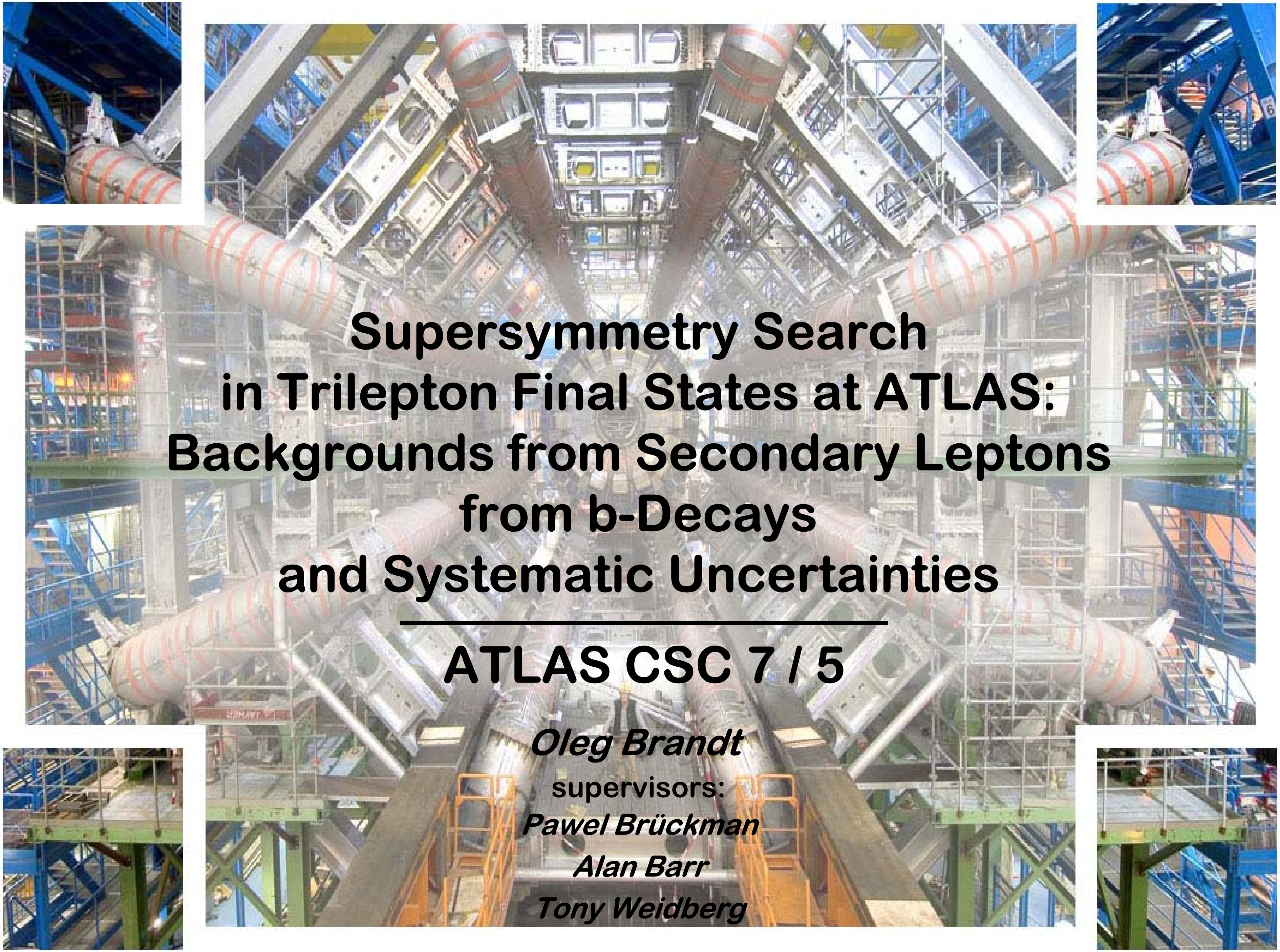


Supersymmetry Search in Trilepton Final States at ATLAS: Backgrounds from Secondary Leptons from b-Decays and Systematic Uncertainties

ATLAS CSC 7 / 5

Oleg Brandt

supervisors:

Pawel Brückman

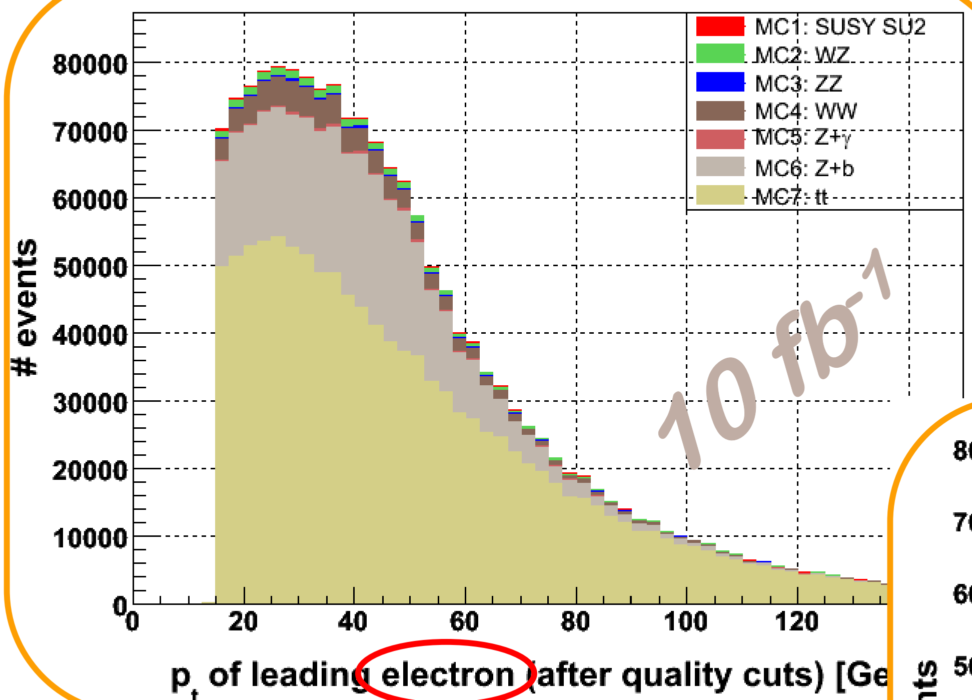
Alan Barr

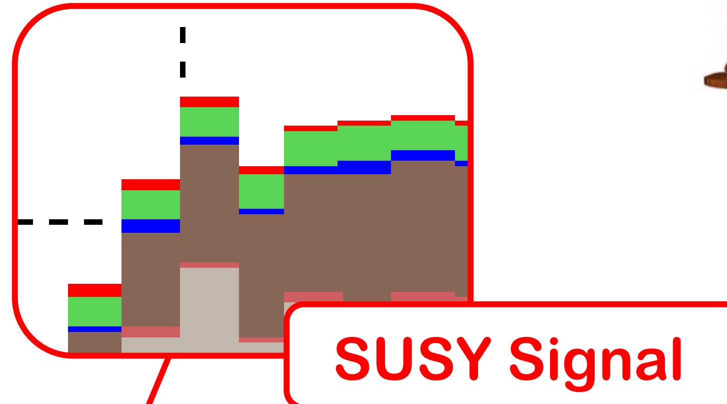
Tony Weidberg

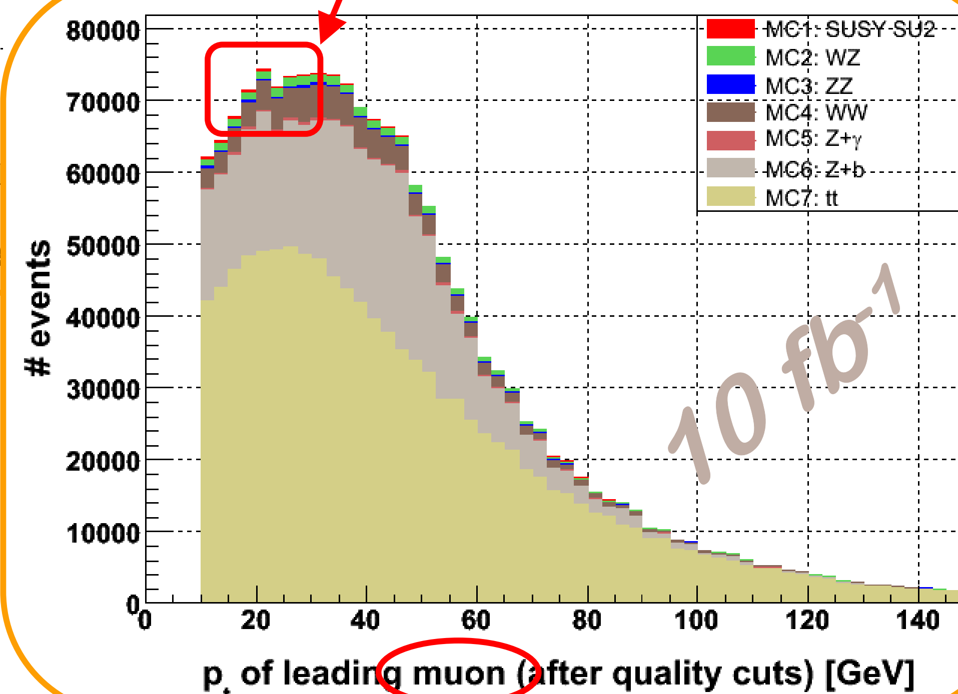
Today's Menu

- Lepton isolation:
  - Track isolation
  - Calorimeter isolation
  - Impact Parameter
- First thoughts on measuring the rate of isolated leptons from b-jets
- Estimation of Systematic Uncertainties
- Conclusion

Leading Lepton Pt for SU2







Need high lepton purity!
Need primary leptons!

Friend and Foe

- Very few SM backgrounds with 3 primary leptons!
- Our most important backgrounds:
  - Z+jets
  - ttbar
- Only 2 primary leptons
- Third lepton from:
  - light jet faking an electron
  - punch-through and in-flight decays to muons
  - secondary leptons from c- and b-decays
    - From MC: O(10) higher rate than the two above!!!

Preselection Outlined

- Preselection (ATLAS SUSY WG cuts in blue):
  - Muons:
    - reconstructed by the MuID algorithm, $|\eta| < 2.5$
    - Calorimeter isolation in $\Delta R = 0.2$ cone: < 10 GeV
    - bestMatch(), isCombinedMuon()
    - 0 < chi^2(track match) < 100
    - Jet isolation: no jets in $\Delta R = 0.4$ cone (against b)
    - Isolation w/r/t each other in: $\Delta R = 0.1$ (against J/Psi & Y)
    - Pt > 10 GeV
  - Electrons:
    - reconstructed by the eGamma algorithm
    - (isEM() & 0x3FF) == 0
    - exclude crack region: $0 < |\eta| < 1.37$; $1.52 < |\eta| < 2.5$
    - Jet isolation: no jets in $\Delta R = 0.4$ cone (against b)
    - Isolation w/r/t each other in: $\Delta R = 0.1$
    - Pt > 10 GeV

Track Isolation: After 3rd Lepton Requirement

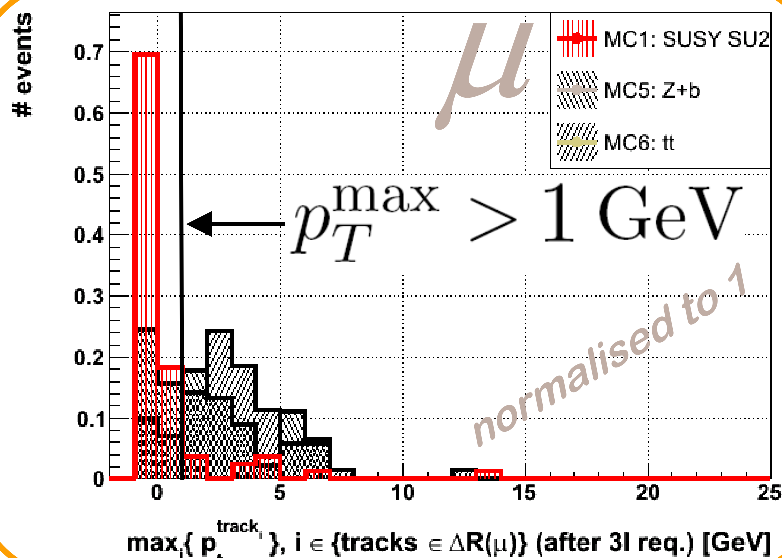
Define track isolation as:

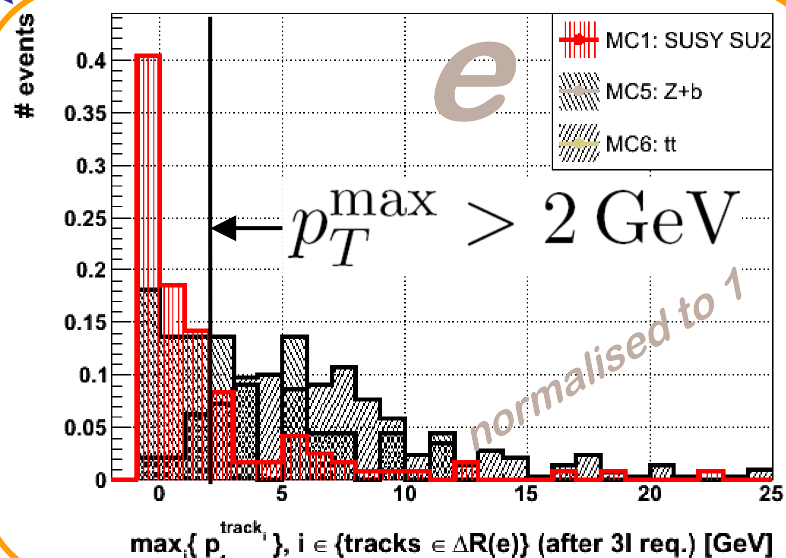
(inspired by H->4l)

$$I^{\rm trk}_{0.2} \equiv p_T^{\rm max}(\ell) \equiv \max_{i,j}\{p_T^{{\rm track}_i} | {\rm track}_i \in \Delta R(\ell_j)\}$$

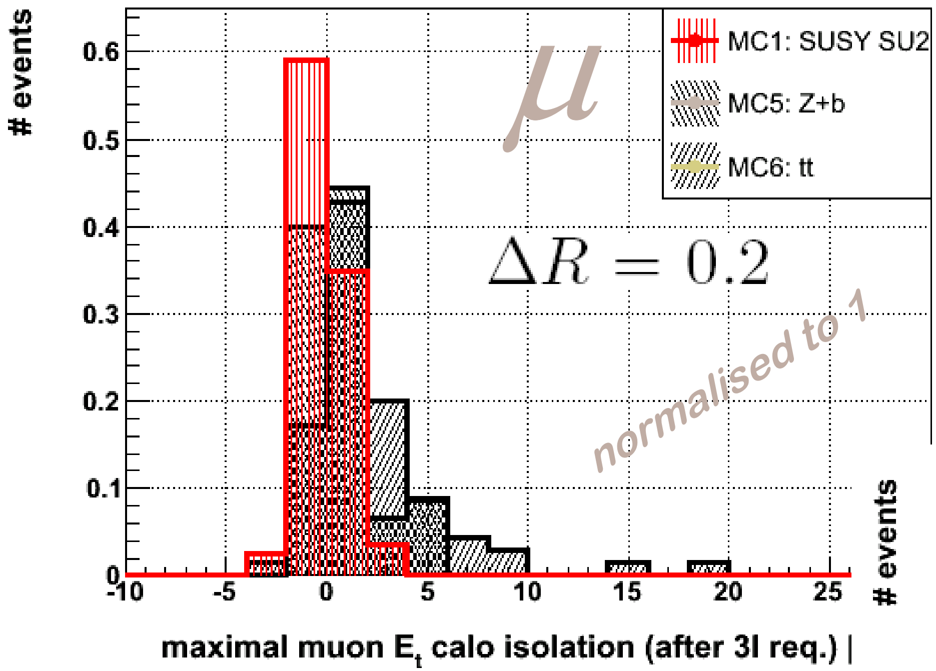
where

$$\ell = \mu\,, e \qquad \Delta R = 0.2$$

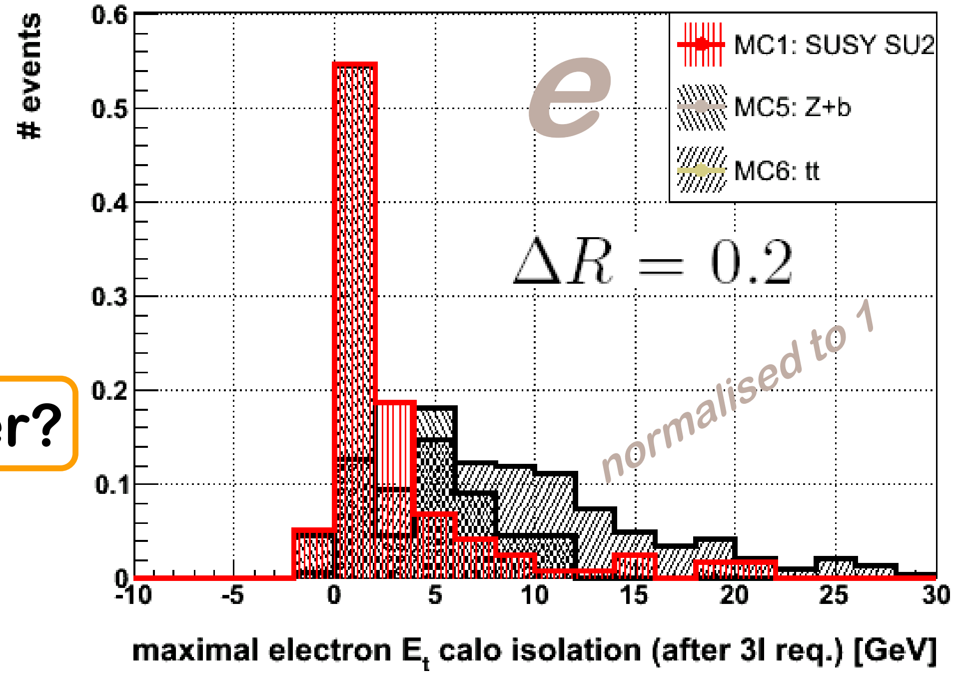




Calorimeter Isolation: After 3rd Lepton Requirement

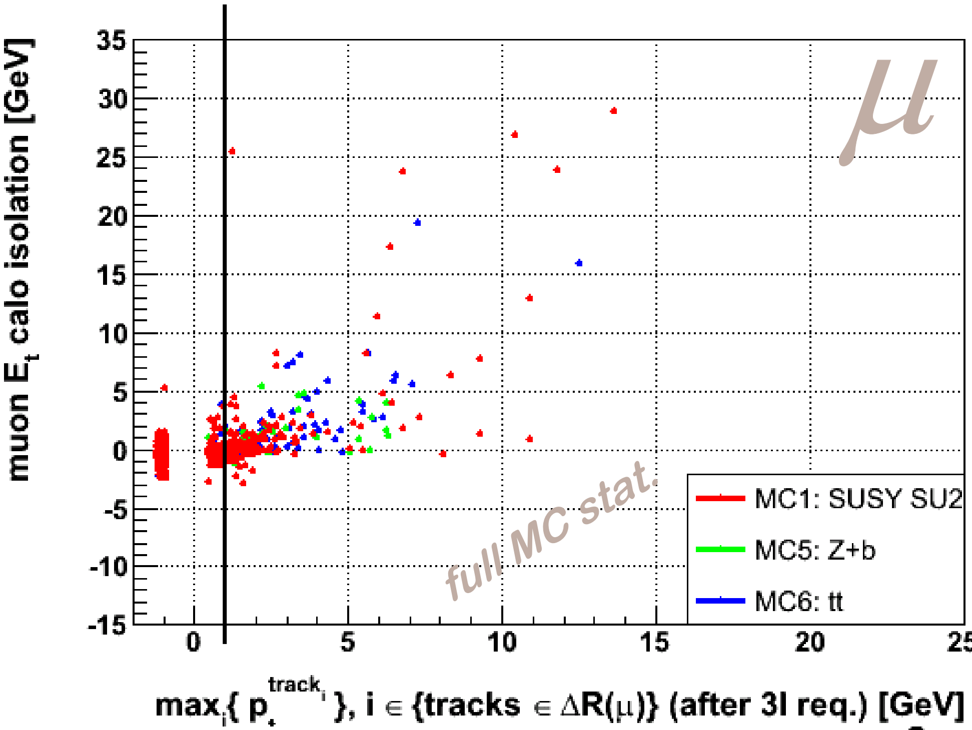


„Conventional“ ATLAS calorimeter isolation from AOD, rel. 12.0.7

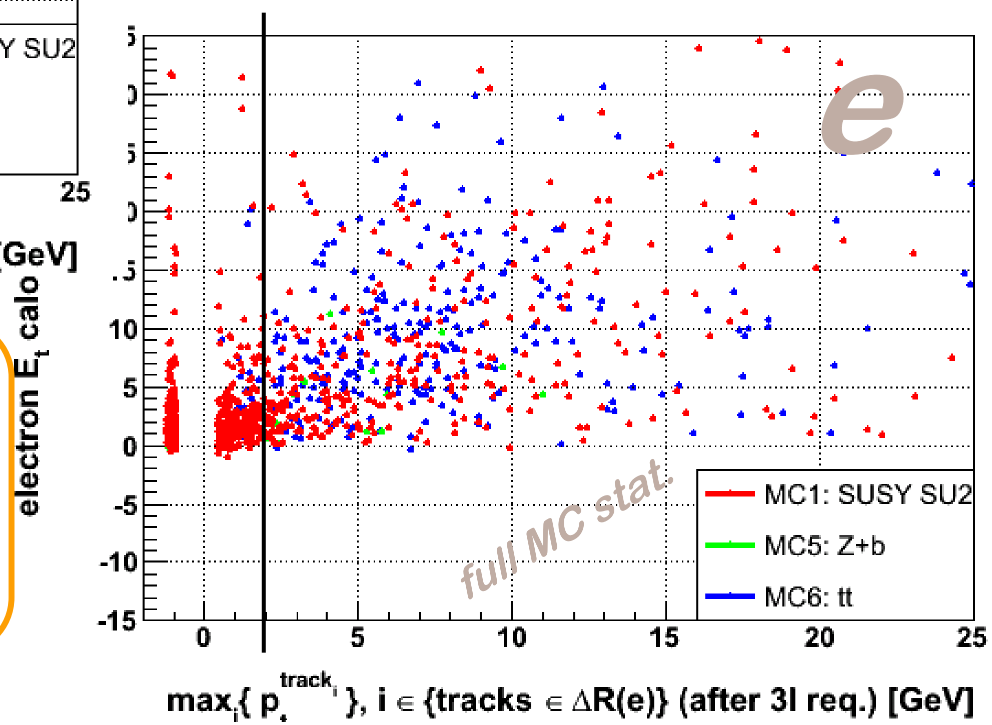


Additional discrimination power?

Track vs. Calorimeter Isolation

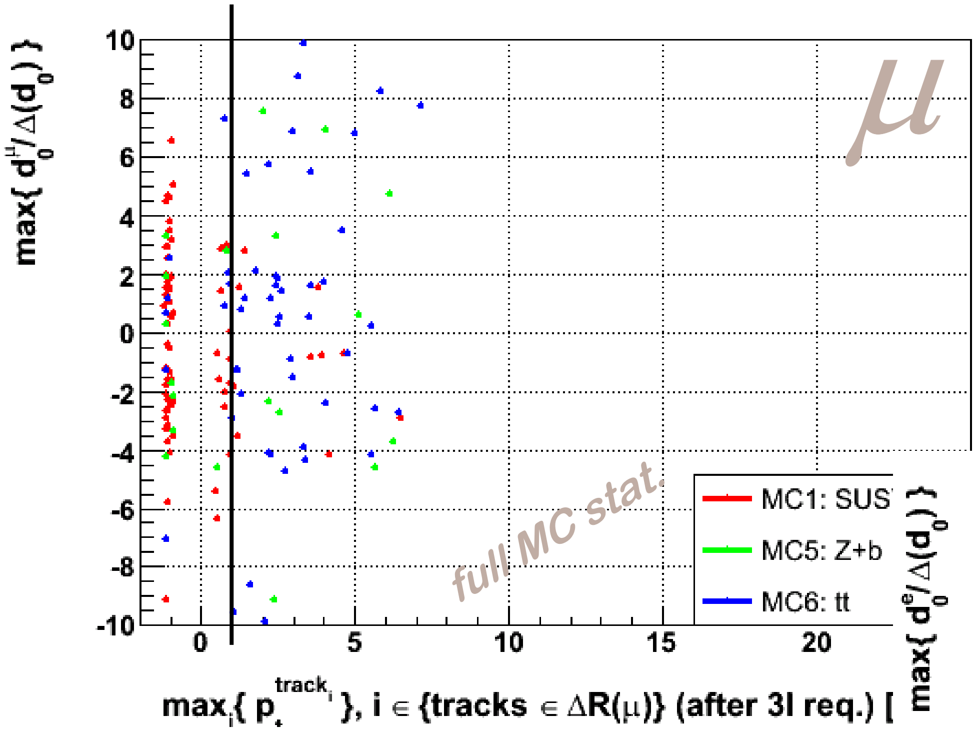


- not 100% correlated :)
- for tight track isolation calo isolation not efficient :(

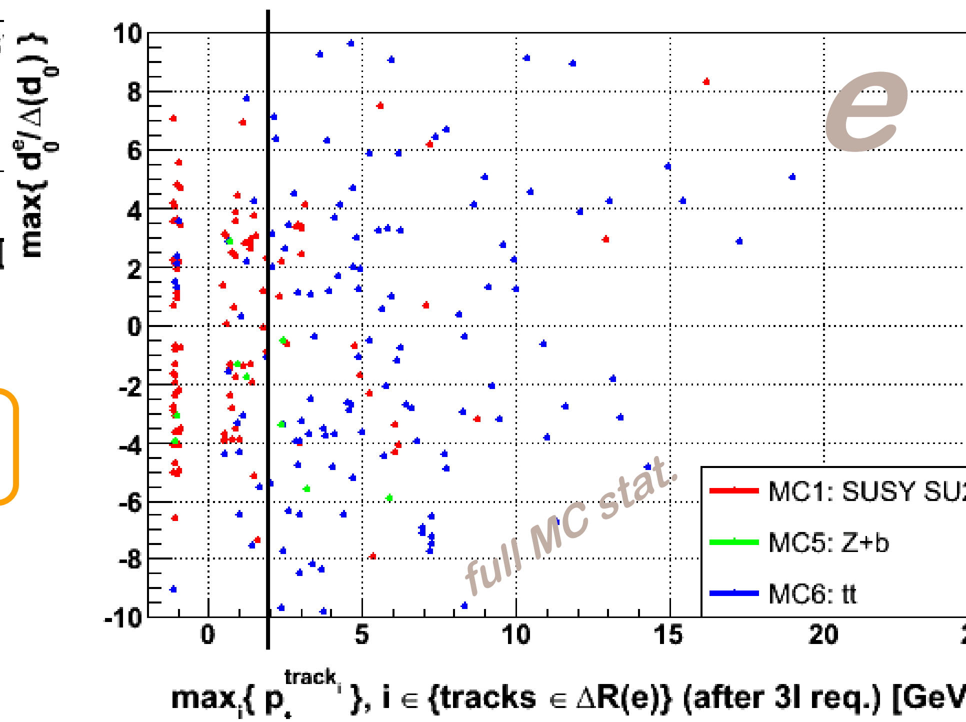


- Calo isolation potentially easier to understand
- Use the discrimination variable first understood!

Normalised Impact Parameter vs. Track Isolation



- Impact Parameter rather weak constraint against secondary leptons from b's

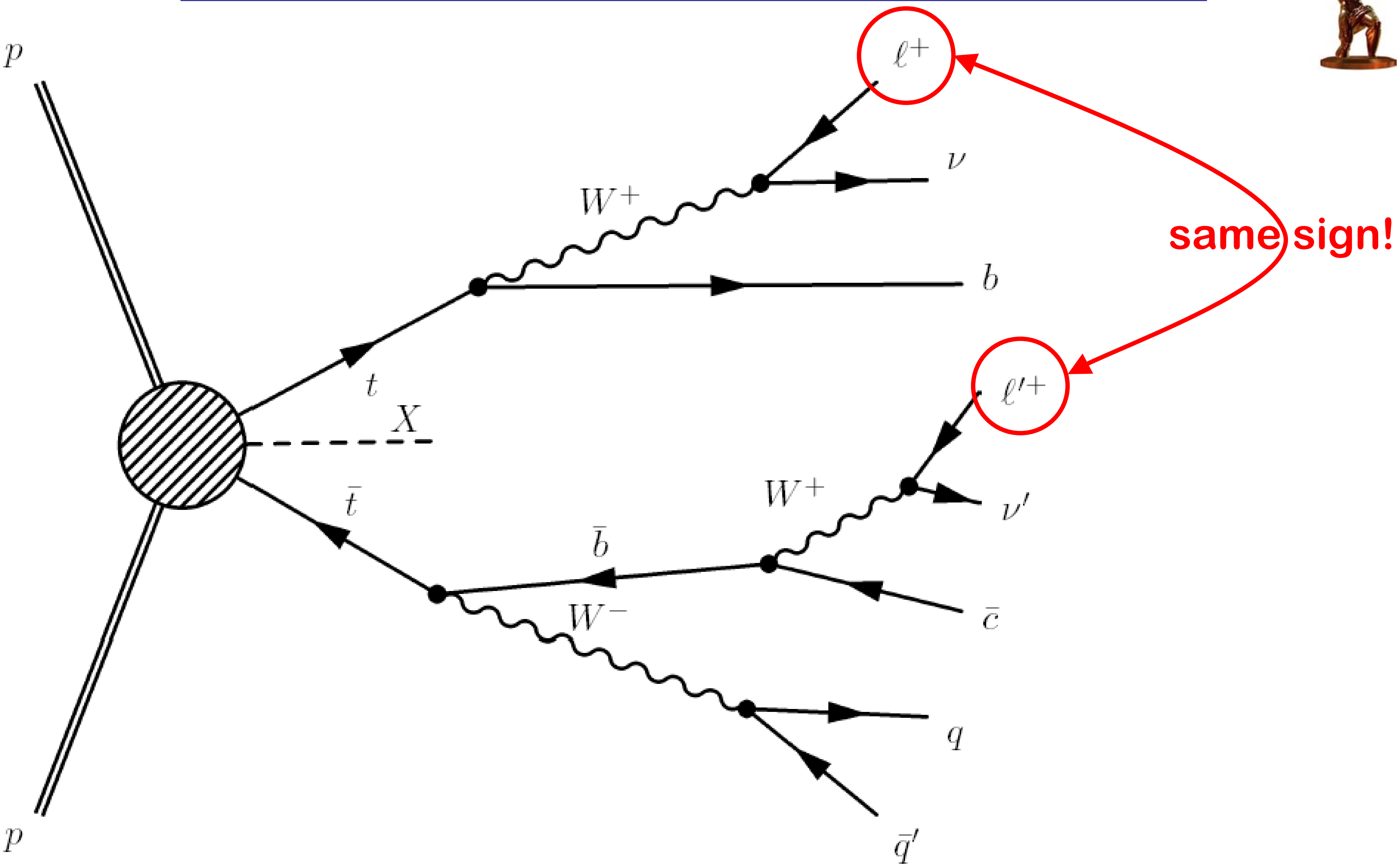


- keep it for cross-checks

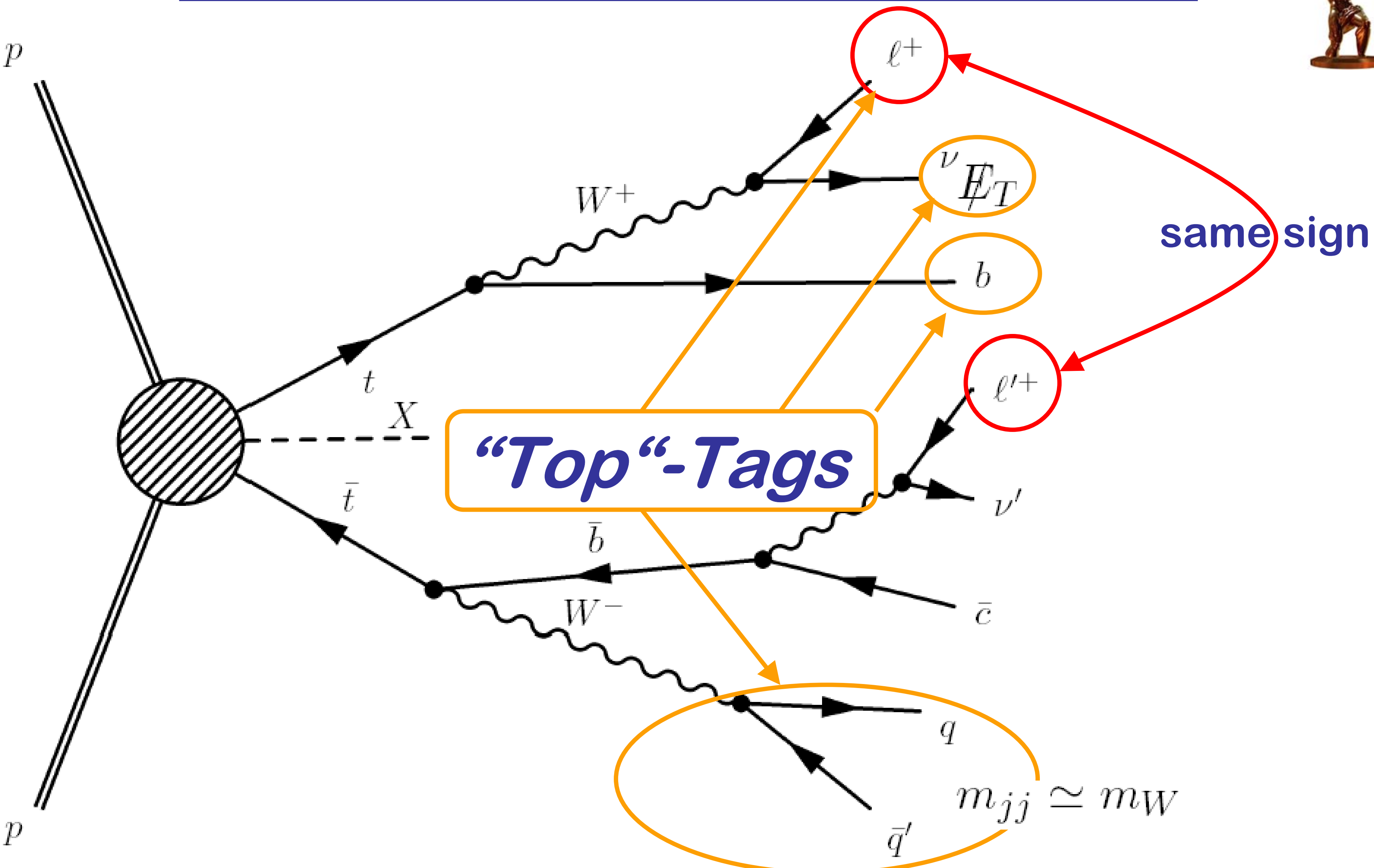
Study Secondary Leptons from b-Jets in $t\bar{t}$ Events

- Study isolated lepton fake rate from b-jets:
  - Need a reasonably pure sample of b-jets:
    - $b\bar{b}$
    - $t\bar{t}$
- $b\bar{b}$:
  - difficult due to high backgrounds, e.g. W+j
- $t\bar{t}$:
  - Several handles to tag $t\bar{t}$ events without using one of the b-jets
  - Use semileptonic $t\bar{t}$ channel
    - Orthogonal sample
    - approx. 10x more statistics than dileptonic $t\bar{t}$

Study Secondary Leptons from b-Jets in $t\bar{t}$ Events: Ansatz



Study Secondary Leptons from b-Jets in $t\bar{t}$ Events: Ansatz



Study Secondary Leptons from b-Jets in $t\bar{t}$ Events: Ansatz

- Define the rate as:

$$R_{\mathrm{sec}} \equiv \frac{\#\text{ of leptons from } b\text{-jets passing the isolated lepton definition}}{\#\text{ of } b\text{-jets}}$$

- Denominator given by "top-tags" from previous page:
  - 1 b-tagged jet
  - 2 jets with $m_{jj} \simeq m_W$
  - >0 lepton
  - $\not{E}_T$
  - This should give reasonably high S/B
  - With typical semileptonic $t\bar{t}$ backgrounds
- Numerator given by:
  - 2x rate of same sign events passing "top"-tag
  - Interested in events with 1 primary, 1 secondary lepton!
  - "Background": events with 2 primary leptons!

Study Secondary Leptons from b-Jets in $t\bar{t}$ Events

- Important processes for the *numerator* of $R_{\rm sec}$
  - Dileptonic $t\bar{t}$
    - lepton charge mismeasurement
  - Single top
    - associated W+t production:
      - hadronic W: contribution to the desired "signal" sample
      - leptonic W: with additional contribution to "background"
    - most of other single top: contribution to the "signal"
  - Z + QCD
    - lepton charge mismeasurement + jets to pass "top"-tag
  - WZ, ZZ
    - leptons from W / Z + additional jets
- $b\bar{b}$ + jets, W + jets
  - not strictly „background" or "signal"
- More detailed discussion:
  - http://www-pnp.physics.ox.ac.uk/~obrandt/TrileptonAnalysis/INT/int/Int.pdf or CSC 7

Systematic Uncertainties: Classification

- Systematic Uncertainties can be classified:
  - Instrumental:
    - Modelling of the detector and its response;
    - Pile-up;
    - Secondary effects like cosmics, cavern background, beam-gas and beam halo interactions;
    - $\int \mathrm{dt}\, \mathscr{L}$.
  - Physics:
    - Total cross sections;
    - PDF's;
    - Differential distributions like $\not{E}_T, p_T$'s;
    - Underlying event.

Systematic Uncertainties: Instrumental

- Missing Et:
  - $\not{E}_T$ cut around 20-30 GeV -> do not bother about tails!
  - Study e.g. in $Zj \rightarrow \ell\ell j$ or ttbar events
- Lepton ID + trigger:
  - Use “Tag and Probe” for efficiency and fake rates
- Lepton Isolation (reject secondary leptons, slides 10ff.)
- Luminosity:
  - include the uncertainty on $\int \mathrm{d}t\, \mathscr{L}$ as systematics
- Pile up:
  - study isolation etc. in blocks of constant $\mathscr{L}$

Systematic Uncertainties: Physics

- Uncertainties on differential distributions like $\not{E}_T$, p_T's:
  - Beyond the scope of this analysis, more $\int \mathrm{d}t\, \mathscr{L}$ needed
- Underlying event:
  - To be tuned in an LHC-wide effort
- PDF uncertainties:
  - Vary PDF sets within their 1σ uncertainties
  - But: PDF sets from various groups differ by > 1σ!
- Cross section:
  - This analysis is a counting experiment
    - affected by cross section uncertainties
  - Use latest calculations available
  - Use control regions!

Use of Control Regions to Evaluate Systematics from Xsec and Lumi

- Control regions:
  - Estimate background cross sections from data
  - Minimise dependence on:
    - $\int \mathrm{dt}\,\mathscr{L}$ uncertainties
    - PDF's
- Define control regions as:
  - $\not\!\!E_T < 20\,\mathrm{GeV}$
    - will isolate $ZZ,\ Zb$
  - $m_{\ell\ell}^{\mathrm{OSSF}} \in [81.2,\ 101.2]\,\mathrm{GeV}$
    - will isolate $WZ,\ ZZ,\ Z\gamma,\ Zb$

Use of Control Regions to Evaluate Systematics from Xsec and Lumi

- Estimate the Zb contribution:
  - Major background with Z production before the $\not{E}_T$ cut
  - Compare areas under the fit to the m_Z peak for:
    - $\not{E}_T < 20\,\mathrm{GeV}$
    - $\not{E}_T > 20\,\mathrm{GeV}$
  - Take from MC only the fraction of those 2 fits!
  - Take into account other backgrounds like $t\bar{t}$
- Estimate the ZZ contribution:
  - Count events with:
    - 2 OSSF lepton pairs
    - $\not{E}_T < 20\,\mathrm{GeV}$
  - Correct for lepton ID efficiency
- Similarly:
  - WZ
  - $t\bar{t}$

Conclusion

Studied lepton isolation:

- **Calorimeter isolation**
  - **probably easier to understand**
- **Track isolation**
  - **more powerful**
- **Systematic uncertainties:**
  - **Instrumental**
  - **Physics**
- **Resulting table of statistical significancies for SUx:**

	SU1	SU2	SU3	SU4	SU8	SU2χ	SU3χ	SU2+JV	SU3+JV
$S/\sqrt{S+B}$	6.4	6	15.9	53	1.3	4	1.9	2.3	1.5
$\int dt\,\mathscr{L}$ for 5σ	6.1	6.8	1	0.1	138.6	15.3	68.5	48.6	118.9

$10\ fb^{-1}$

Backup slides following

Efficiencies and Fake Rates: Object Definitions

- **Lepton efficiency defined as:**

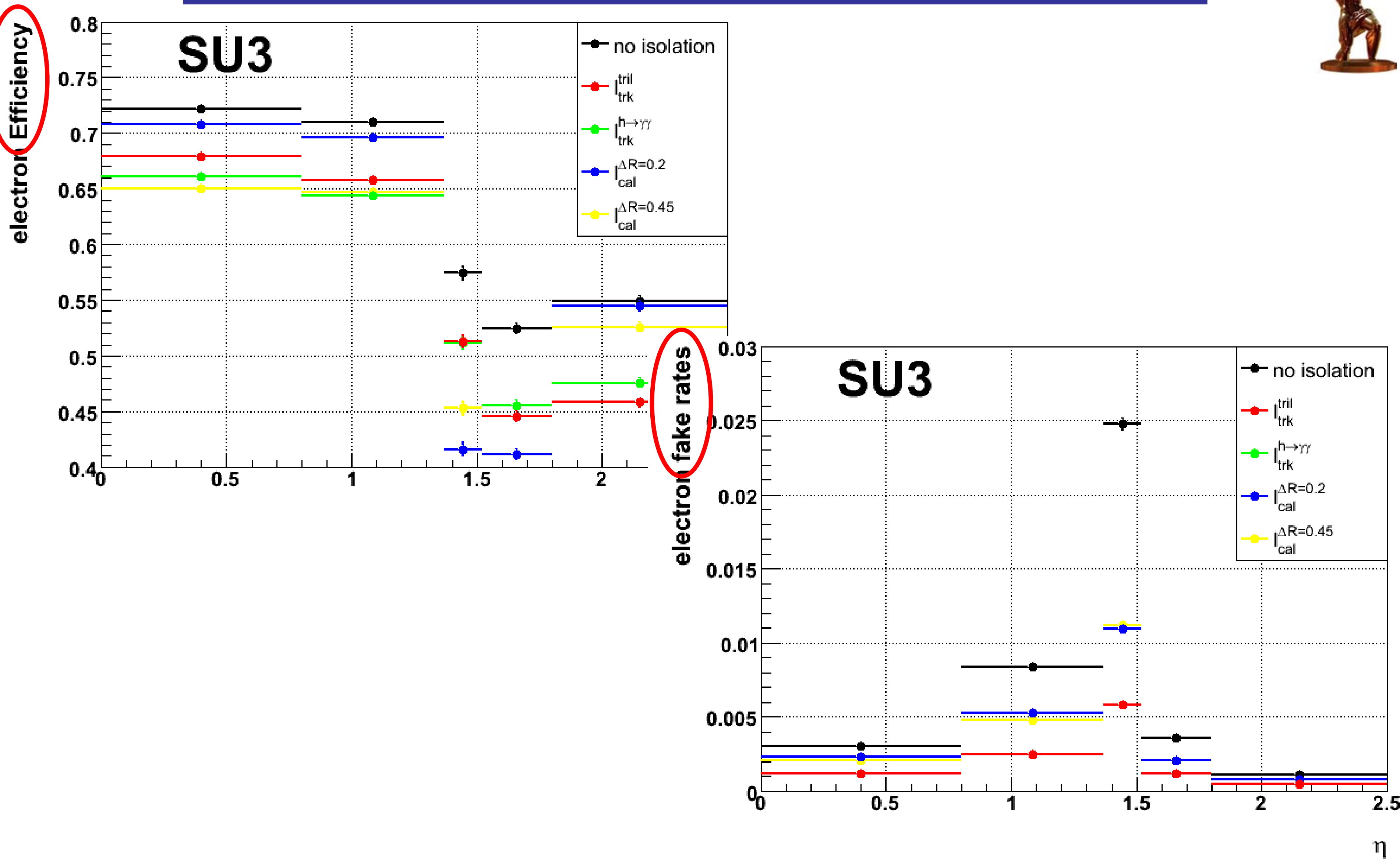
$$\varepsilon_e^{\mathrm{primary}} \equiv \frac{\#\ e^{\mathrm{reco}}\ \text{matched to}\ e^{\mathrm{truth}}(W, Z, \tau, \tilde{f})\ \text{in}\ \Delta R = 0.02}{\# e^{\mathrm{truth}}(W, Z, \tau, \tilde{f})}$$

- **Lepton fake rate defined as:**

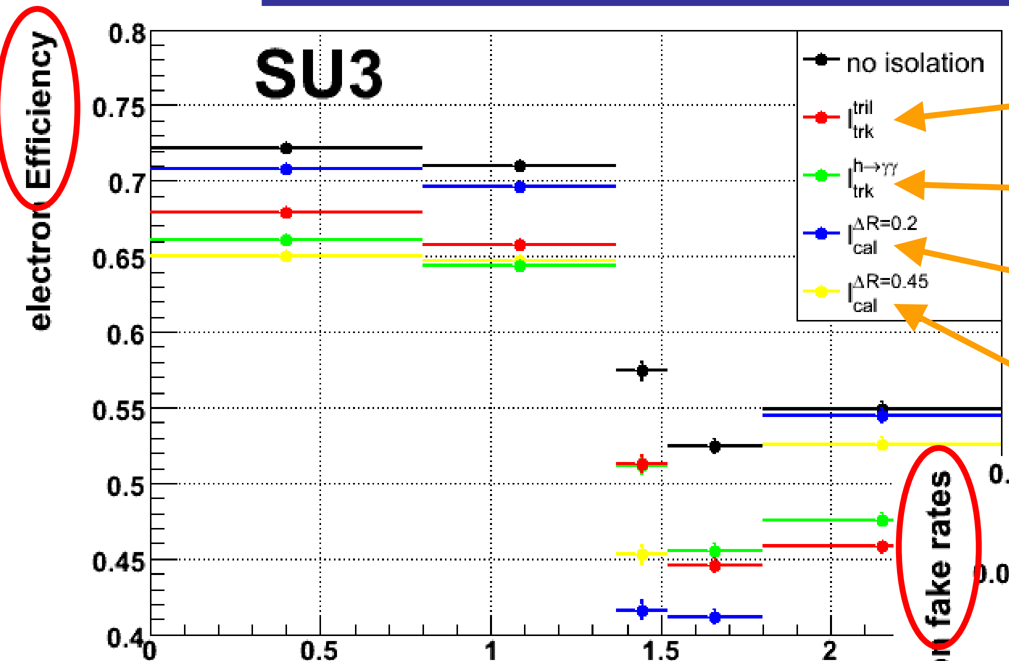
$$\Gamma_e^{\mathrm{fake}} \equiv \frac{\#\ e^{\mathrm{reco}}\ \textbf{not}\ \text{matched to}\ e^{\mathrm{truth}}(W, Z, \tau, \tilde{f})\ \text{in}\ \Delta R = 0.02}{\# j^{\mathrm{reco}}\ \text{after overlap removal}}$$

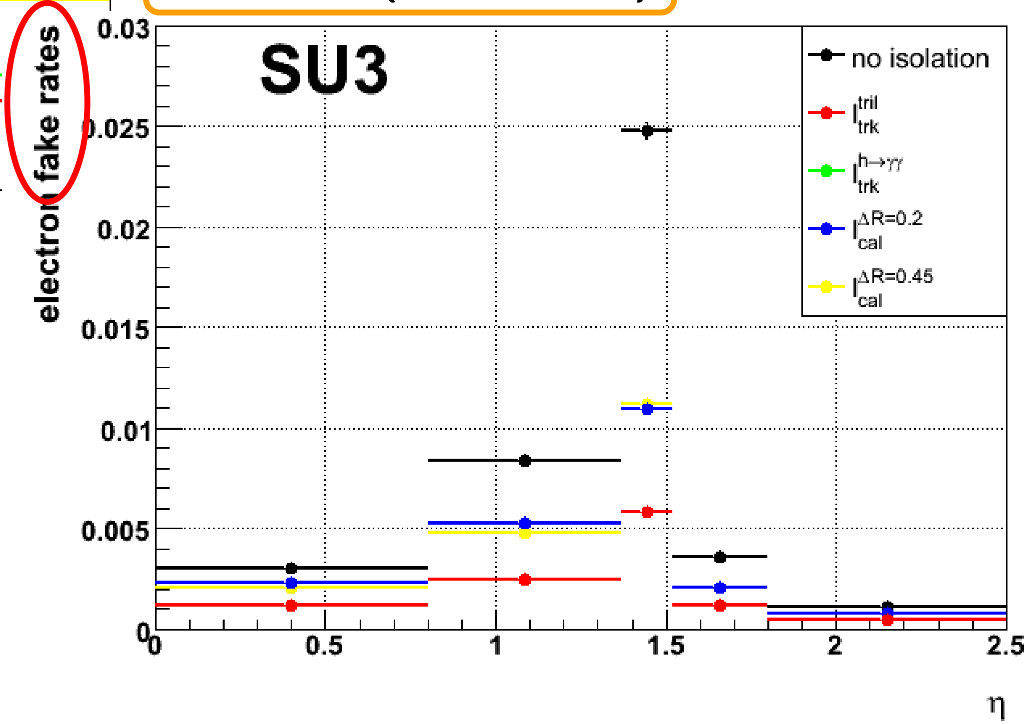
- **Reconstructed electrons:**
  - **Pt > 6 GeV cut for efficiency**
  - **Pt > 10 GeV for fake rates**
- **MC level electrons:**
  - **Pt > 10 GeV cut for efficiency**
  - **Pt > 6 GeV cut for fake rate**
  - **no Geantinos, final state particles only**
- **Jets: reco level jets like in analysis:**
  - **after overlap removal w/ electrons in dR=0.2, Pt > 10 GeV**

Efficiency & Fake Rate: SU3

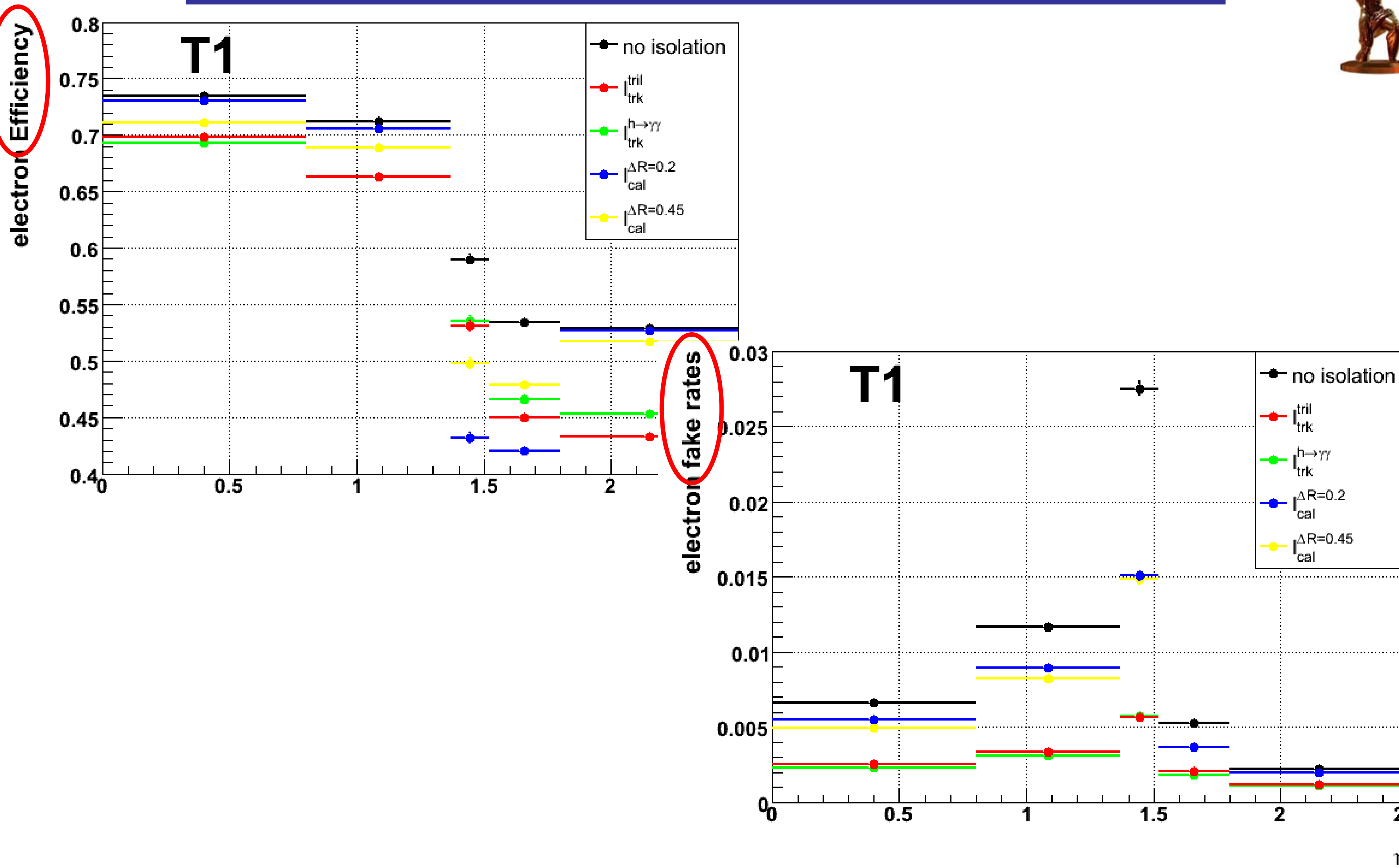


Efficiency & Fake Rate: SU3

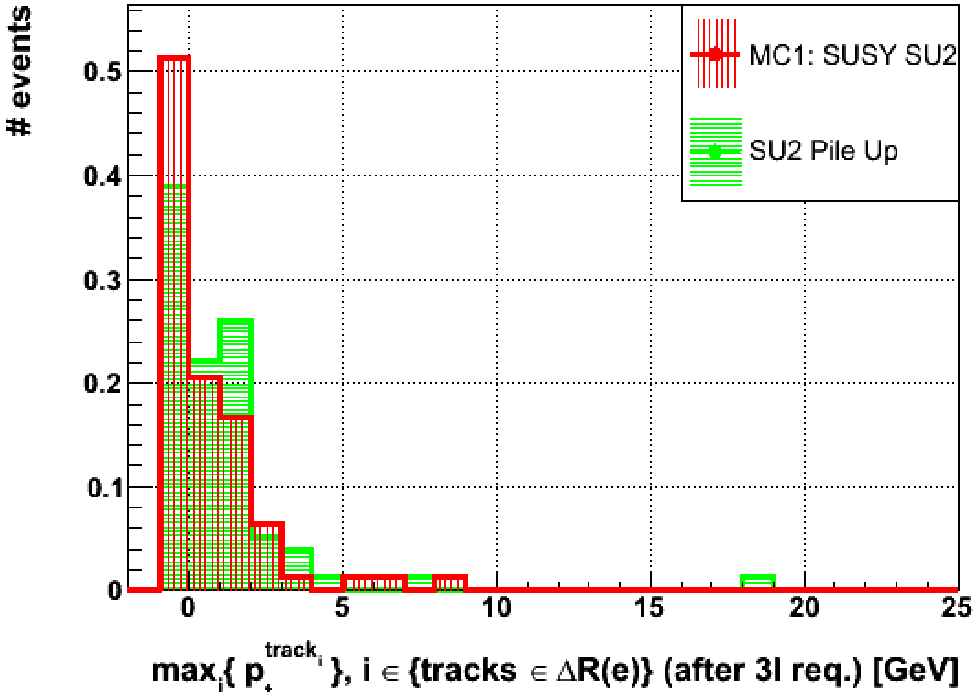




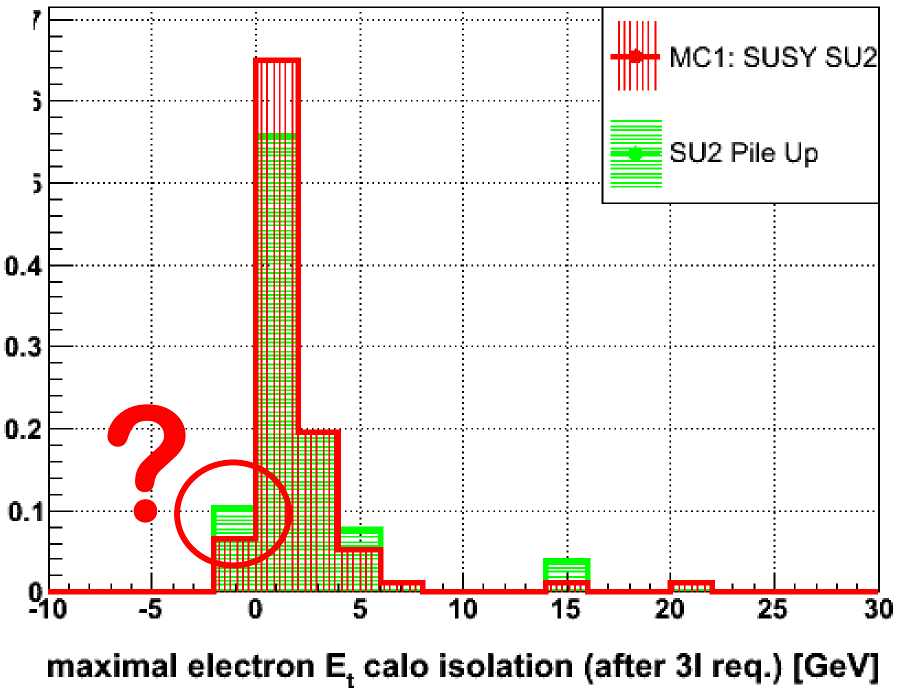
Efficiency & Fake Rate: ttbar



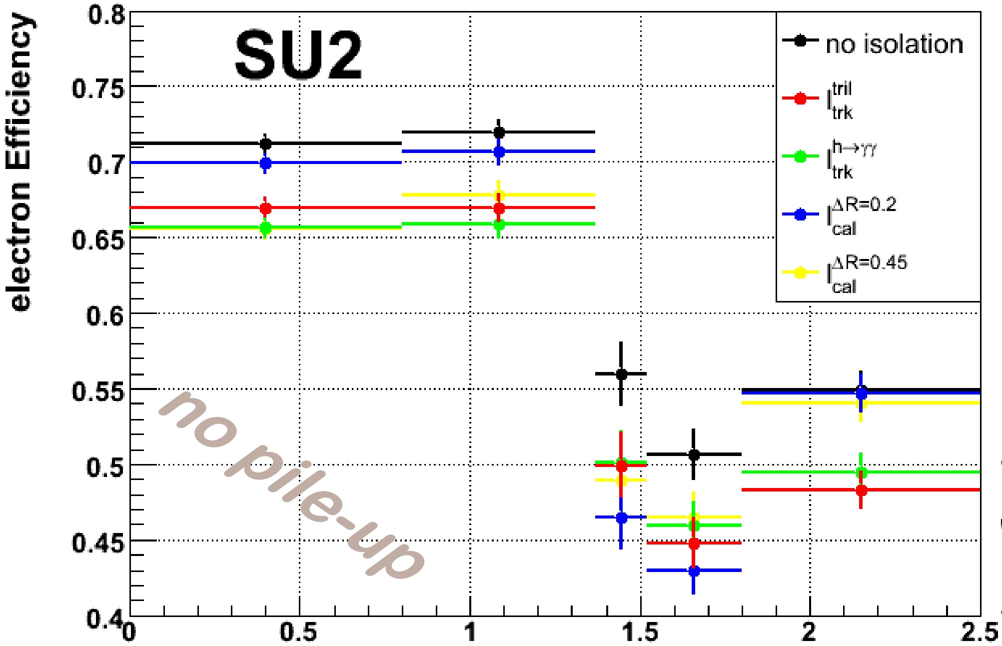
Isolation in Pile-Up Conditions

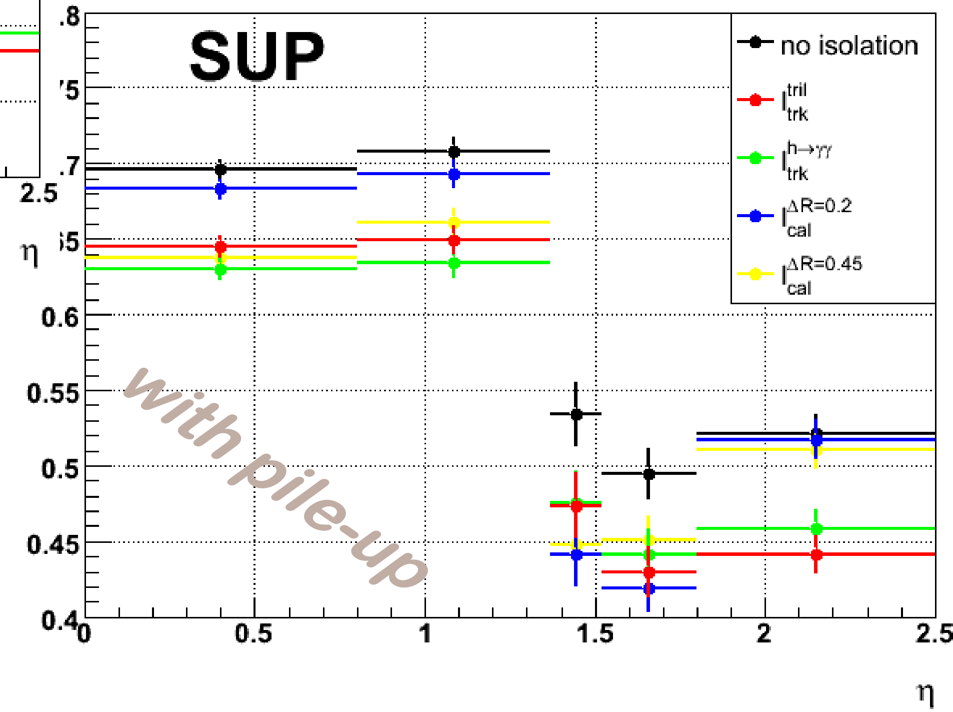


- Pile Up affects:
  - Track Isolation
  - Calorimeter Isolation
- No optimisation for pile up so far



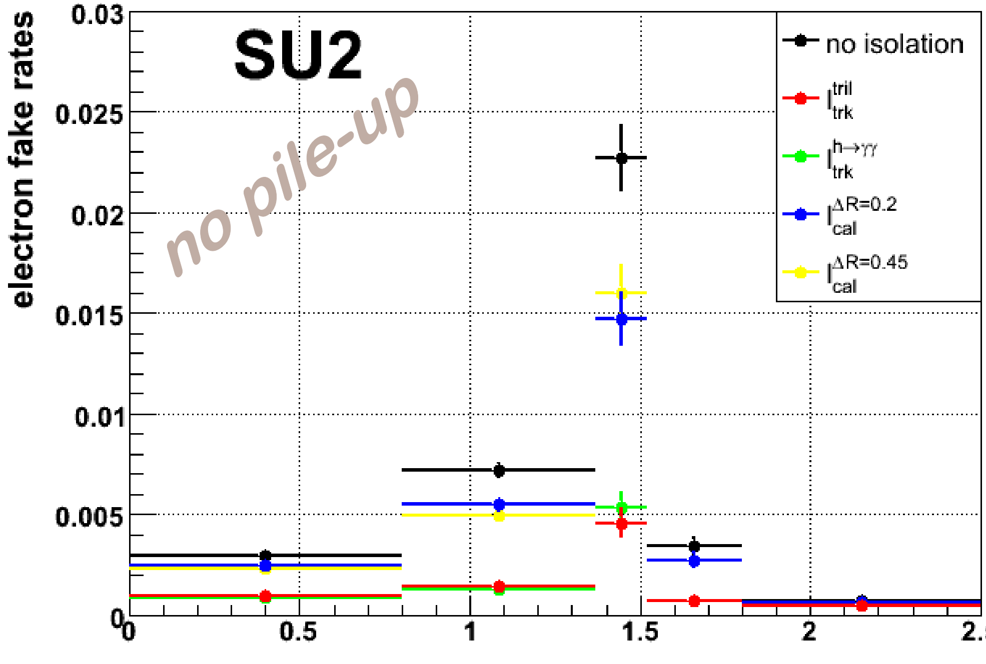
Efficiency with Pile-Up: SU2

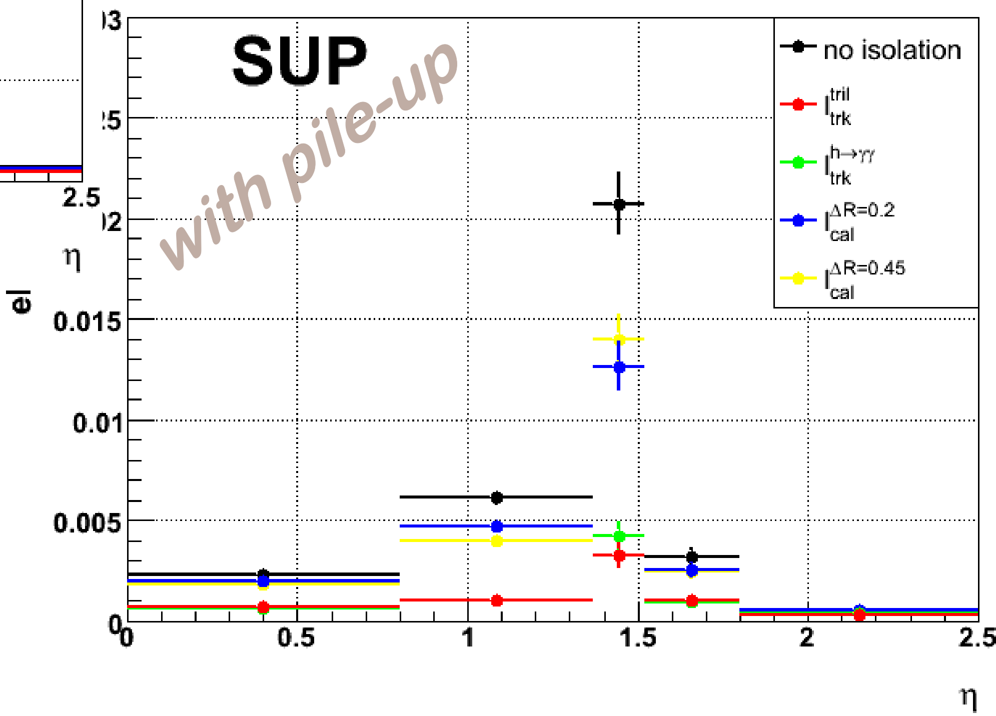




- Very similar degradation for track and calo isolation
- In central region:
  - "Pt_max" track isolation slightly better than "Pt_sum"

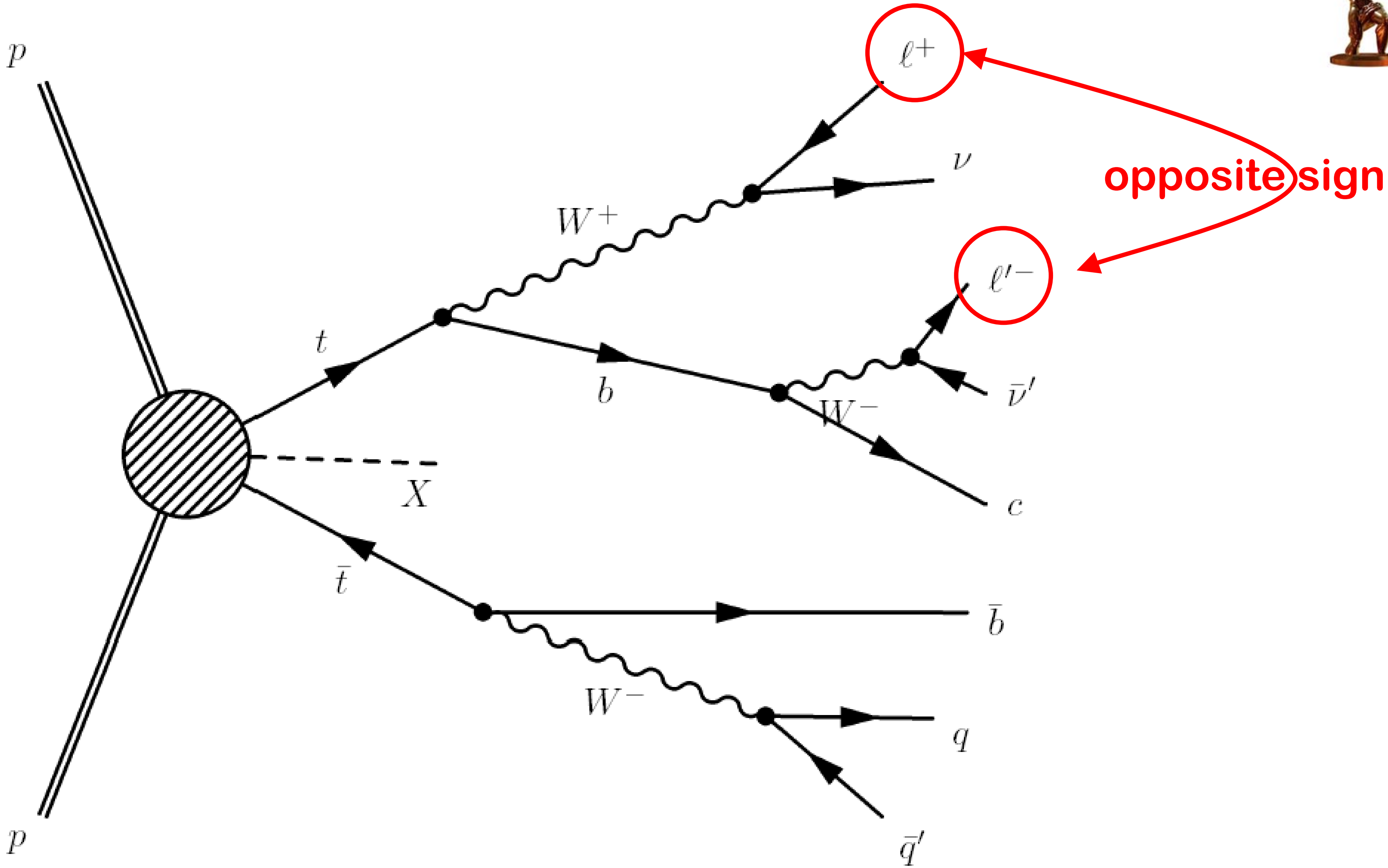
Fake Rate with Pile-Up: SU2



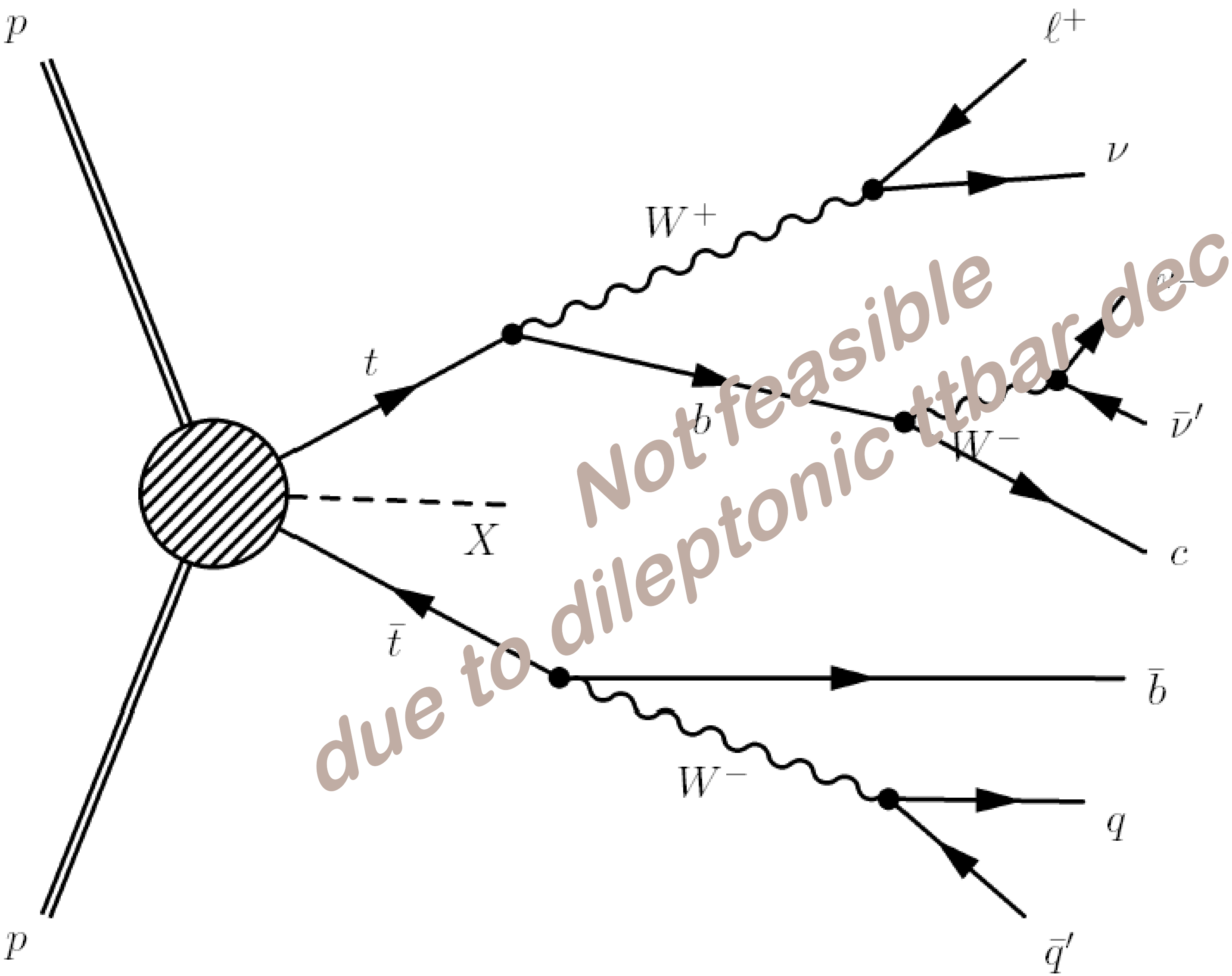


- **Slight improvement for track and calo isolation**

Study Secondary Leptons from b-Jets in ttbar Events: Ansatz



Study Secondary Leptons from b-Jets in ttbar Events: Ansatz



Not feasible due to dileptonic ttbar decays!