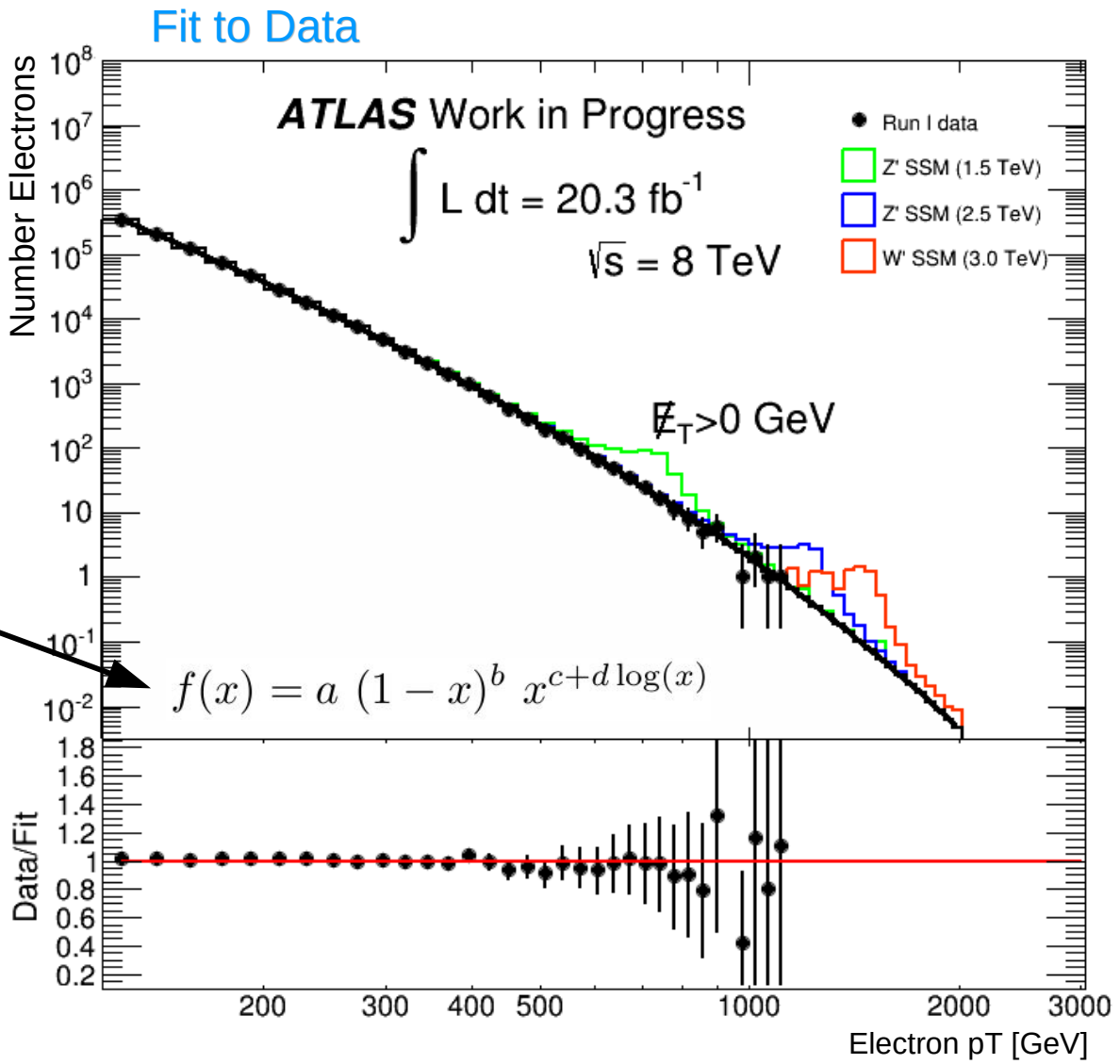
From Idea to Reality: Building an inclusive Z' Analysis

- Want to generalize Dilepton Analysis Selection
  - Dilepton Search requires two high pT, well isolated leptons
  - Relax requirements to be fully inclusive
- Isolating a Signal
  - Able to isolate signal with MET cut or 2-lepton requirement



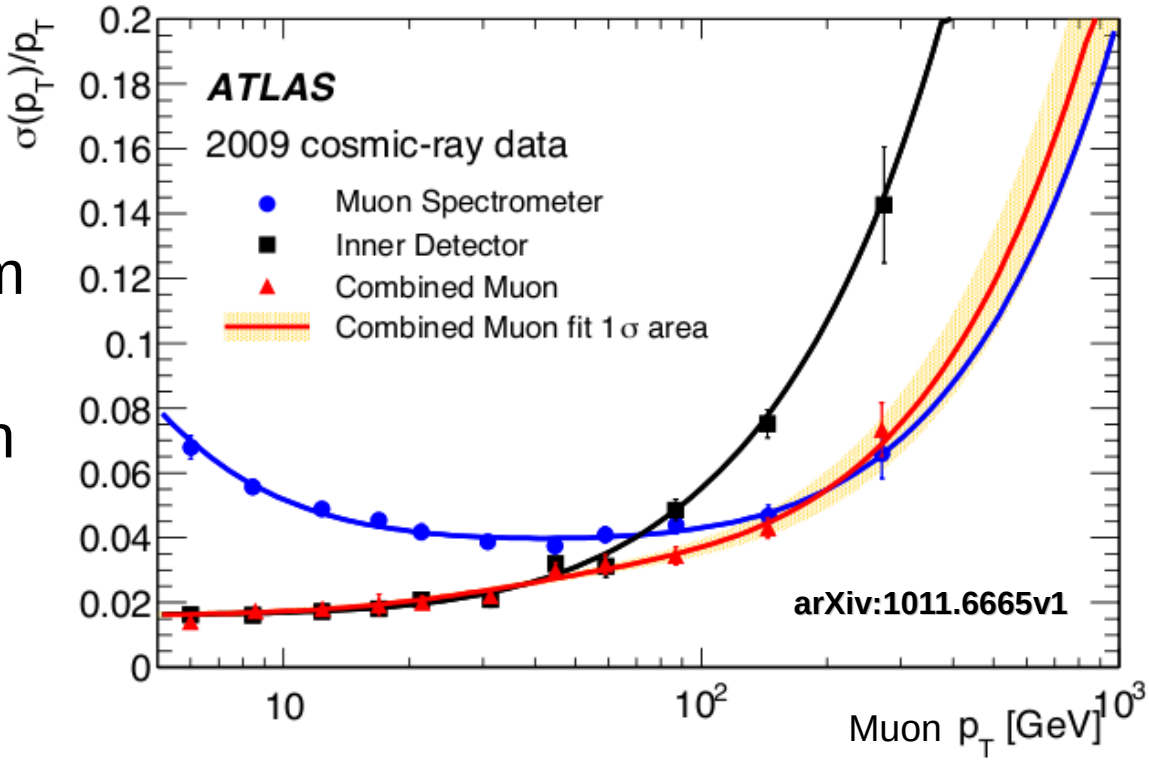
From Idea to Reality: Fitting to Run-I Data

- Ultimately want to fit to data
  - Avoid any mismodelling in MC
- Parameterize backgrounds with smoothly falling function
  - Dijet function as nominal case
- Fit done on [125,300] GeV
  - Extrapolation to 2.0 TeV
  - Strategy: refit as data come in



Muon Resolution Considerations

- What about the Muons?
  - Crucial question: "Is resolution in Muon channel adequate to confirm hint from Electron channel?"
  - Answer by doing comparison
- Luminosity Study
  - Generated signal and background MC samples using ResBos
  - Minimal Selection
  - Used ATLAS resolution functions to smear truth level MC

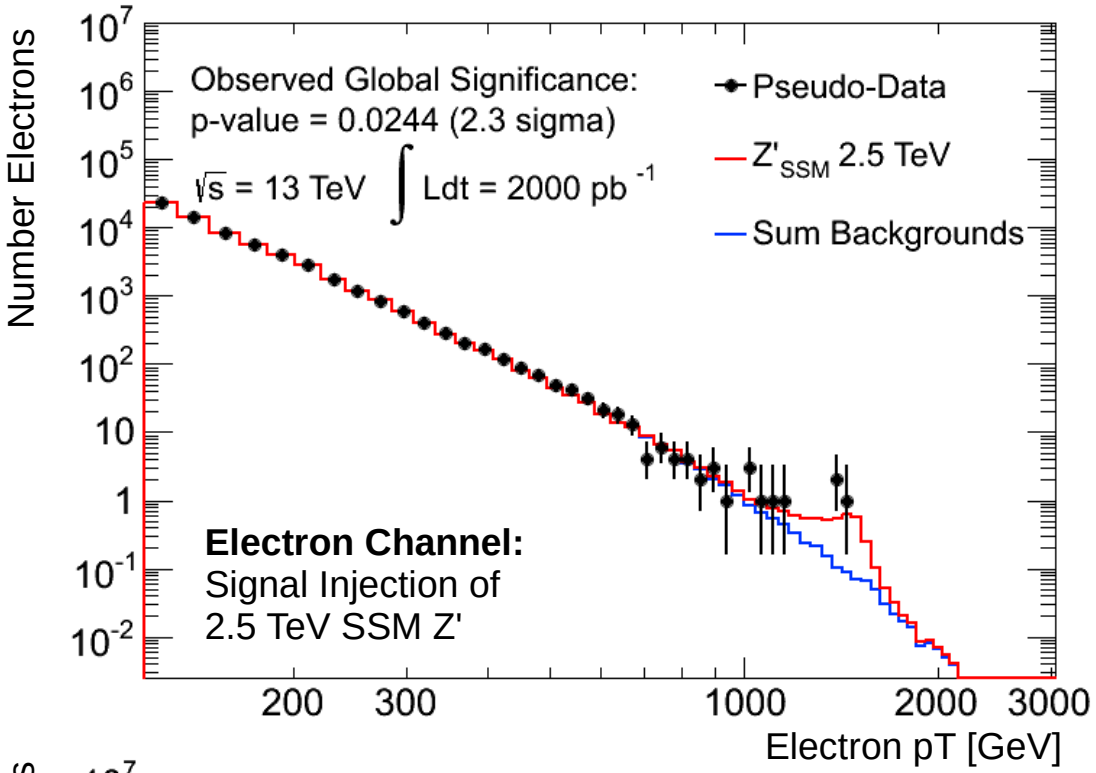


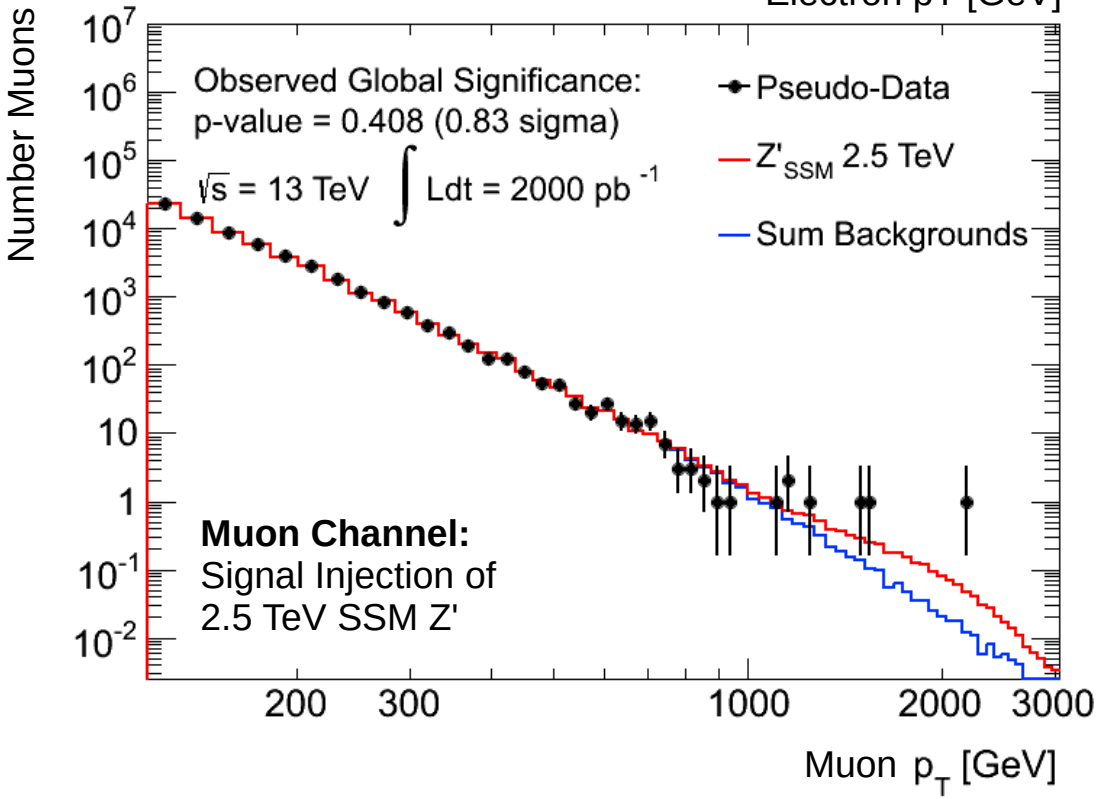
$$\frac{\sigma(p_T)}{p_T} = p_1 \oplus \frac{p_0 p_T}{\sqrt{1+(p_3 p_T)^2}} \oplus p_2 p_T$$

$$\frac{\sigma(E)}{E} = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$$

Proving It Works

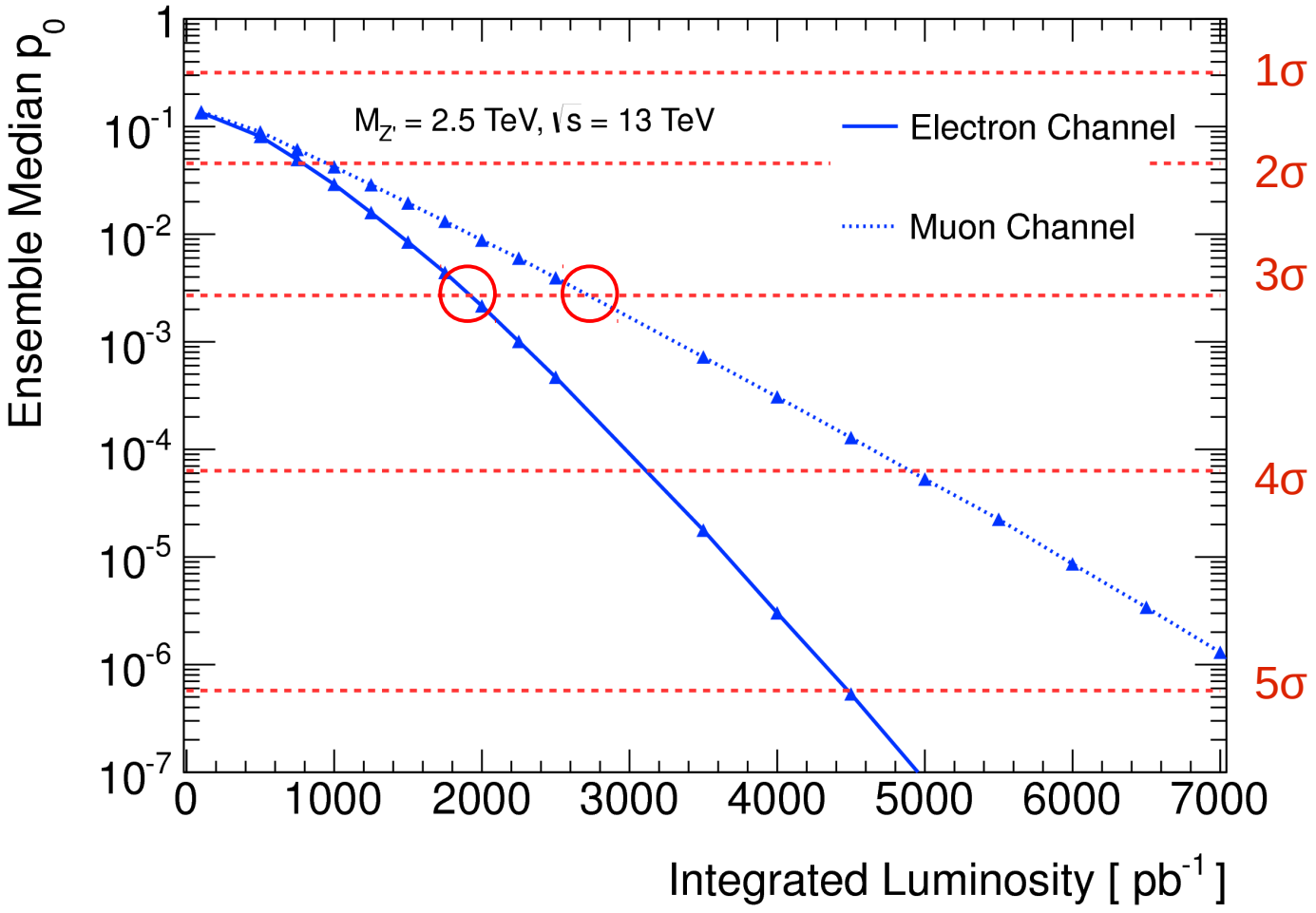
- Quantify “Luminosity-Lag” via Pseudo-Experiments
- Build up distribution of p-values at each luminosity scale
- Use median ensemble value as metric to quantify “Lumi-Lag”





Pseudo-Experiment Results

- Results for 2.5 TeV SSM Z'
  - 3σ excess at 2.0/fb (2.8/fb) for Electrons (Muons)
  - Lumi-Lag = 0.8/fb
- Bottom line: Muons aren't a deal breaker



Conclusion

- Discussed the Need for an EWS
  - **Not meant to be a discovery tool or rival analysis**
  - Instead a tool to provoke discussion and make strategy decisions (“Are we in discovery or exclusion mode?”)
- Presented the EWS idea: use inclusive lepton pT
  - Discussed how to build the inclusive lepton pT distribution
  - Showed that choice of fit and extrapolation is robust against range and luminosity scale
- Showed that EWS can work
  - Discussed Muon Resolution issues: Not a deal breaker
  - Quantified the “Luminosity Lag” between Electron and Muon channels
- Actively used in ATLAS right now

Backup

Event Selection Details

Event Level Selection

1. Event is in the Good Runs List;
2. Event has at least one primary vertex, with number of tracks > 2;
3. Event passes the triggers: `EF_e24vhi_medium1` || `EF_e60_medium1` || `EF_g35_loose_g25_loose`;
4. Event fulfills LArError < 2, which provides protection against noise bursts and data corruption;

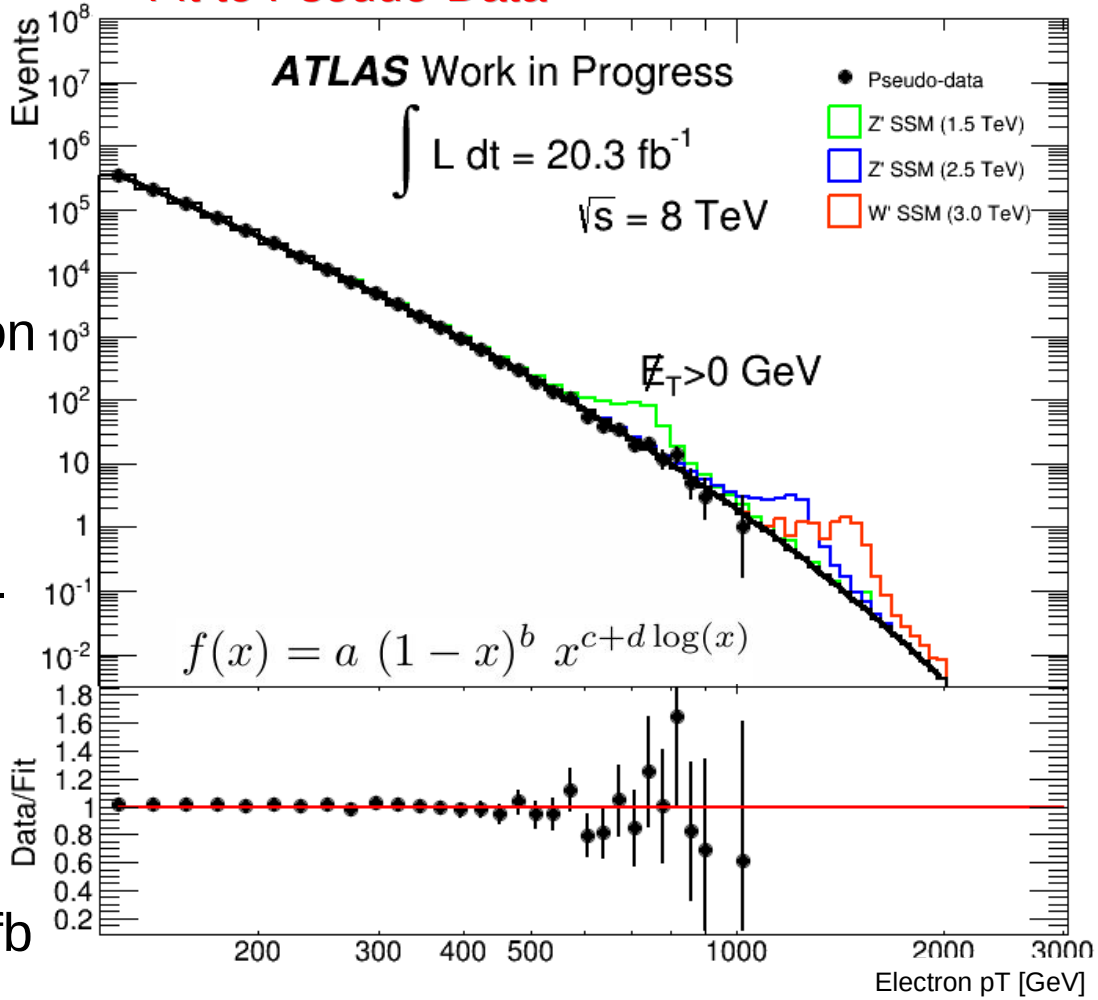
Object Level Selection

1. Each electron has author 1 or 3;
2. Each electron must have $|\eta| < 2.47$ excluding the crack region $1.37 < |\eta| < 1.52$;
3. Each cluster must pass calorimeter quality requirements;
4. Each electron must have $p_T > 40$ GeV;
5. Each electron must have at least isEM MEDIUM++ identification;
6. Each electron must be isolated using an E_T dependent cut: `EtCone20_pT_NPV_corrected` $< 0.007 \times E_T + 5.0$ GeV;
7. To be fully inclusive, in case multiple event electrons satisfy the requirements above, all passing electrons are selected.

Fitting Dijet function to Pseudo-Data

- Established fit works for MC and Data at 20.3 / fb
  - What about for different luminosities?
- Want to simulate data collection
  - Treat inclusive lepton pT distribution from Run-I data as template to randomly sample from
  - Use sampled values to build up “new” inclusive lepton pT “Pseudo-Data” distribution
  - Repeatedly try refitting and extrapolating after sampling some characteristic number of events
  - Works consistently through 20.3 / fb
- Pseudo-Experiments provide credibility that fit works at different luminosity scales

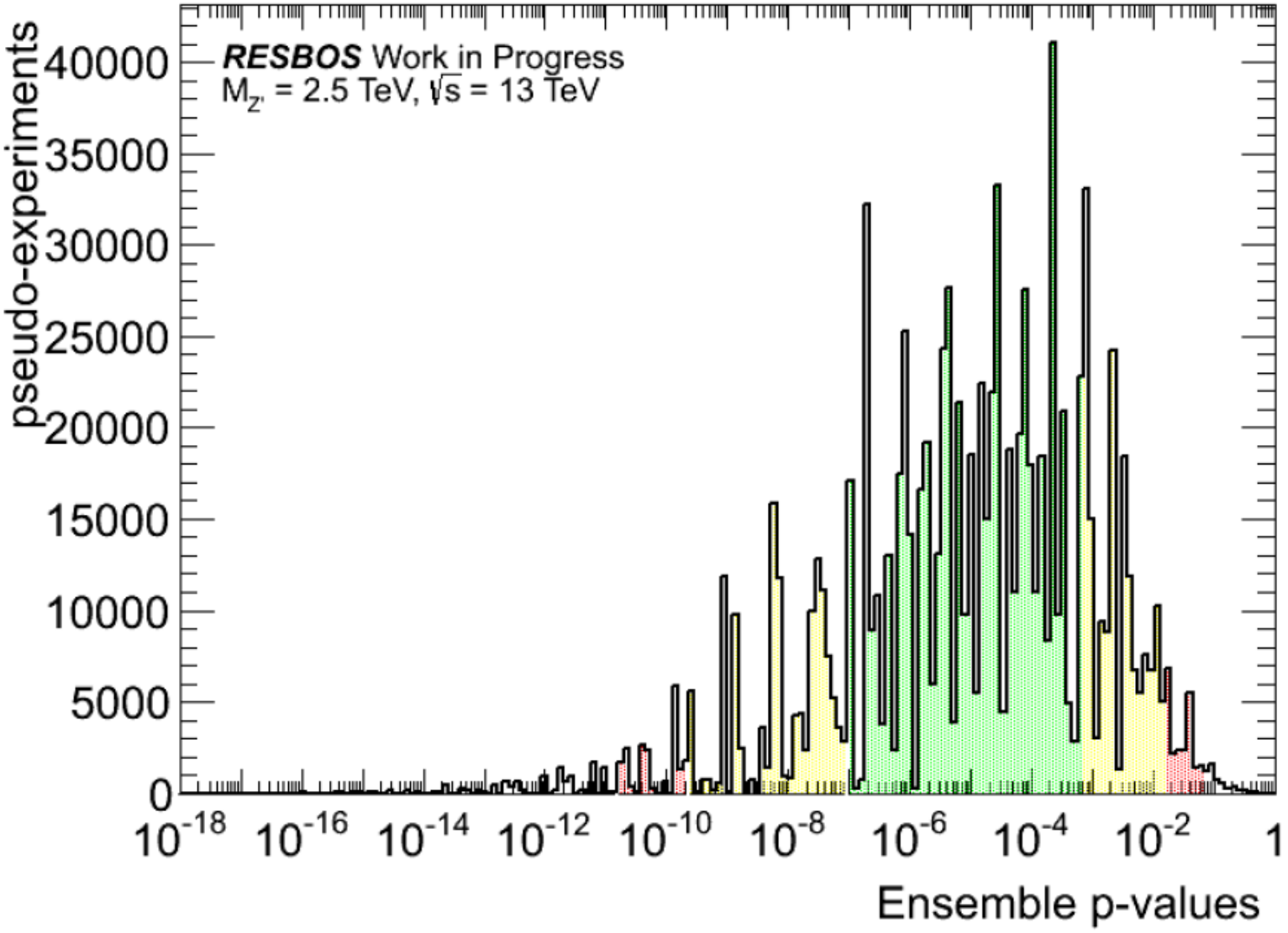
Fit to Pseudo-Data



Pseudo-Experiment Procedure

- Pseudo-Experiments
  - 1. The inclusive lepton pT spectrum is set to a specified integrated luminosity
  - 2. Poisson Random Numbers are thrown using the histogram bin content as the Poisson mean
    - (a) according to the S+B hypothesis: the lepton pT spectrum + Z' signal.
    - (b) according to the B-Only hypothesis: the lepton pT spectrum only.
  - 3. To account for the Look-Elsewhere-Effect, Fisher's Method is sued to combine bin-by-bin local p-values
  - 4. Repeat 1e5 times to generate an ensemble
  - 5. Build up distribution of global p-values

p-value distribution at 2.0 / fb for Electron Channel



Results for a 0.5 TeV SSM Z'