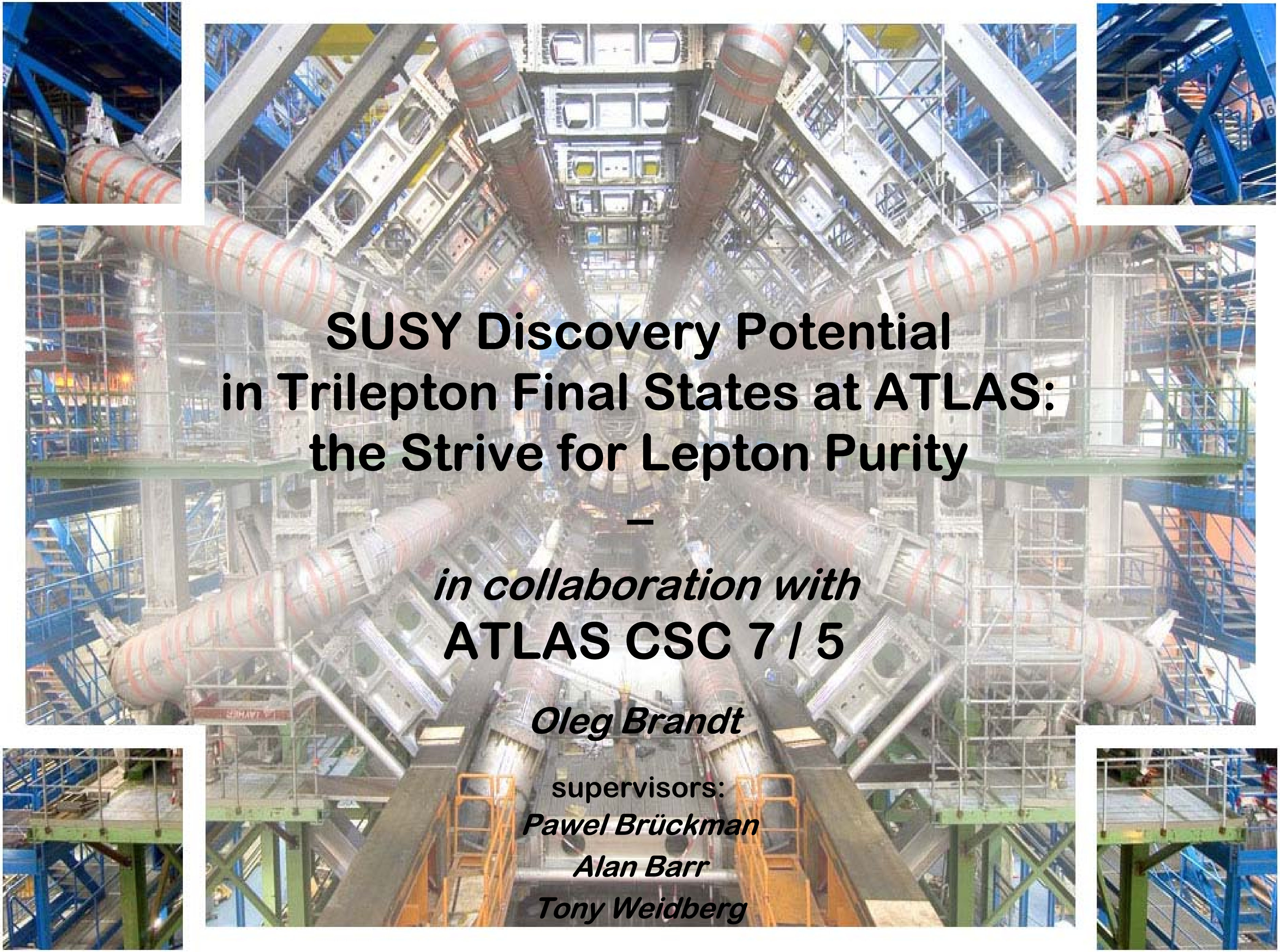

SUSY Discovery Potential in Trilepton Final States at ATLAS: the Strive for Lepton Purity

–

in collaboration with

ATLAS CSC 7 / 5

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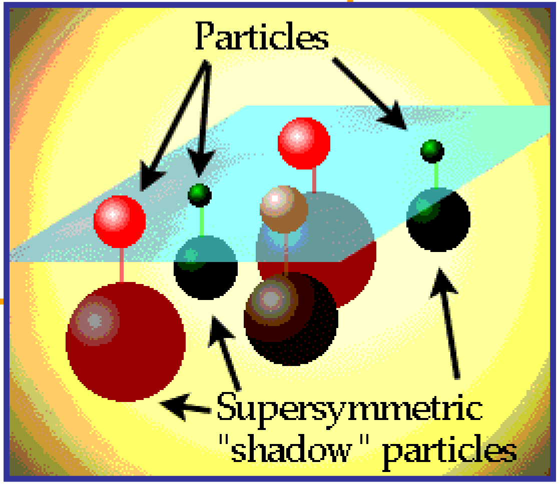
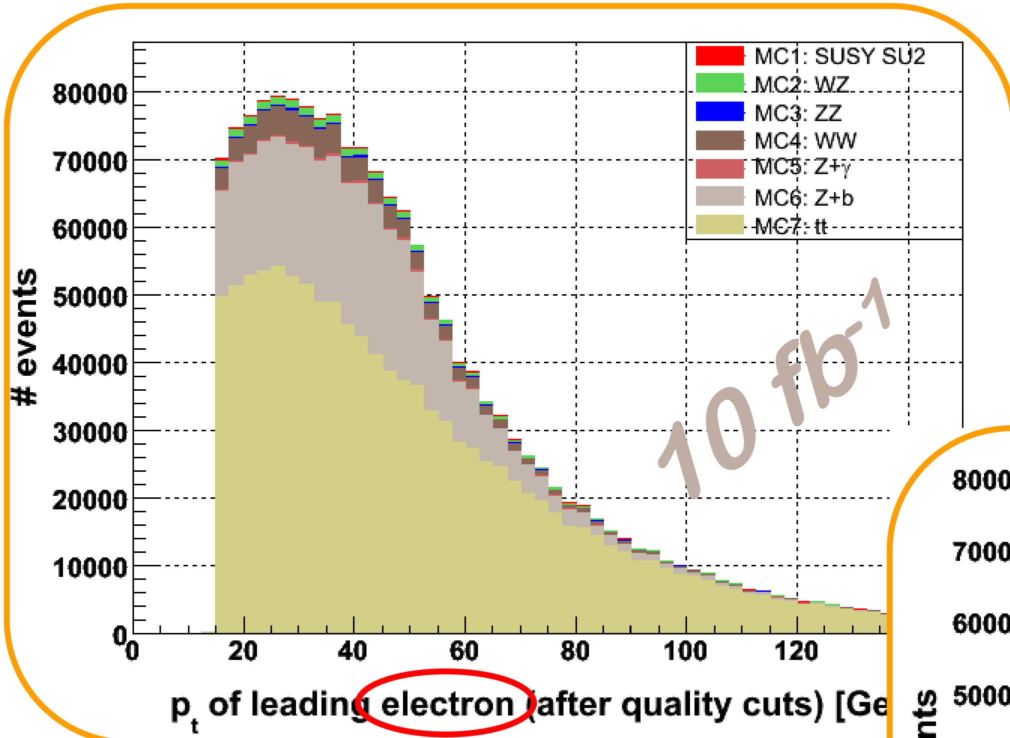
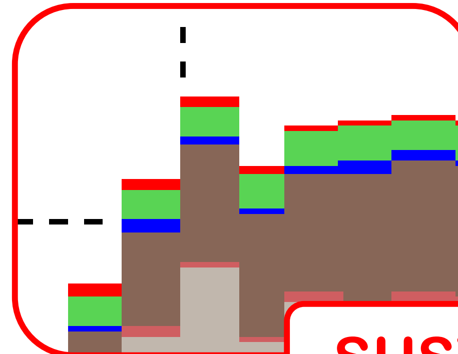
Today's menu

- Short overview of lepton preselection
- Lepton isolation:
  - Track isolation
  - Calorimeter isolation
- OSSF lepton selection:
  - First thoughts on measuring the isolated lepton rate from b-jets
- Conclusion
- Outlook

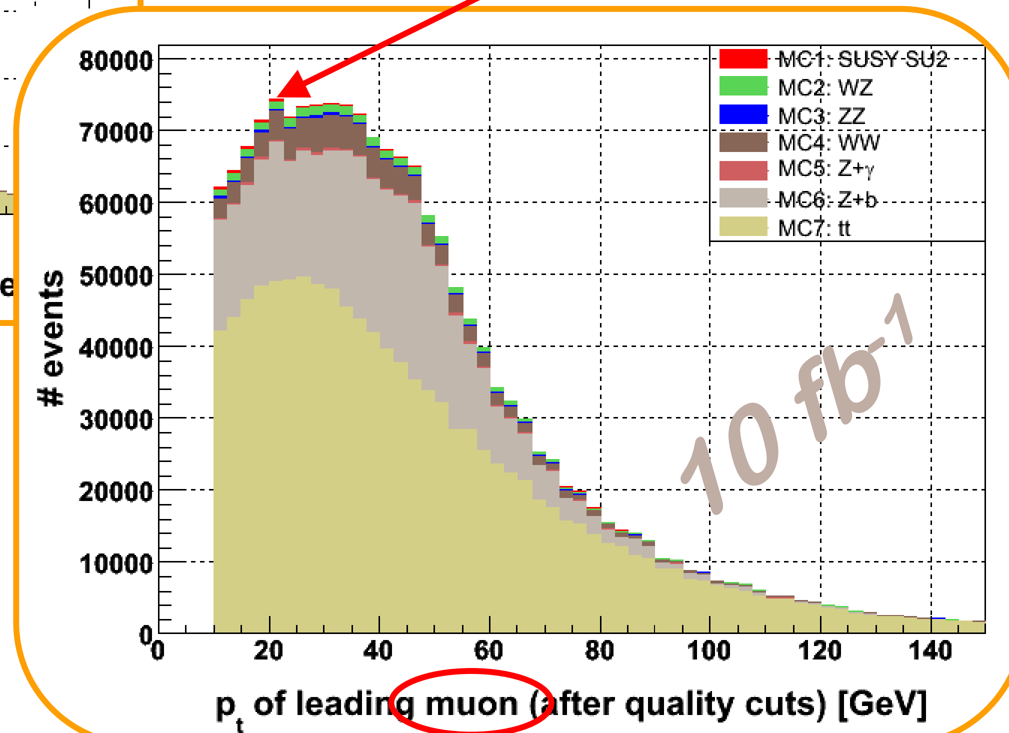


Leading lepton Pt for SU2





SUSY Signal



Need high lepton purity!

Preselection outlined

- Preselection (ATLAS SUSY WG cuts in blue):
  - Muons:
    - MuID
    - $|\eta| < 2.5$
    - Calorimeter isolation in $\Delta R = 0.2$ cone: < 10 GeV
    - bestMatch(), isCombinedMuon()
    - chi^2/NDF for track < 5, track match: < 20
    - 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:
    - $|\eta| < 2.5$
    - (isEM() & 0x3FF) == 0
    - reconstructed by eGamma algorithm
    - Isolation w/r/t each other in: $\Delta R = 0.1$
    - Pt > 15 GeV

Track isolation: after 3rd lepton requirement

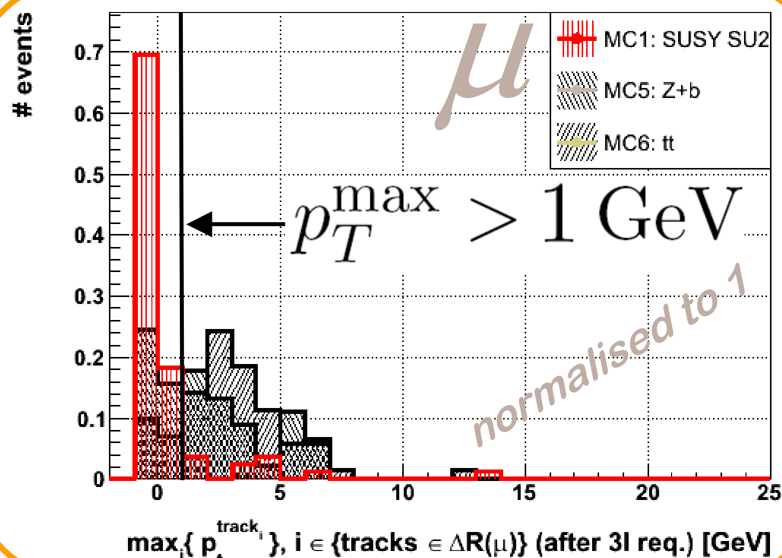
Define track isolation as:

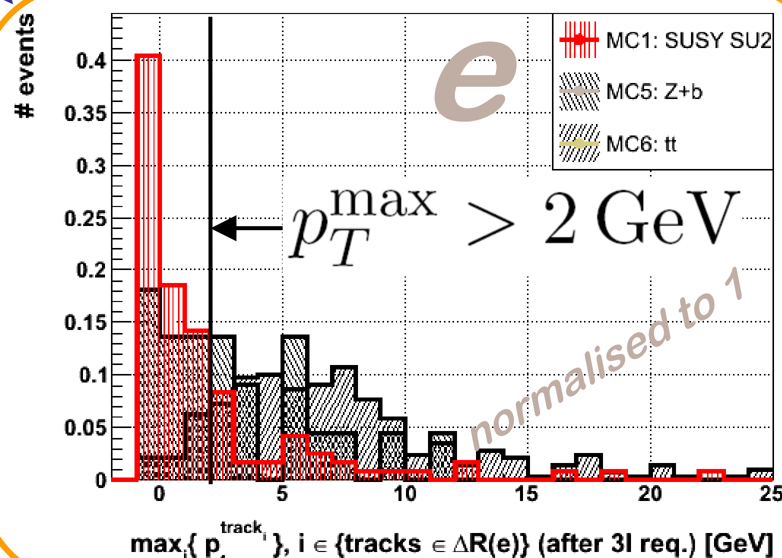
(inspired by H->4l)

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

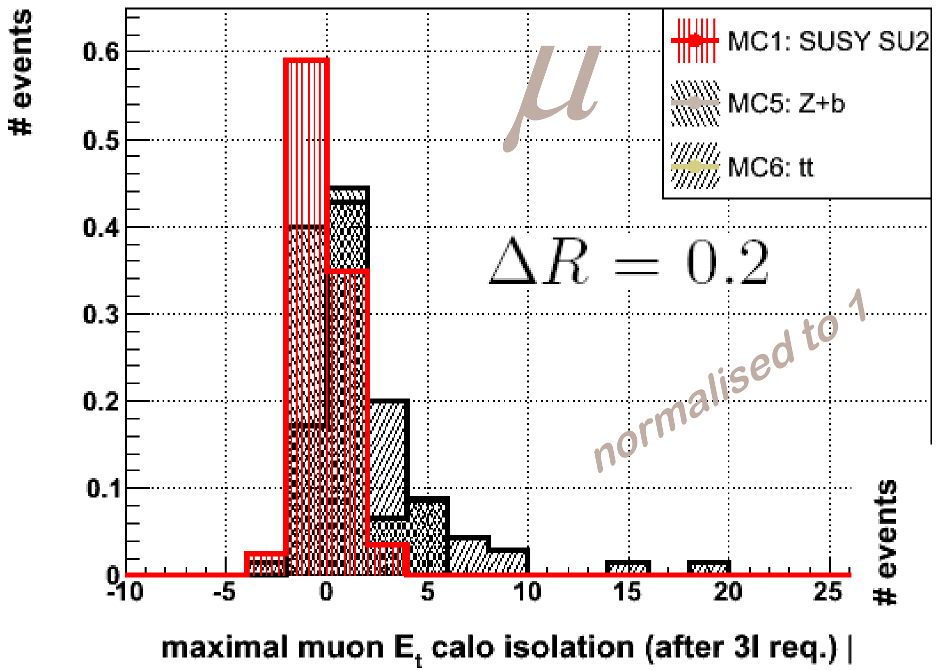
where

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

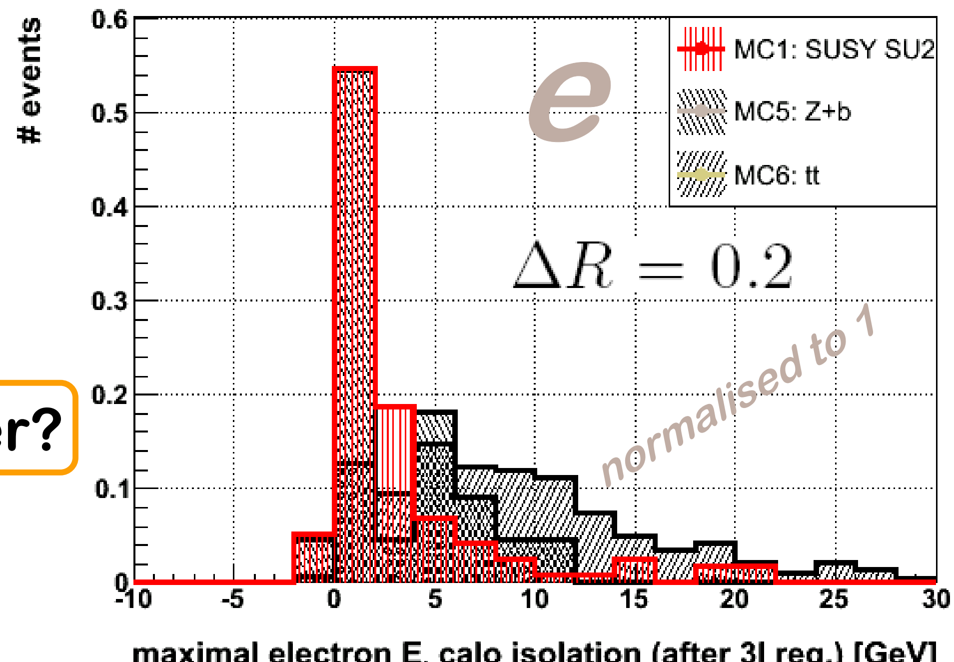




Calorimeter isolation: after 3rd lepton requirement

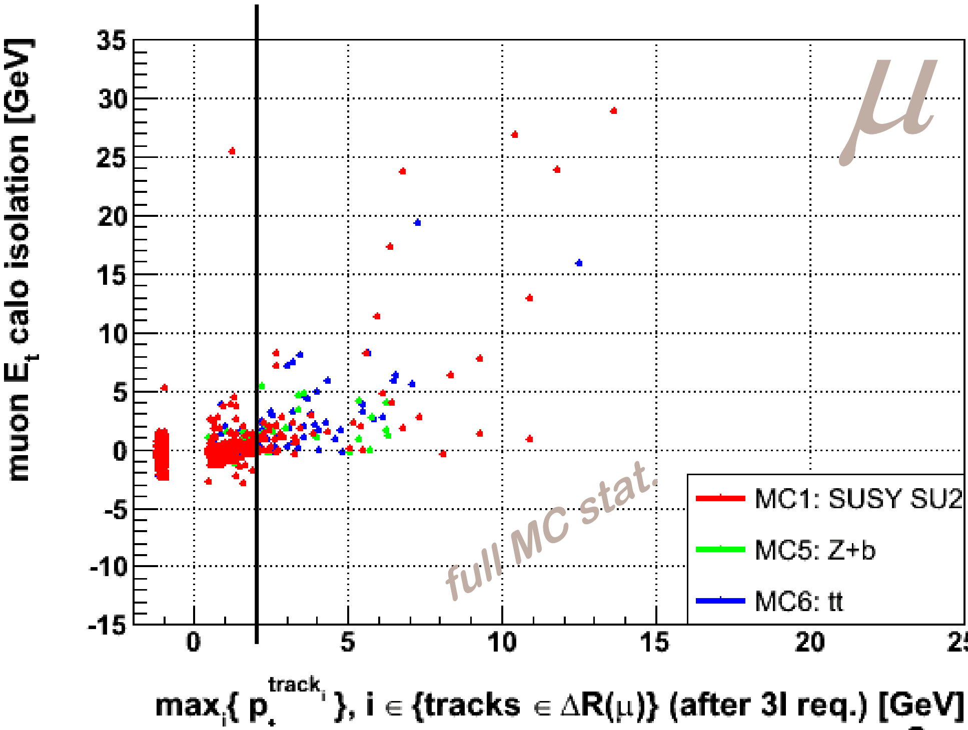


„Conventional“ ATLAS calorimeter isolation from AOD, rel. 12.0.7

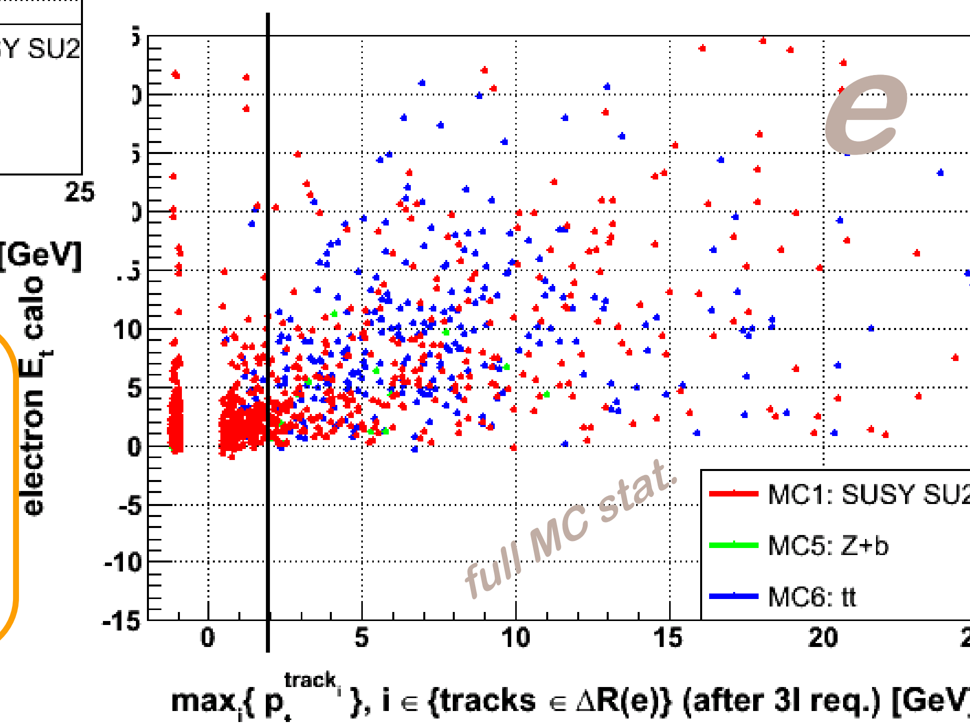


Additional discrimination power?

Track vs. Calorimeter isolation



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



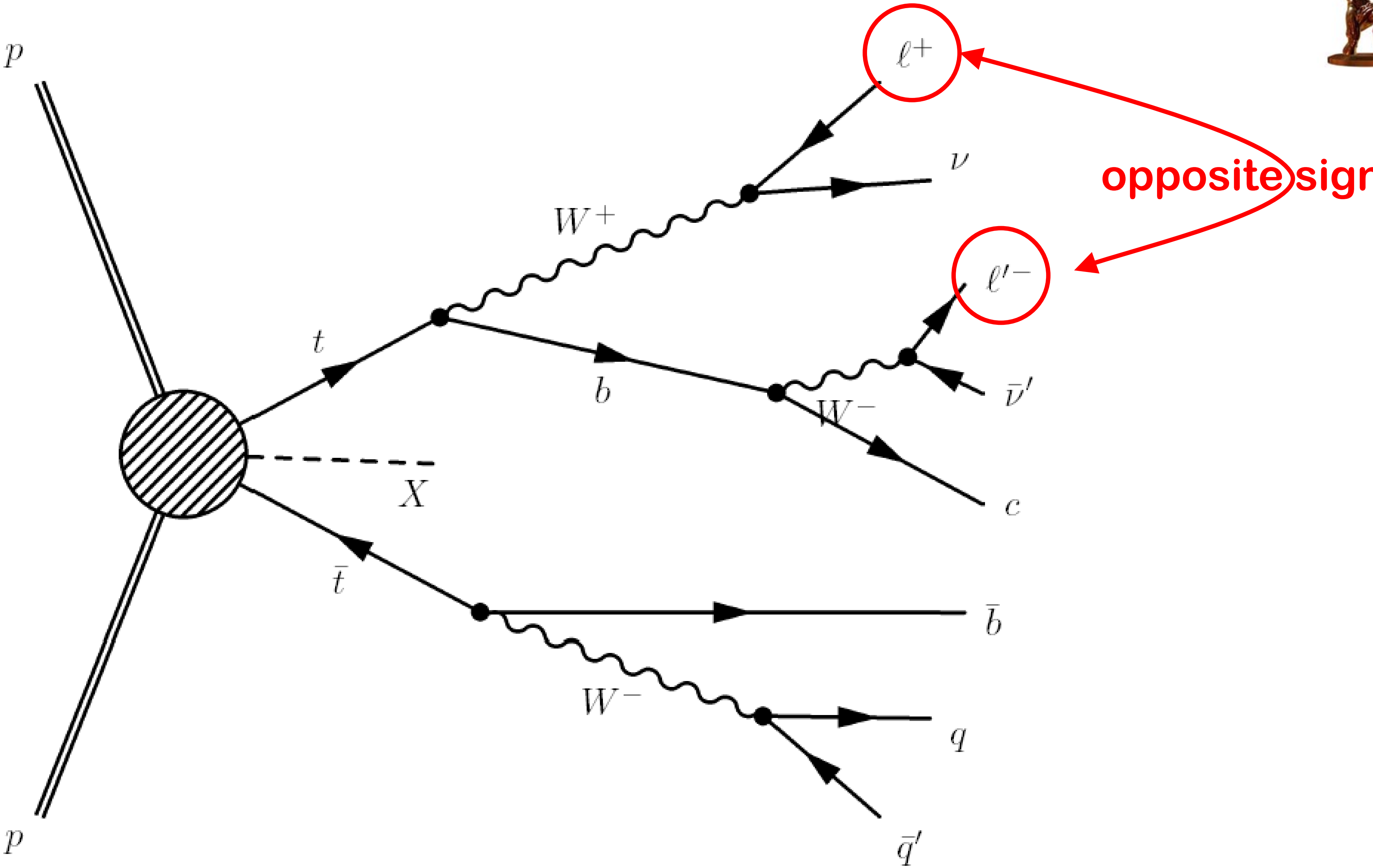
- Calo isolation potentially easier to understand
- Use the discrimination variable first understood!

Oxford Physics

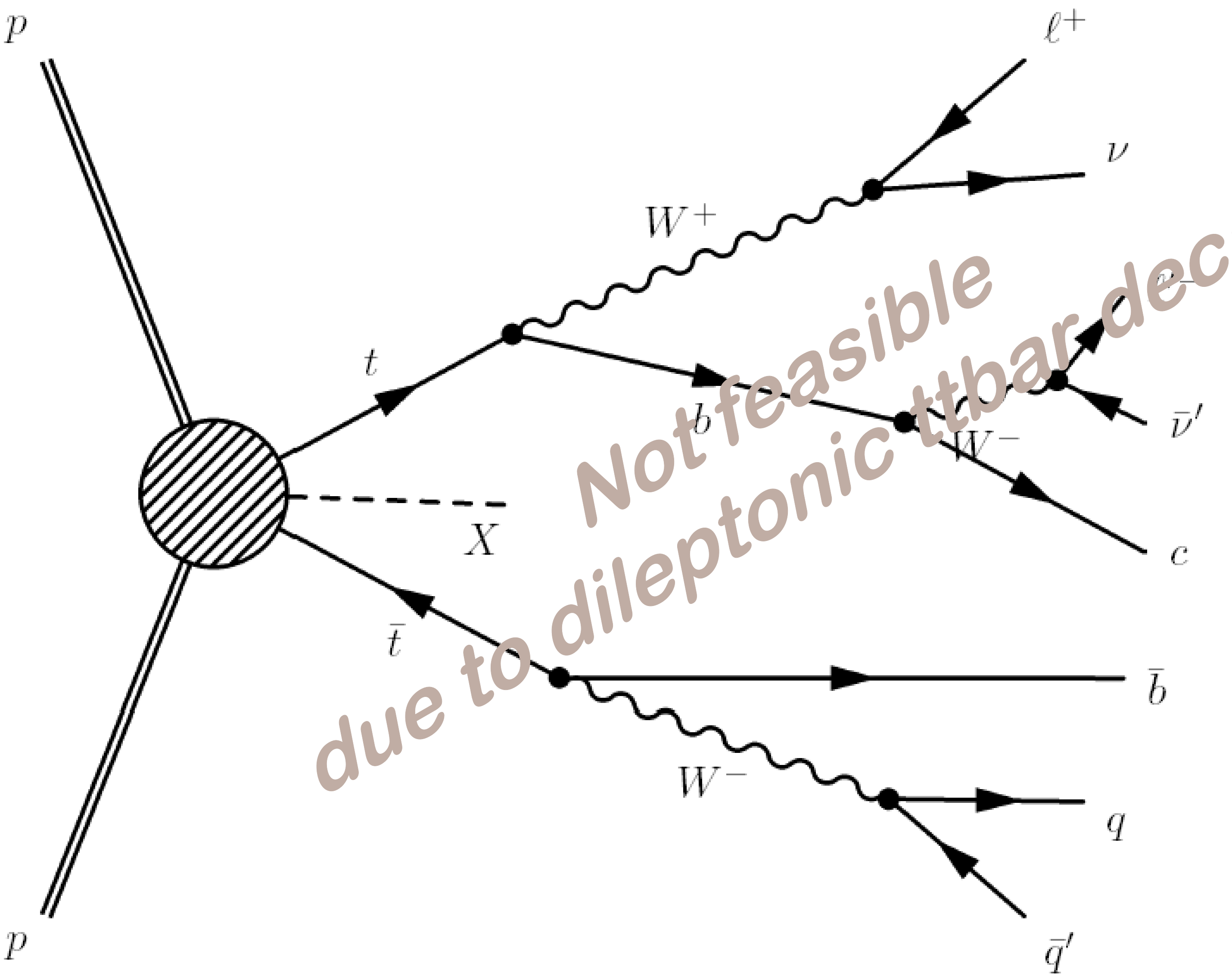
Study fake isolated leptons from b-jets in ttbar events

- 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 QCD backgrounds, e.g. W+j
    - not realistic
- $t\bar{t}$:
  - Several handles to tag ttbar events without using one of the b-jets
  - Use semileptonic $t\bar{t}$ channel
    - Orthogonal sample
    - approx. 10x more statistics

Study fake isolated leptons from b-jets in ttbar events: Ansatz

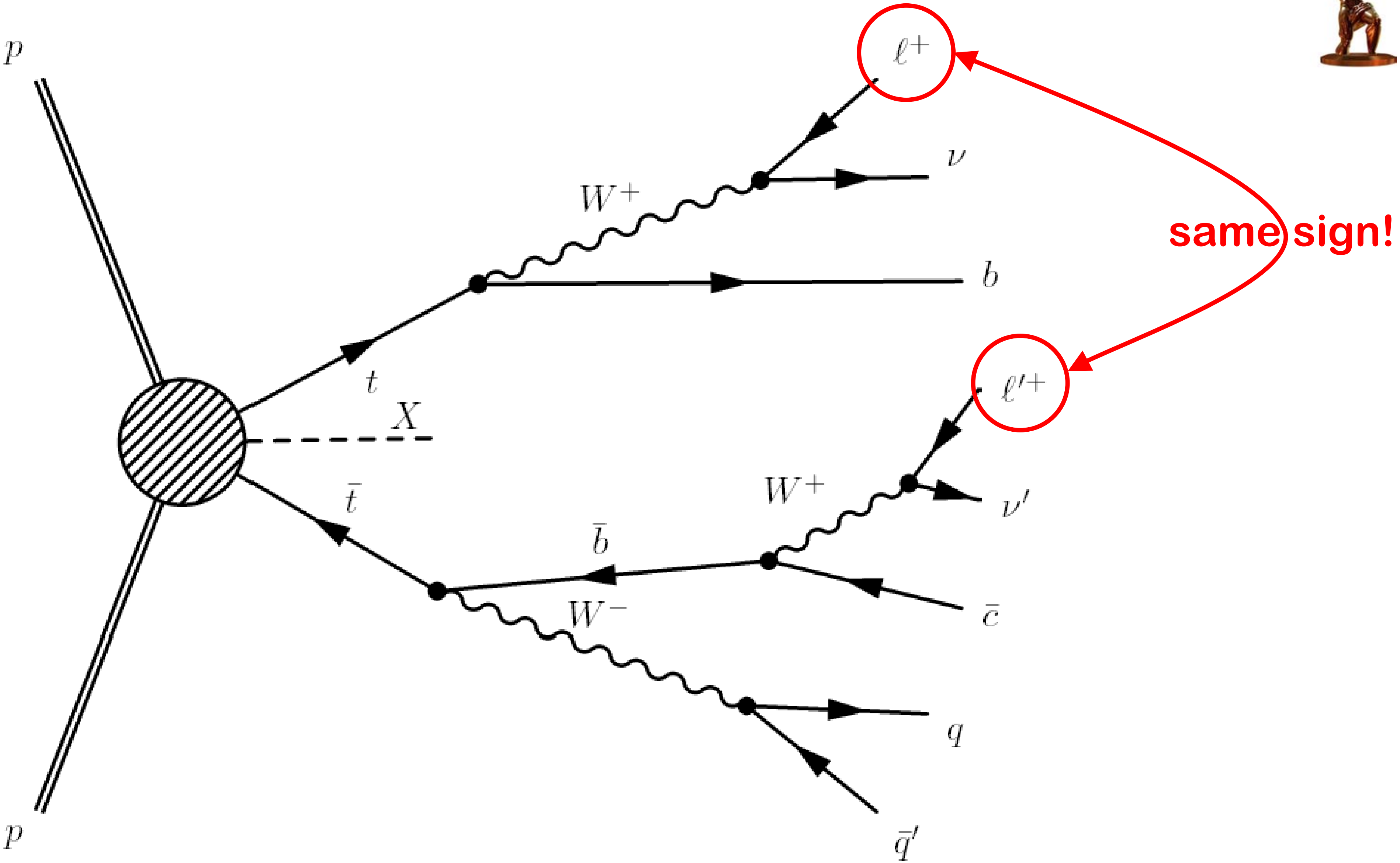


Study fake isolated leptons from b-jets in ttbar events: Ansatz

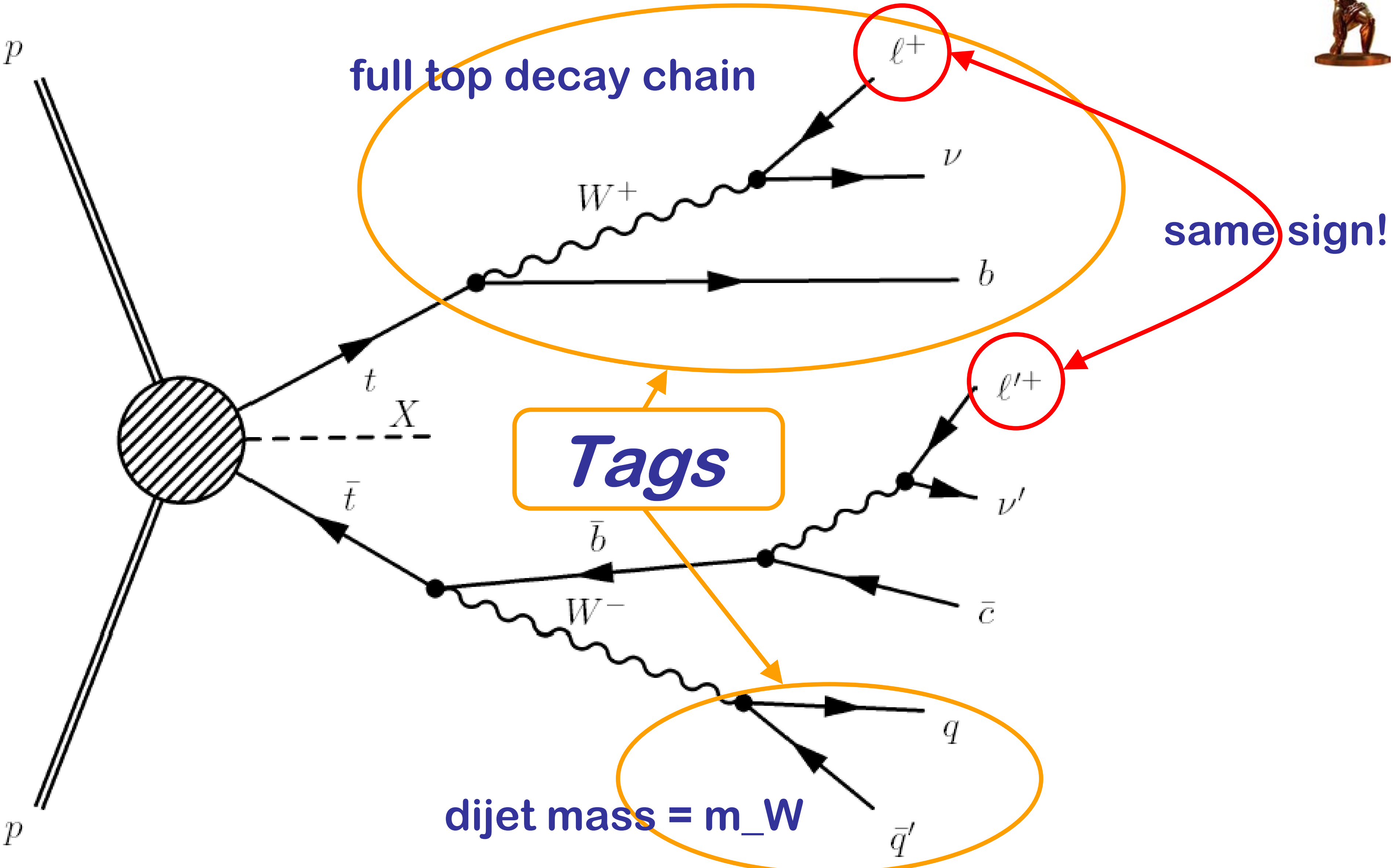


Not feasible due to dileptonic ttbar decays!

Study fake isolated leptons from b-jets in ttbar events: Ansatz



Study fake isolated leptons from b-jets in ttbar events: Ansatz



Study fake isolated leptons from b-jets in ttbar events

- Possible backgrounds (probably in order of importance):
  - 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 ($t+b\bar{b}$ ...):
      - contribution to the „signal“
  - Z + QCD
    - lepton charge mismeasurement + additional jets to mimic $t\bar{t}$
  - $b\bar{b}$ + jets
    - semileptonic b-decays with oscillaton / consecutive c-decays
  - W + QCD
    - 1 true lepton and one from QCD + additional jets
  - WZ, ZZ
    - leptons from W / Z + additional jets
  - ... Ideas?

Conclusion

Studied lepton isolation:

- Calorimeter isolation
  - Probably easier to understand
- Track isolation
  - More powerful
- Correlation

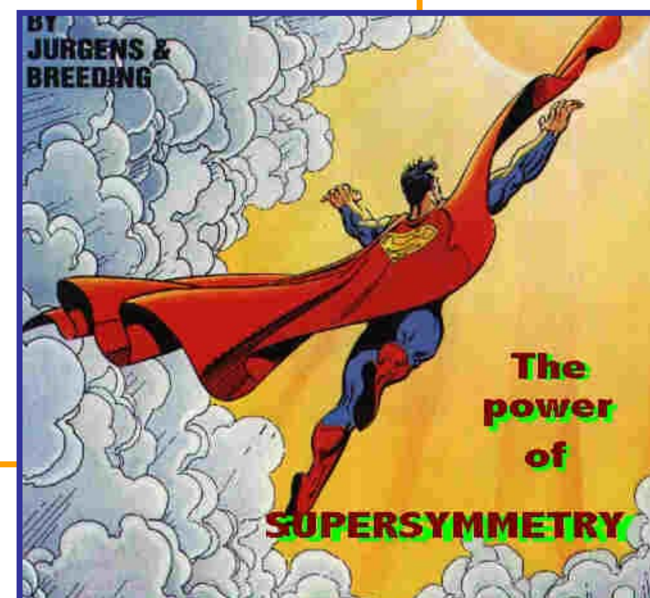
- Resulting table of statistical significancies for SUx:

	SU1	SU2	SU3	SU4	SU8	SU2 jet veto	SU3 excl. $\chi^{\pm}\chi^{0}$
$S/\sqrt{S+B}$	5.4	5.4	13.5	40.8	1.2	2.25	3.1
$\int dt\,\mathscr{L}$ for 5σ	8.6	8.5	1.4	0.2	161.5	49.4	26.1

$10\ fb^{-1}$

Outlook

- Proceed with writing up CSC 7 / CSC 5 notes!
- Study triggers for $\mathscr{L} = 10^{31}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$:
  - look at new trigger menu version in 13.0.30
  - Identify optimal handles to adjust trigger rate
- Study isolated lepton fake rate from b-jets:
  - Identify relevant backgrounds
  - First steps towards a way to measure this rate in data ...
- Do more studies:
  - background
  - systematics



Backup slides following

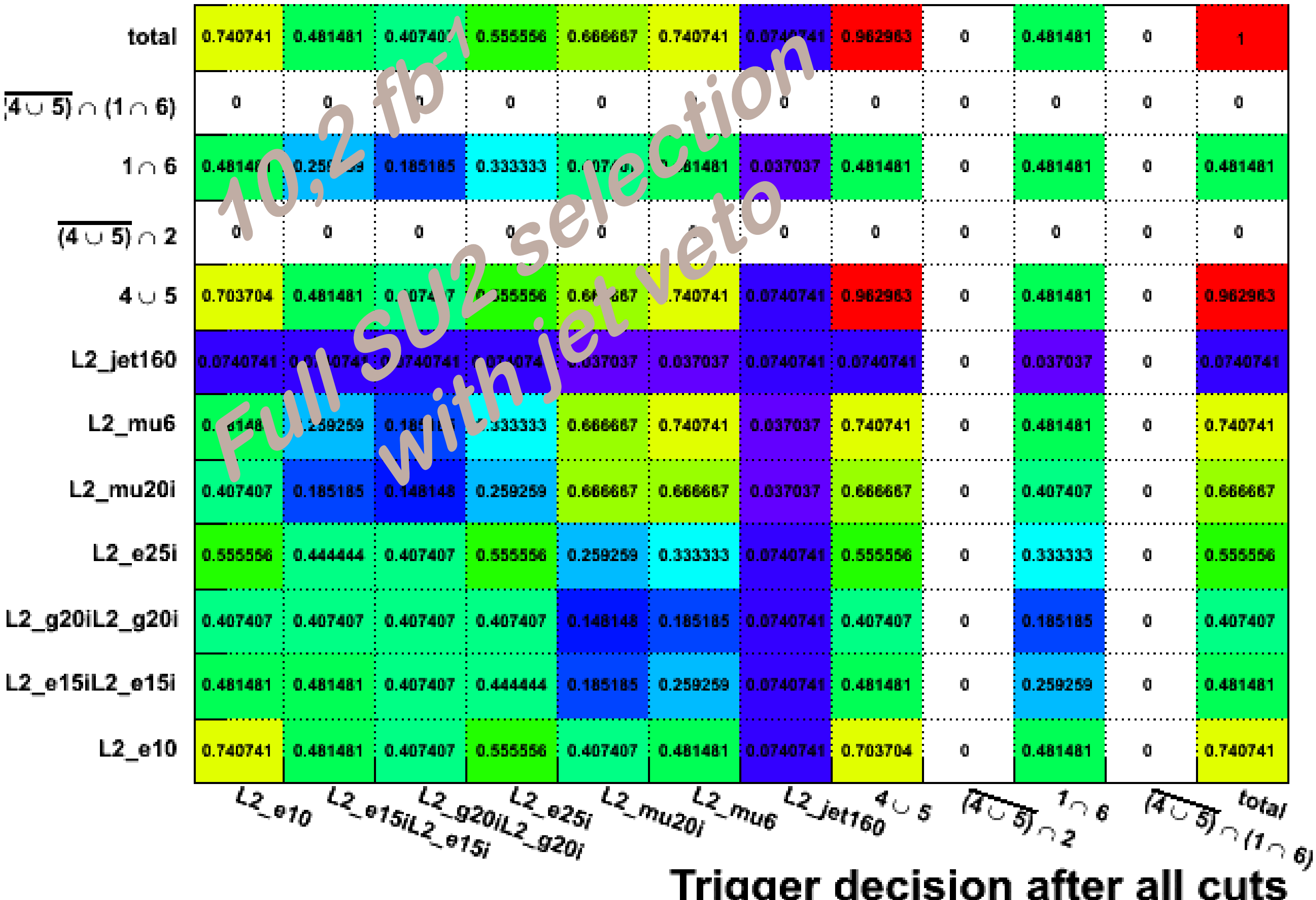
Lepton trigger study

- First running will be at

$$\mathscr{L} = 10^{31}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$$

- Focus on the „Worst Case“ scenario
  - the most critical SUSY analysis
  - cannot trigger on jets
  - triggering on MEt dodgy
  - need lepton triggers
  - rather low-Pt leptons
- Lepton triggers for start-up:
  - efficient
  - unprescaled
  - failsafe:
    - no „risky“ cuts
    - rate adjustment
  - simple to understand

Lepton triggers analysed:



Lepton triggers: Summary

	SU2 „$\chi^{\pm}\chi^{0}$“			SU2 inclusive			SU2 inclusive		
Selection stage	jet veto			no jet trig.			all		
	L2_e25i	L2_mu20i	$\cup$	L2_e25i	L2_mu20i	$\cup$	L2_e25i	L2_mu20i	$\cup$
$\geq 2\ell$	46%	53%	87%	48%	53%	88%	55%	55%	89%
OSSF+$3^{\mathrm{rd}}\ell$	42%	49%	86%	43%	50%	87%	50%	49%	88%
after all cuts	71%	54%	96%	69%	58%	92%	70%	65%	95%
	jet veto			NO jet trigger fired			all of SU2		

to be updated with updated selection

SUSY SU2 in Trilepton Channel

- MSSM: 105 paramers
- SUSY spontaneously broken -> SUGRA
- Mass unification at GUT scale -> mSUGRA
- ATLAS mSUGRA benchmark points:

Process	M_0 [GeV]	$M_{1/2}$[GeV]	A_0 [GeV]	$\tan\beta$	$\arg\mu$	σ [pb]	region
SU2	3550	300	0	10	+	4.86	Focus
SU3	100	300	-300	6	+	18.59	Bulk
SU4	200	160	-400	10	+	262	Low Mass

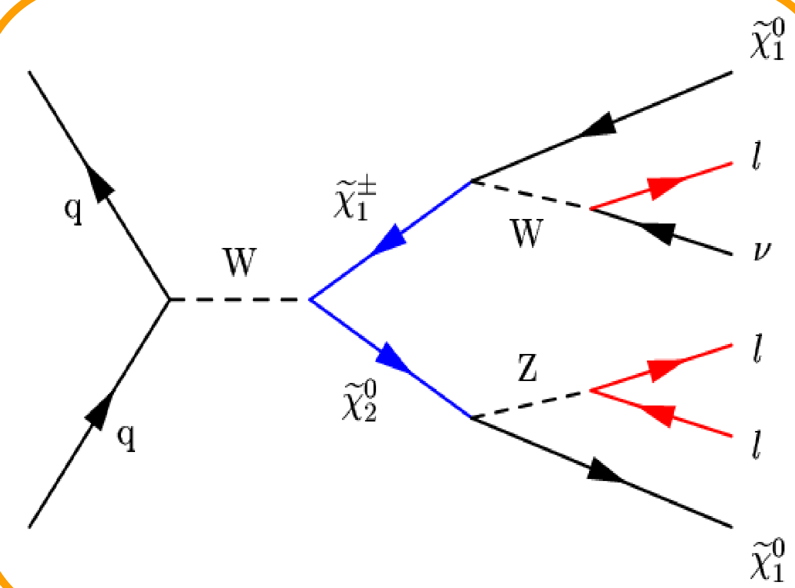
- SU2: very hard to detect
- SU3: „generic“
- SU4: light SUSY
- „flat“ search performance in multilepton final states

SUSY SU2 in Trilepton Channel

- SU2 (Focus point region):
  - Very few sfermions produced
  - charginos / neutralinos „light“
  - Look for signal in the „gold-plated“ trilepton channel
- 2/3 signal from decay chains starting with gluinos
  - 6/7 due to higher Pt scale
- „Worst case“ scenario:
  - gluino mass exempt from unification at GUT scale
  - m_gluino ~ m_squark, *not* ~850 GeV

➔ ONLY EW associated $\chi^{\pm}\chi^{0}$ production

➔ ONLY multileptonic signal for discovery



Technical aspects of the analysis

- **Signal and background MC used:**
  - **csc11 and mc12 full simulation**
  - **detector geometry ATLAS-CSC-01-02-00**
  - **AOD's in Athena 12.0.6**

Process	$\sigma \times \varepsilon_{\mathrm{gen}}$ [pb]	MC events	$\int \mathrm{dt}\, \mathscr{L}$ [fb^{-1}]
SU2	4.86	49,700	10.2
SU3	19.3	347,250	18.7
SU4	262	99,050	0.378
WW	24.5	50,000	2.04
WZ	7.8	49,900	6.4
ZZ	2.1	55,050	26.2
$Z\gamma$	2.58	10,000	3.9
Zb	102	18,900	0.186
$t\bar{t}$	461	542,250	1.18

Comparison: selection of the OSSF pair

- All CSC 7 analyses require Opposite Sign Same Flavour (OSSF) lepton pair
- Different treatment when eee or μμμ present:
  1) take pair with $\mathrm{minimal}\ \Delta R(\ell\ell)$
  2) take pair with $\mathrm{maximal}\ p_T^{\ell_1}, p_T^{\ell_2}$
  3) take pair with $\mathrm{minimal}\ |M_{\ell\ell} - m_Z|$
- All CSC7: Take 3rd lepton with highest Pt

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  3) take pair with minimal $|M_{\ell\ell} - m_Z|$
- All CSC7: Take 3rd lepton with highest Pt

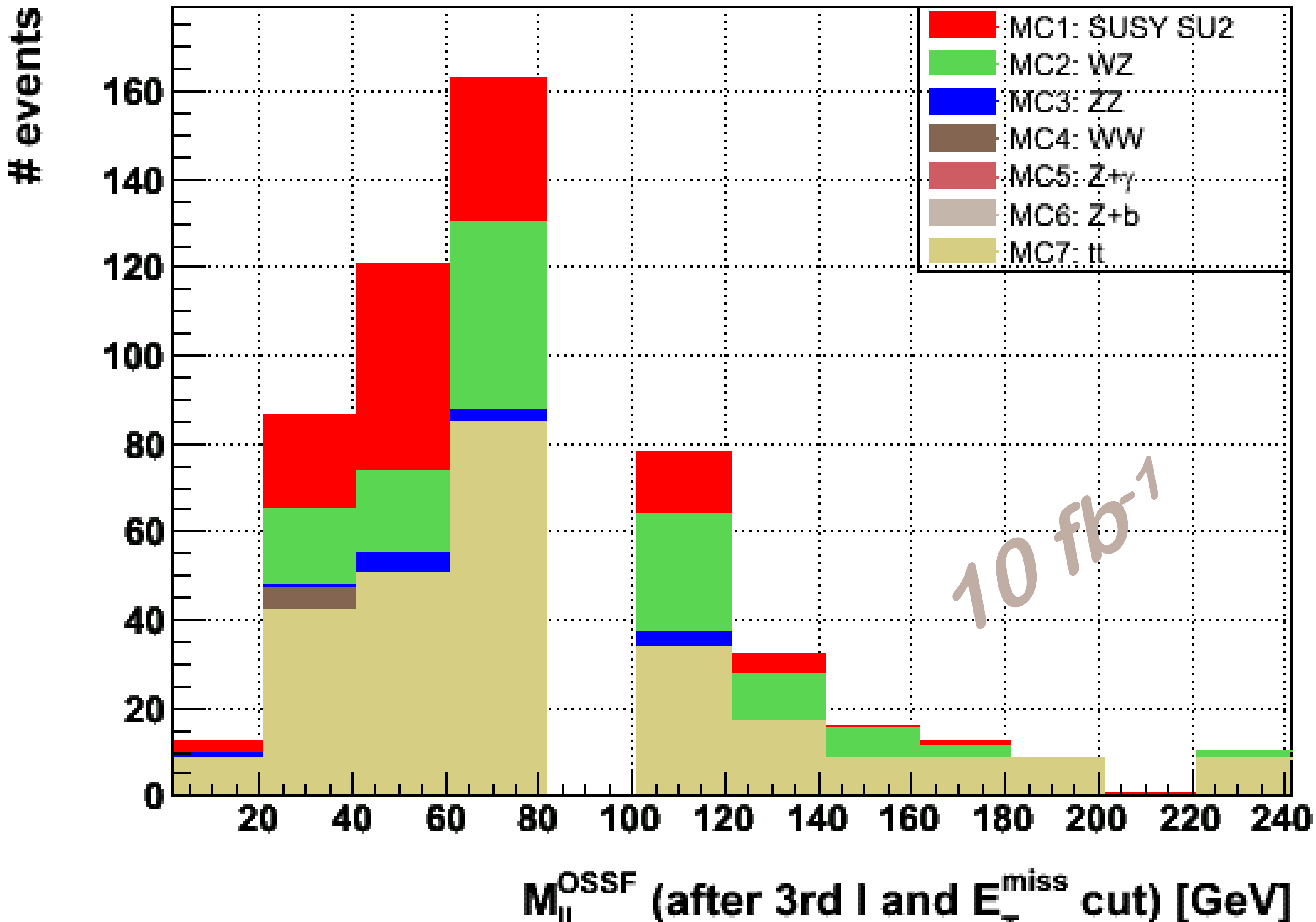
Process	SU2	SU3	SU4	WZ	ZZ	WW	$Z\gamma$	Zb	$t\bar{t}$
1) $\not{E}_T$ & $m_{\ell\ell}$, 3 bin	111.1	385.7	2063.2	189.1	22.9	4.9	0	0	212.3
2) $\not{E}_T$ & $m_{\ell\ell}$, 3 bin	92.7	342.3	1983.8	96.9	11.1	4.9	0	0	178.3
3) $\not{E}_T$ & $m_{\ell\ell}$, 3 bin	100.9	334.2	1930.9	78.2	8	4.9	0	0	178.3

after full selection, $m_{\ell\ell} \in [21.2,\ 81.2]$ GeV

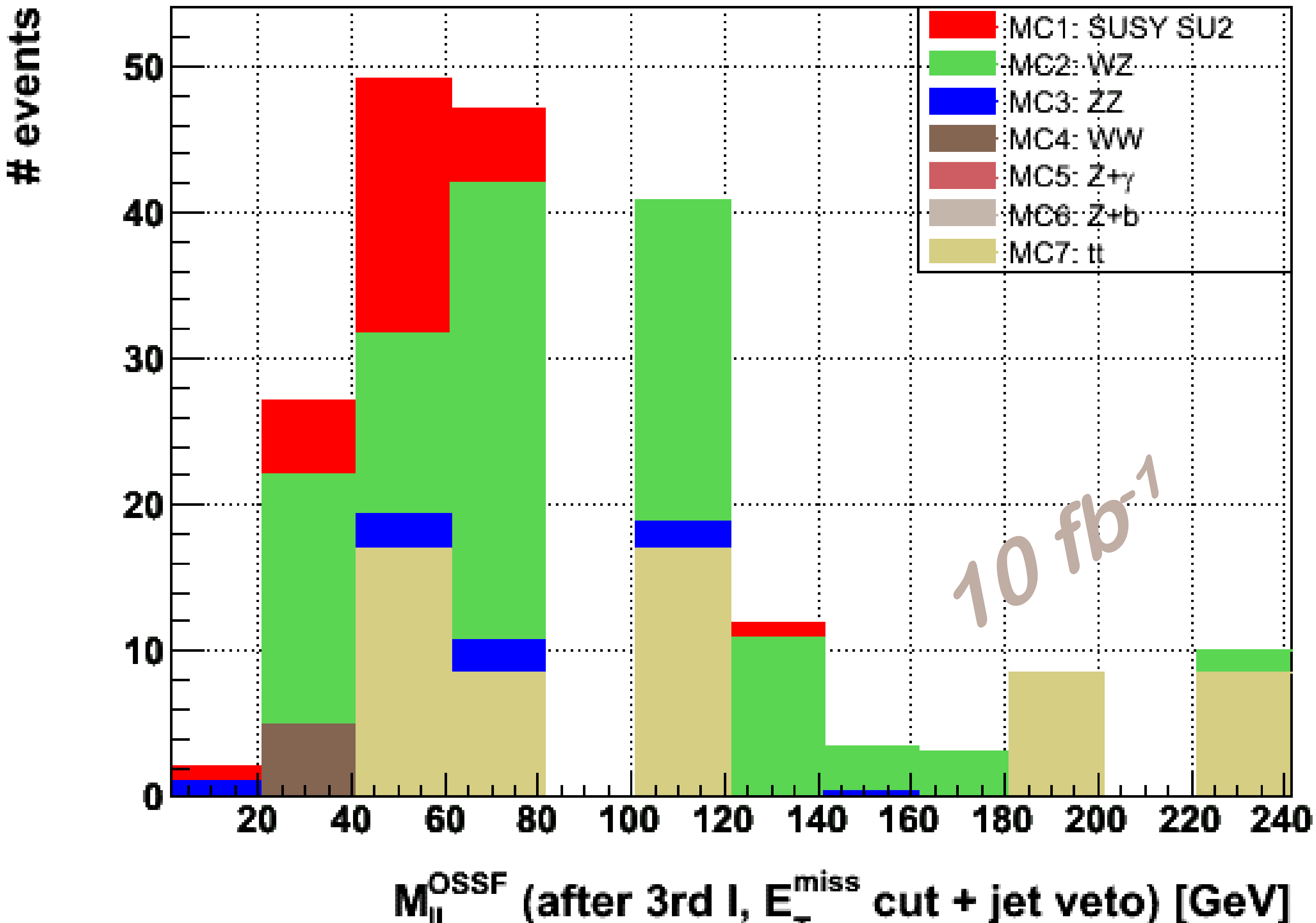
10 fb-1

- full tables: http://www-pnp.physics.ox.ac.uk/~obrandt/TrileptonAnalysis/DifferentOSSF.pdf
- The preferred way to go: 3)

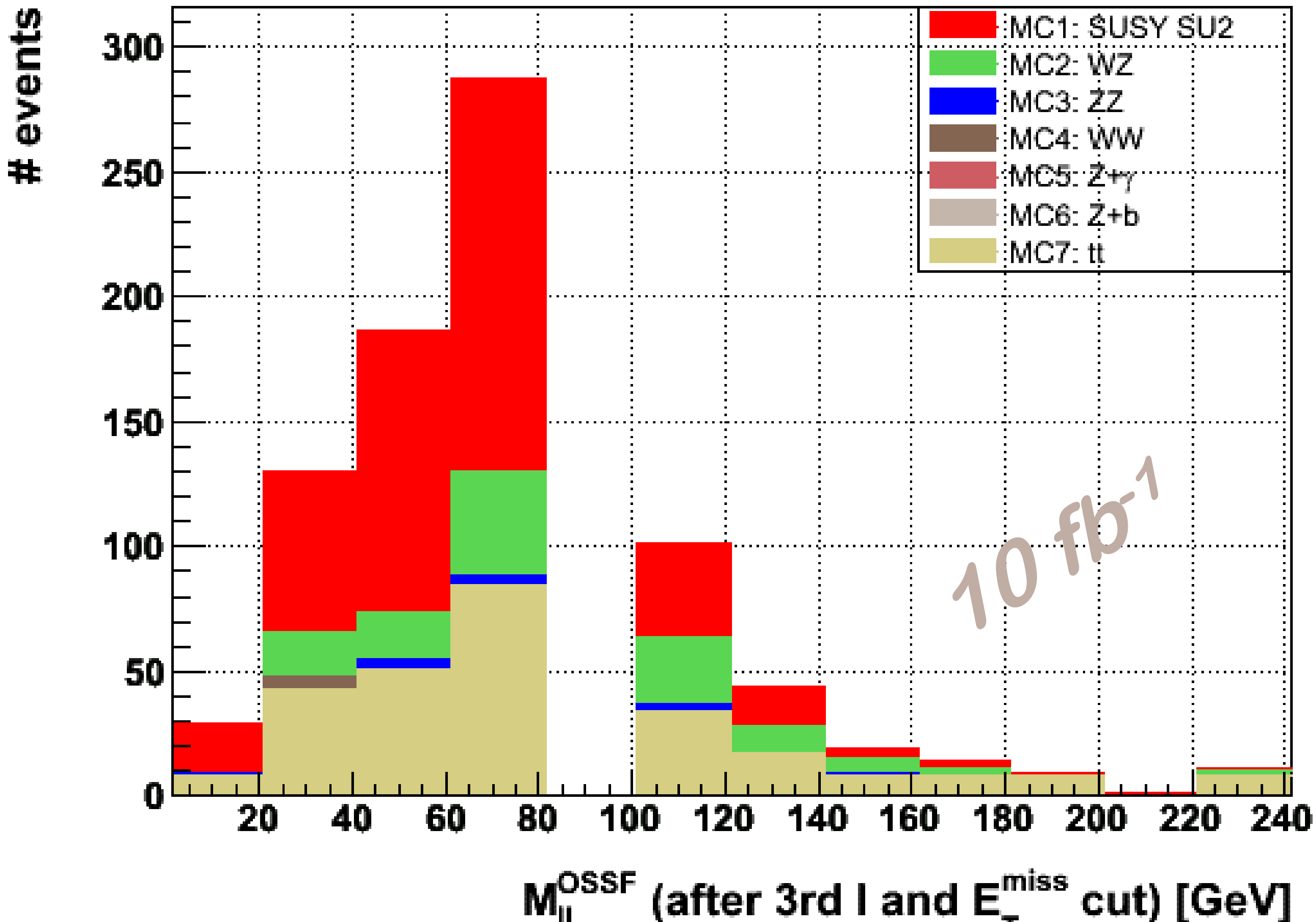
Cut on MEt and dilepton mass



„Worst Case“ scenario

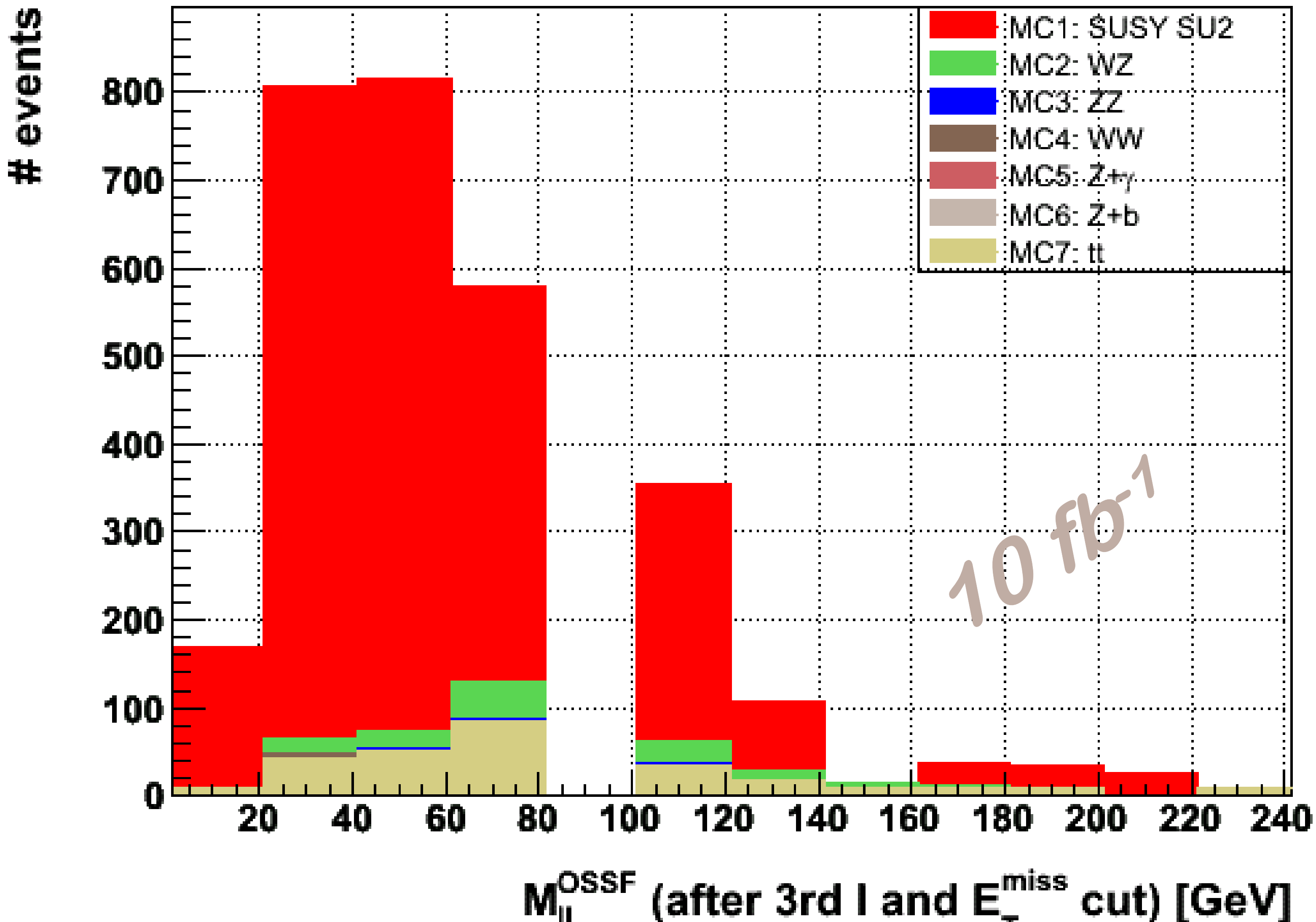


Same for SU3



events
MC1: SUSY SU2
MC2: WZ
MC3: ZZ
MC4: WW
MC5: Z+γ
MC6: Z+b
MC7: tt
10 fb-1
0
50
100
150
200
250
300
20
40
60
80
100
120
140
160
180
200
220
240
M_ll^OSSF (after 3rd l and E_T^miss cut) [GeV]

Same for SU4



events
800
700
600
500
400
300
200
100
0
20
40
60
80
100
120
140
160
180
200
220
240
MC1: SUSY SU2
MC2: WZ
MC3: ZZ
MC4: WW
MC5: Z+γ
MC6: Z+b
MC7: tt
10 fb-1
M_ll^OSSF (after 3rd l and E_T^miss cut) [GeV]

Cut Flow Table

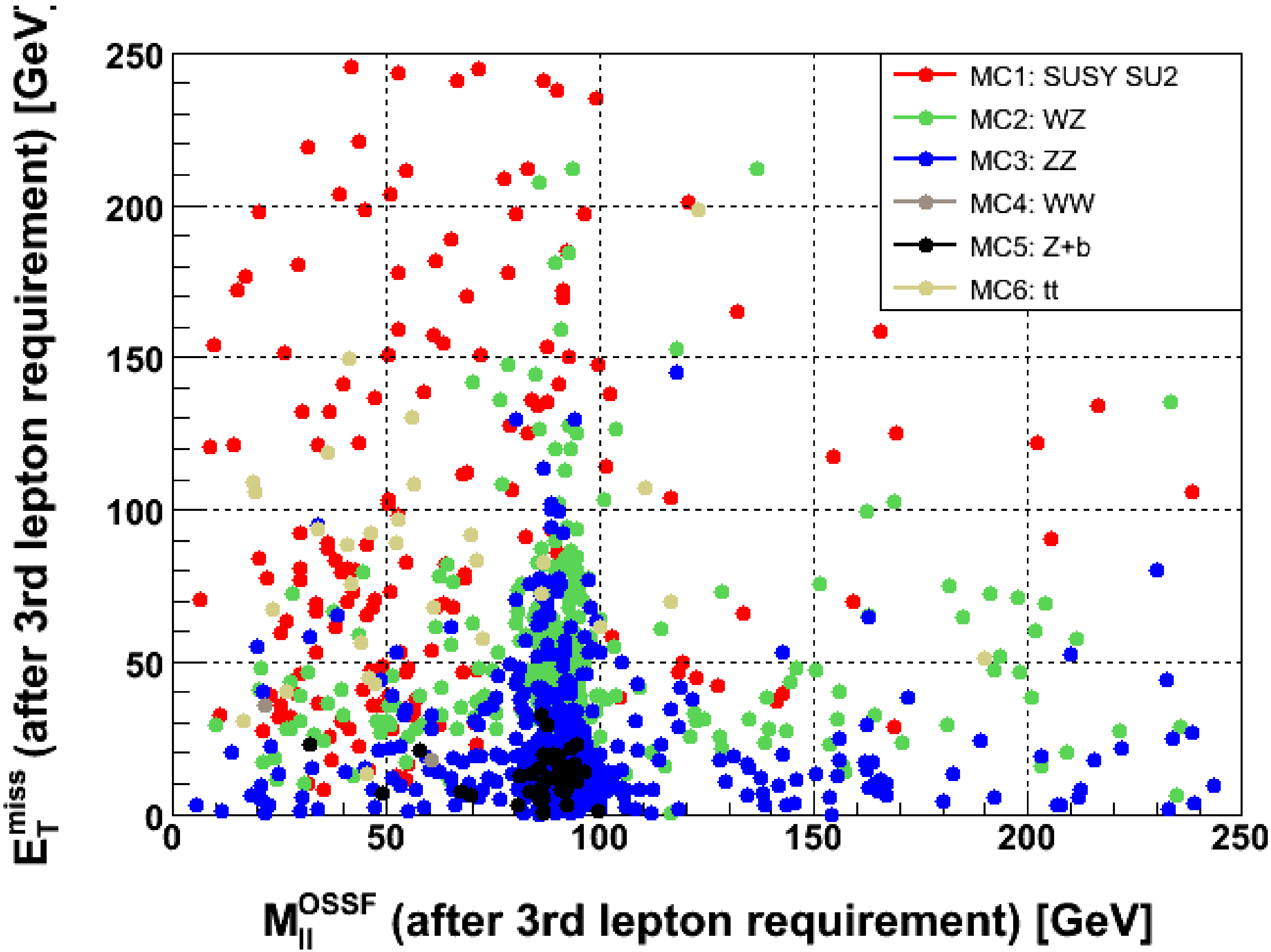
Process	SU2	SU3	SU4	WZ	ZZ	WW	$Z\gamma$	Zb	$t\bar{t}$
OSSF pair	992.4	6337.1	45707.8	6735.5	5106	5845.7	5276.1	323511	100701
OSSF+3$^{rd}\ell$	206.8	904.7	5713.5	869.1	317.4	19.6	61.9	3598.1	3023.2
Track isol.	160	641.2	3174.2	765.9	252.2	4.9	18.1	1503.7	348.2
$\not{E}_T$ & $m_{\ell\ell}$	125.3	416.2	2539.3	126.6	13	4.9	0	0	271.8
$\not{E}_T$ & $m_{\ell\ell}$, 3 bin	100.9	334.2	1930.9	78.2	8	4.9	0	0	178.3
Jet veto	29.5	22.5	0	101.6	8	4.9	0	0	59.4
Jet vetol, 3 bin	27.5	20.4	0	61	4.6	4.9	0	0	25.5

"3 bin":
only events with $m_{\ell\ell} \in [21.2, 81.2]$ GeV

Selection outlined

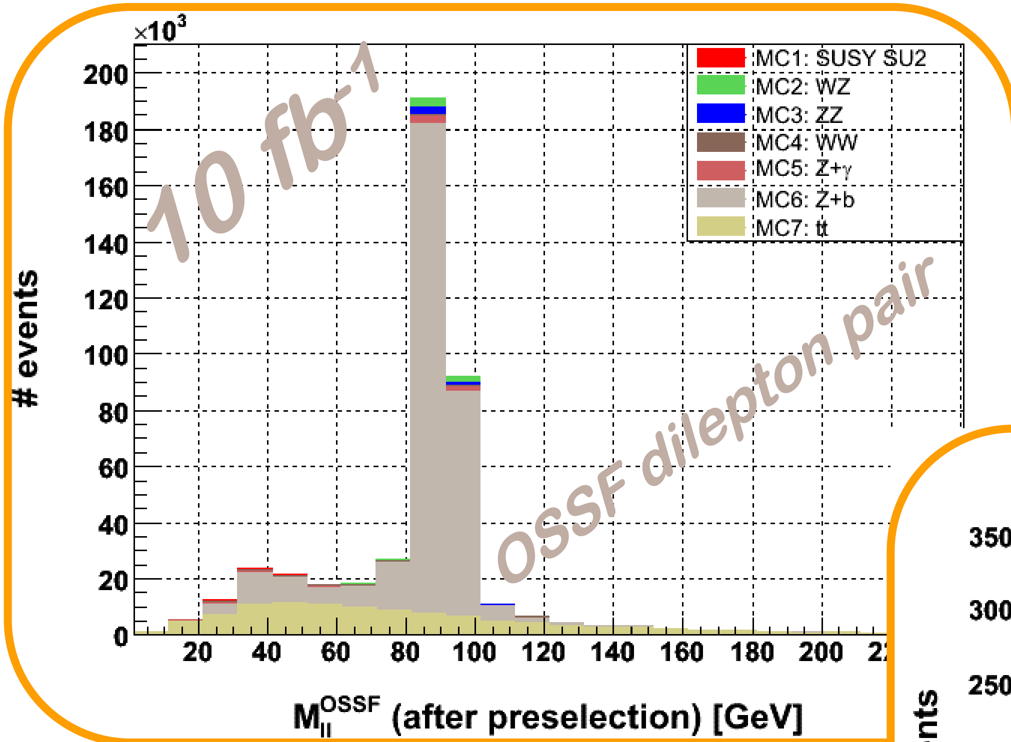
- „Worst case“ scenario:
  - eliminate decay chains starting with gluino pairs
    - 2/3 of signal Xsec, enhanced to 6/7 due to higher Pt scale
  - Jet veto:
    - No jet with Et > 30 GeV in eta < 2.4
    - No jet with b-jet LH > 0.3
- Jet overlap removal crucial:
  - take only jets with eta < 2.4
  - Consider overlap with Electrons / Photons defined as:
    - (isEM() & 0xFB) == 0 OR (isEM() & 0xF7) == 0
      - this means no track based cuts
      - no identification on 1st / 2nd LAr sampling)
  - Overlap distance: $\Delta R = 0.2$

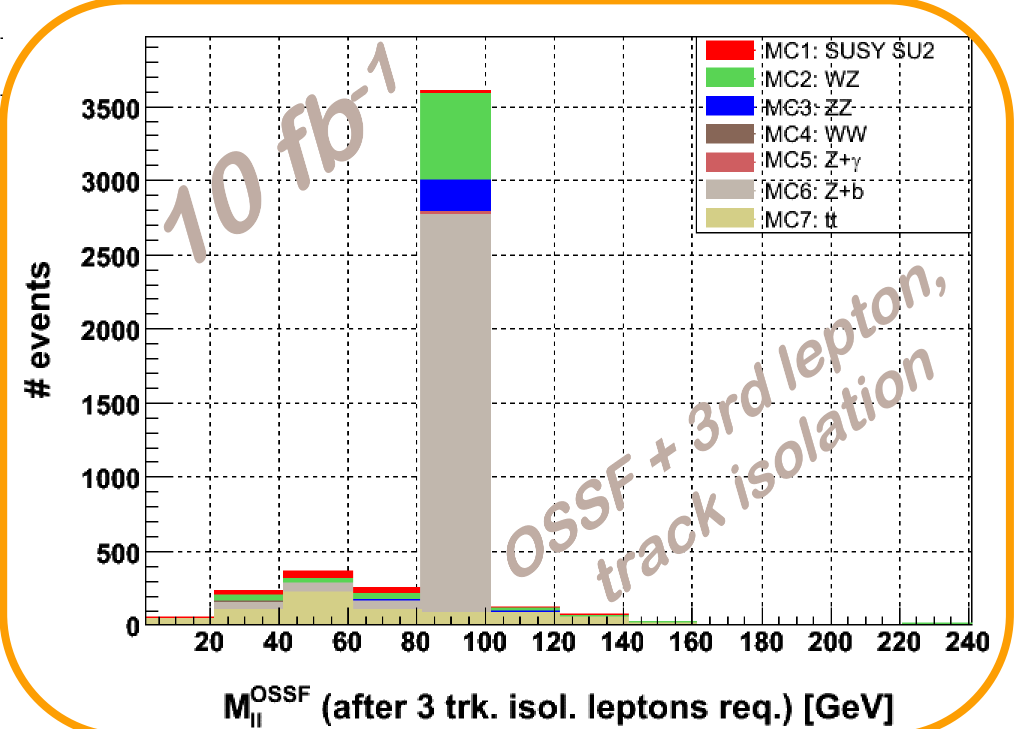
Dilepton mass vs. missing Et



No normalisation here

3rd lepton requirement + track-isolation (SU2)





Backup & further discussion