SUSY

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On behalf of the Italian SUSY Groups

V ATLAS-Italia Physics Workshop

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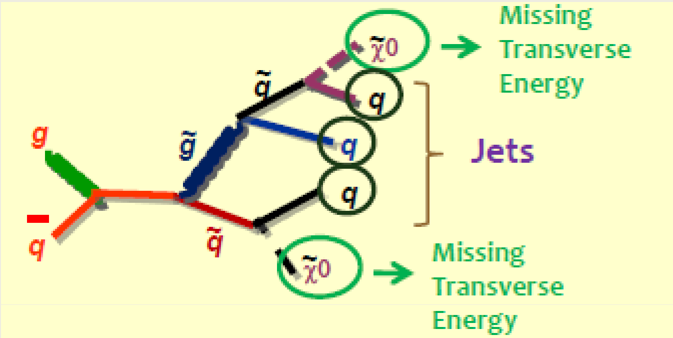
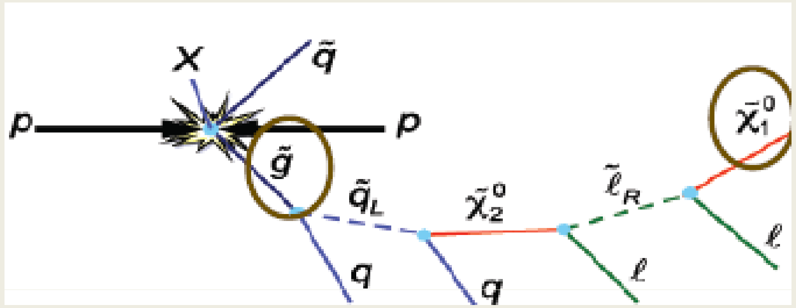
Outline

- Introduction
- Italian SUSY Group
- The 2010 SUSY Analysis and the Italian contribution
- The 2011 activity
- Conclusions

SUSY Basic Analyses Strategy

Complex (and model-dependent) squark/gluino cascades





Tipical SUSY signatures in R-parity conserving model, identified by:

- -large Missing ET
- -High transverse momentum jets
- -Leptons
  - •Perform separate analyses with and without lepton veto (0-lepton / 1-lepton / 2-leptons)
- -B-jets: to enhance sensitivity to third generation squarks

Specific model assumed only for interpretation of the results and to assess experimental reach

Introduction

ATLAS 2010 analyses based on Missing Et, using common object identification and kinematic cuts

Primary vertex
- At least 1 good vertex with Ntracks>4

Cosmic Veto
- Impact Parameter z0<10

Jets
- anti-kT, R=0.4
- pT> 20 GeV, |η|<2.5

Electrons
- pT> 20 GeV, |η|<2.47
- reject events if el. candidates are in transition region (1.37<|η|<1.52)

Muons
- pT> 20 GeV, |η|<2.4
- combined/extrapolated info from ID and MS
- Sum pTof tracks <1.8 GeV in DR<0.2

Remove overlapping objects
- If DR(jet,e)<0.2, remove jet
- If 0.2<DR(jet,e)<0.4, veto electron
- If DR(jet,m)<0.4, veto muon

Missing ET
- Calculated from objects and clusters

Short review of 0 and 1 Lepton Anlyses results

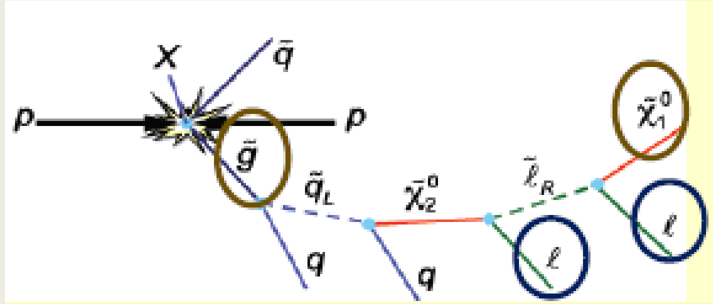
- Search for squarks and gluinos using final states with jets and missing transverse momentum with the ATLAS detector in √s = 7 TeV proton-proton collisions
  - http://arxiv.org/abs/1102.5290, Submitted to Phys. Lett. B.
  - In mSUGRA model if $m_{squark}= m_{gluino}$ esclude < 775 GeV
- Search for supersymmetry using final states with one lepton, jets, and missing transverse momentum with the ATLAS detector in √s =7 TeV pp collisions.
  - http://arxiv.org/abs/1102.2357, Phys. Rev. Lett.106,1318002 (2011)
  - In mSUGRA model if $m_{squark}= m_{gluino}$ esclude < 700 GeV

Combined limit from 0 and 1-lepton results:

if $m_{squark}= m_{gluino}$ esclude < 815 GeV **Presently the most stringent one**

2-Lepton analysis (The main SUSY italian activity)

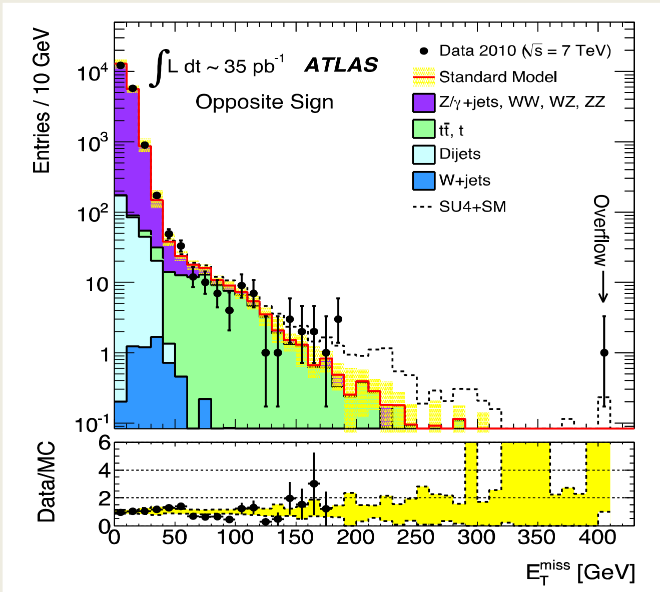
- Search for dilepton(e,μ) pairs from neutralino/chargino decays
- Two search strategies, requiring opposite-sign (OS) and same-sign (SS) dilepton sevents

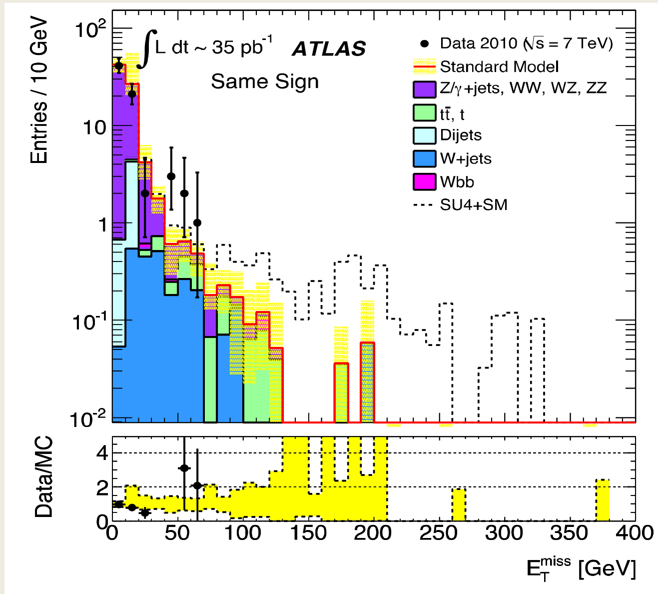


Event selection
- exactly two isolated leptons
- M(ll) > 5 GeV

Signal regions
- OS: ETMiss> 150 GeV
- SS: ETMiss> 100 GeV

Main Backgrounds
- OS: **top pair, Z+jets**
- SS: misidentified (fakes) muons





2-lepton analysis (another possible strategy)

Search for **excess of identical flavour opposite-sign lepton pairs:**

-Sensitive to SUSY particle cascade →no excess expected in SM (aside for Z/γ^* sources)

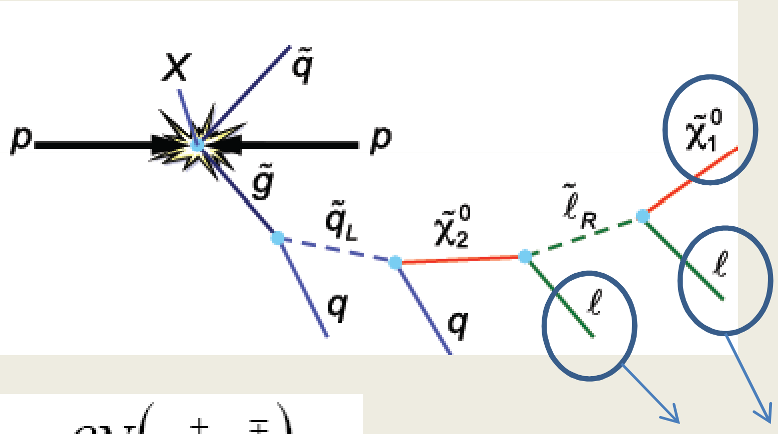
-Subtraction allow "cancellation" of systematic uncertainties:

❖ If no excess, set very robust limits

❖ If discovery, help measuring SUSY particle masses

Same cutflow used for 2 lepton analysis + MET

From N(ee), N(eμ) and N(μμ), quantify same flavour excess: S= **N×Eff×Acc**



Same flavor for lepton flavor conservation

$$S = \frac{N(e^{\pm}e^{\mp})}{\beta(1-(1-\tau_e)^2)} - \frac{N(e^{\pm}\mu^{\mp})}{1-(1-\tau_e)(1-\tau_\mu)} + \frac{\beta N(\mu^{\pm}\mu^{\mp})}{(1-(1-\tau_\mu)^2)}$$

Where β is the ratio between the the electron and muon reconstruction efficiencies $\varepsilon_e/\varepsilon_\mu$ and τ are the trigger efficiencies wrt recostruction.

SUSY 2-lepton 2010 analysis results

- Good agreement between data and SM expectations within uncertainties
- Use sum of ee,μμ,eμchannel for SS, combination of the three channels for OS
- 95% C.L. upper limits on effective cross section of non-SM processes × acceptance × efficiency
  - SS: σ<0.07 pb
  - ee: 0.09 pb, μμ: 0.21 pb, eμ: 0.22 pb

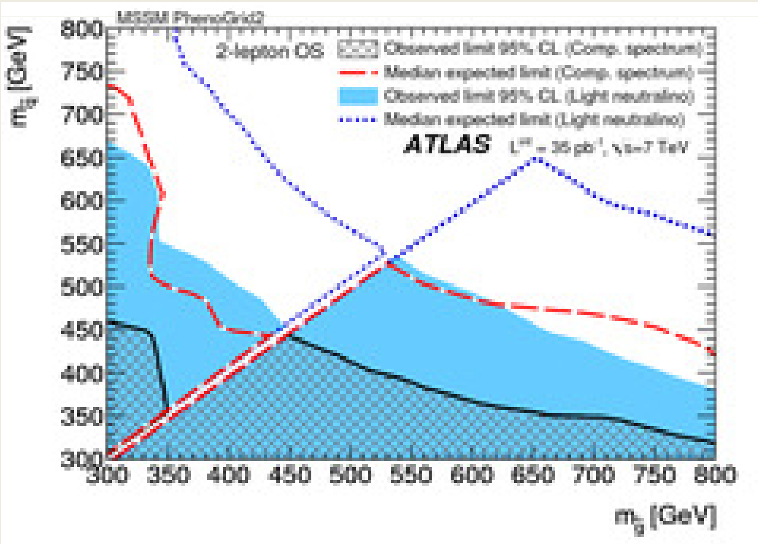
$E_T^{miss} > 100$ GeV	$e^\pm e^\pm$	$e^\pm \mu^\pm$	$\mu^\pm \mu^\pm$
Data,	4	13	13
$t\bar{t}$	$2.50^{+1.03}_{-0.96}$	$6.61^{+2.72}_{-2.52}$	$4.71^{+1.87}_{-1.80}$
Z+jets	0.37 ± 0.15	0.36 ± 0.13	0.91 ± 0.26
fakes	0.31 ± 0.24	-0.15 ± 0.46	0.01 ± 0.01
single top	0.13 ± 0.08	0.70 ± 0.21	0.67 ± 0.20
WW+WZ+ZZ	0.30 ± 0.15	0.36 ± 0.18	0.61 ± 0.30
cosmics	0	$0^{+1.32}_{-0}$	$0^{+1.32}_{-0}$
total	$3.56^{+1.24}_{-1.12}$(uncorr.)± 0.36(corr.)	$7.81^{+3.31}_{-2.69}$(uncorr.)± 0.94(corr.)	$6.82^{+2.54}_{-1.93}$(uncorr.)± 0.67(corr.)
$E_T^{miss} > 150$ GeV	$e^\pm e^\pm$	$e^\pm \mu^\pm$	$\mu^\pm \mu^\pm$
Data	1	4	4
$t\bar{t}$	$0.62^{+0.31}_{-0.28}$	$1.24^{+0.62}_{-0.56}$	$1.00^{+0.50}_{-0.45}$
Z+jets	0.19 ± 0.08	0.08 ± 0.03	0.14 ± 0.04
fakes	-0.02 ± 0.02	-0.05 ± 0.04	0
single top	0.03 ± 0.03	0.06 ± 0.05	0.10 ± 0.06
WW+WZ+ZZ	0.09 ± 0.04	0.06 ± 0.03	0.15 ± 0.08
cosmics	0	$0^{+1.32}_{-0}$	$0^{+1.32}_{-0}$
total	$0.91^{+0.36}_{-0.34}$(uncorr.)± 0.14(corr.)	$1.37^{+1.46}_{-0.57}$(uncorr.)± 0.28(corr.)	$1.39^{+1.42}_{-0.50}$(uncorr.)± 0.22(corr.)

SUSY 2-lepton 2010 analysis results

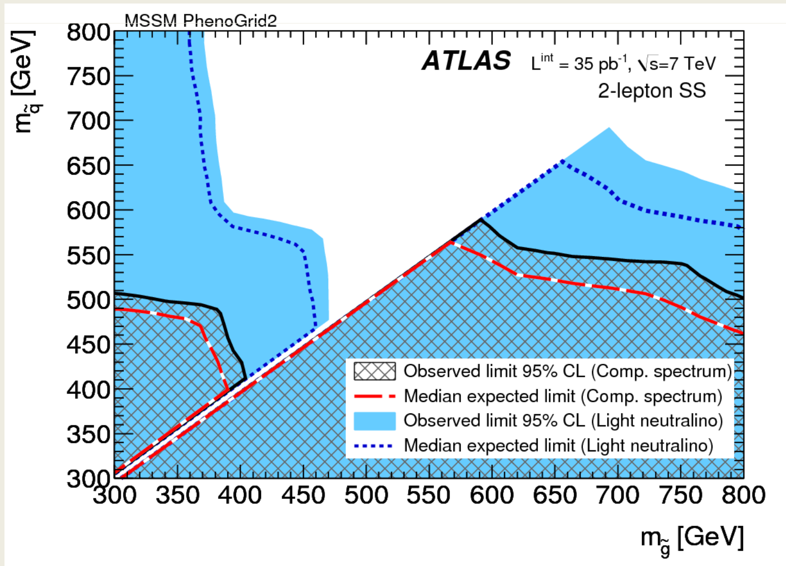
Consider more general MSSM 24-parameter framework:

- mA=1000 GeV, m=1.5×min(mgl,mq) , tanβ=4, A_t=μ/tanβ, A_b=A_l = μtanβ
- Common squark,sleptonmass for $1^{st,}$ 2^{nd} generation, 3^{rd} generation at high mass

Limits shown as a function of squark and gluino masses, with the scalar lepton lighter than the second neutralino and for "Light Neutralino scenario" (hard Kinematics) and for "Compressed Spectrum Scenario" (ΔM = 50 GeV between lightest neutralino and colored particle ,Soft Kinematics) .



Limits on squarkmass for m(gl)=m(q)+10 GeV



OS: m(q)>560 GeV(LN), >450 GeV(CS)
SS: m(q)>690 GeV(LN), >590 GeV(CS)

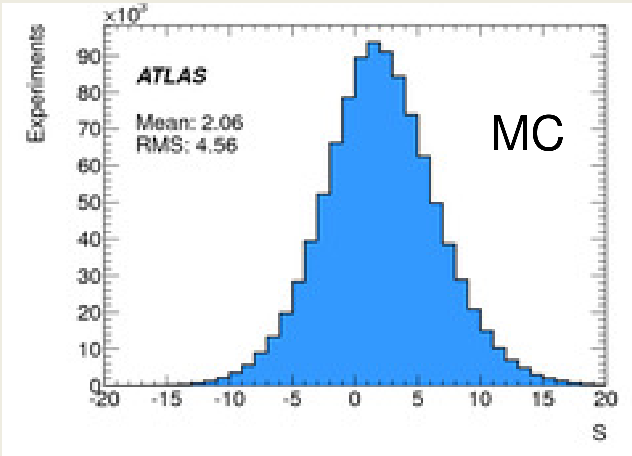
SUSY 2-lepton 2010 analysis results

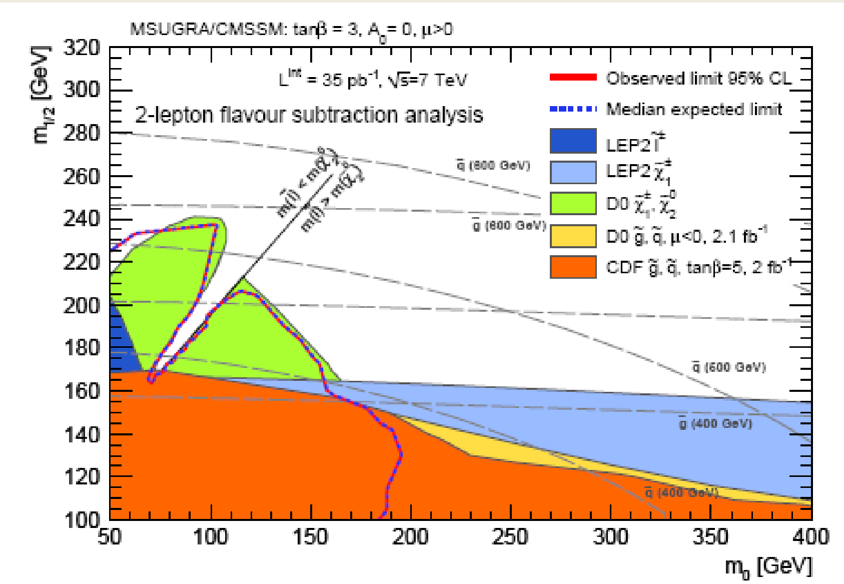
From flavour subtraction method

Analysis Results:

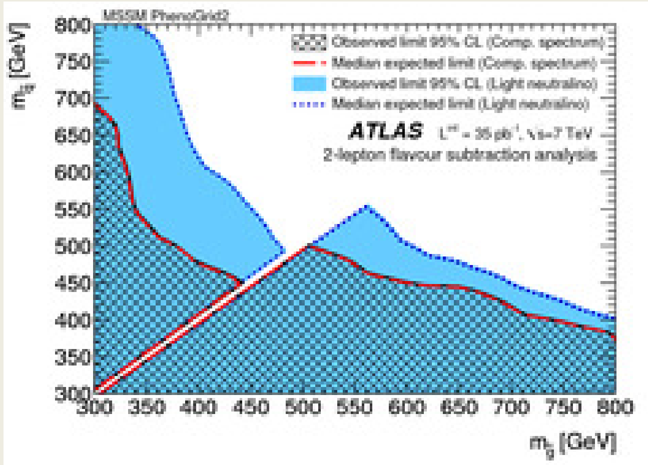
$$S_{\text{expected}} = 1.98 \pm 0.79 \pm 0.78$$

$$S_{\text{observed}} = 1.8 \pm 0.2(\beta) \pm 0.01(\tau_e) \pm 0.01(\tau_\mu)$$





Limits for m(g)=m(q)+10 GeV
m(q)>560 GeV(LN), >450 GeV(CS)



Italian SUSY Group (Who we are)

Four institutes involved in one/two leptons + MET SUSY Analyses

- Pavia (G.Polesello, G. Gaudio, S. Franchino, M. Uslenghi)
- Milano (C. Troncon, T. Lari, F. Meloni, C. Giuliani, F.C.Ungaro)
- Lecce (E. Gorini, M. Primavera, A. Ventura, M.Bianco)
- Udine **(Joined the cluster in 2011)** (B. Acharia, M. Cobal, S. Brazzale, I. Serenkova, Rachik Soulah, M. Pinamonti, U. De Sanctis, K. Shaw)

Italian Contributions to 2010 SUSY Analysis

Milan, Pavia and Lecce have had a leading role in the 2-leptons Analysis in 2010. Contribution given to:

- Muon trigger efficiency (Lecce)
- Definition of SUSY test model (Pavia)
- Estimation of the top background (Milan, Pavia)
- Signal region definition (Milan, Pavia)
- Calculation of discovery and exclusion p-values (OS), (Milan)
- Analysis egamma stream (ee +eμ) (Milan)
- Analysis muons stream (μe + μμ) (Pavia, Lecce)

All this contribution present in several paper:

- arXiv:1103.6214 submitted to EPJC (**G. Polesello editor of the paper)**
- arXiv:1103.6208 accepted EPJC

T. Lari co-convener of ATLAS SUSY (Background Forum)

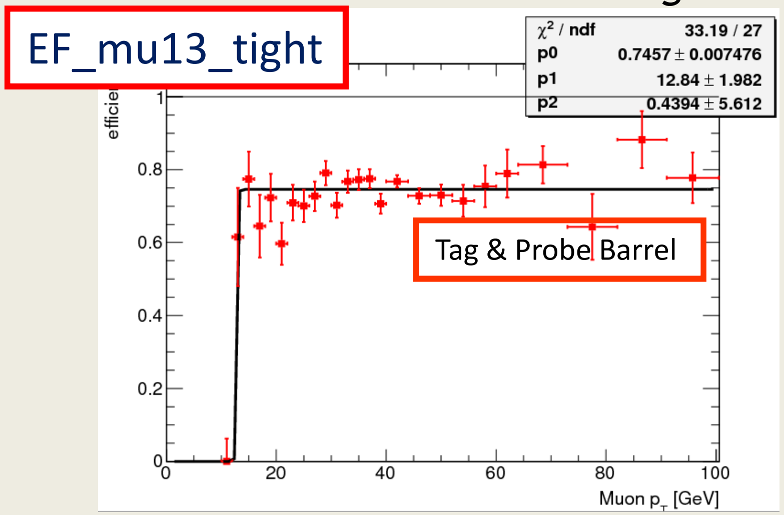
Lecce Trigger studies also included in SUSY 1-lepton analysis support note

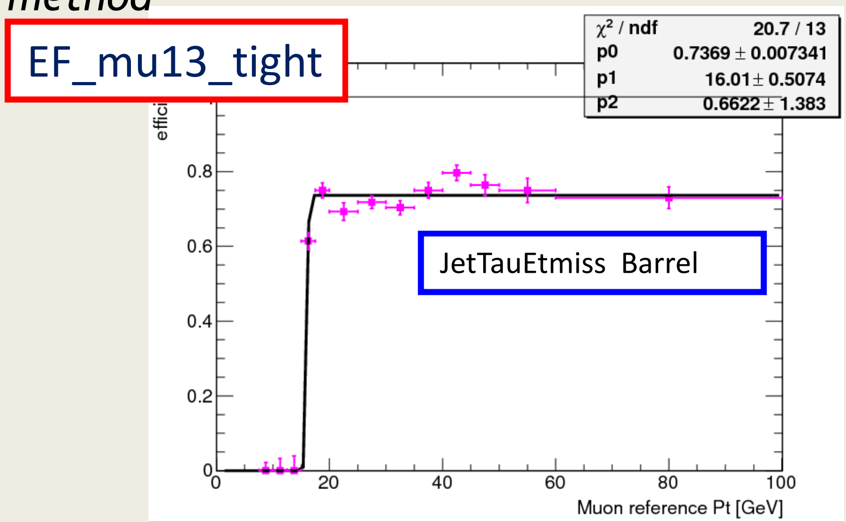
Muon trigger efficiency

- Chains analyzed:
  - mu6, mu10, mu10_MG, mu13, mu13_tight, mu13_MG_tight, mu20, mu40_MSonly
  - GRL in which all analyzed chains are unprescaled
- Streams:

  physics_Muons (used for higher statistics in Tag & Probe with Z)

  physics_JetTauEtmiss (*inclusive sample*, asking for ORed L1_J* triggers instead of EF_j*, to improve statistics)
- Methods and selection:
  - ✓ Use offline MuidCB for reference
  - ✓ Primary vertex with: 3 or more tracks, |z|<150mm
  - ✓ muon *selection (*standard cuts required for the muon trigger conf. note!*)*
  - ✓ *TAG & PROBE and Orthogonal trigger method*



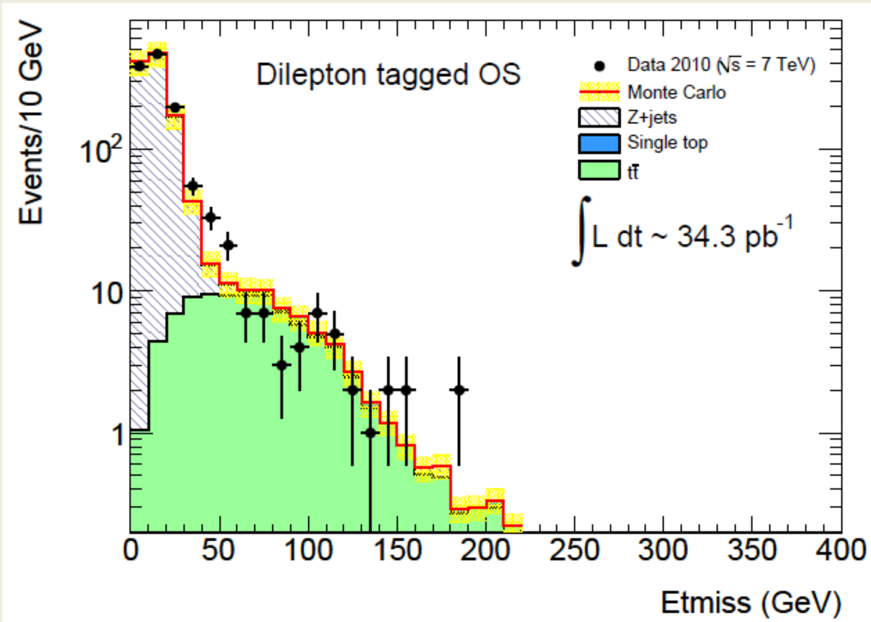


Top Background Studies

The technique is based on the use of a control region (Moderate EtMiss and top-like kinematics) to determine the normalization of the data and to extrapolate to the signal region with MC

This includes:

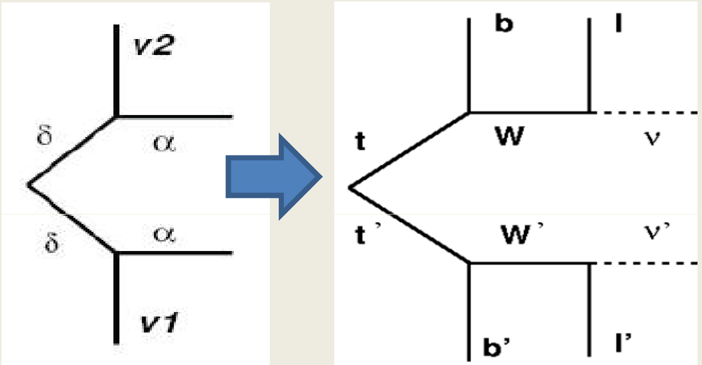
- Also background estimation of non-top in the control region.
- Estimate of systematics in the signal region extrapolation.
- Signal control regions and signal region optimization (work in progress)



Top Background Studies

New variable definition for top rejection and top tagging in 2-lepton analysis

Variables of the MCT class developed to find kinematic boundaries for this situation

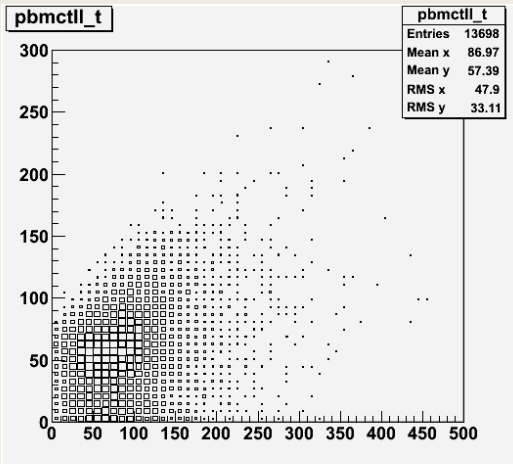


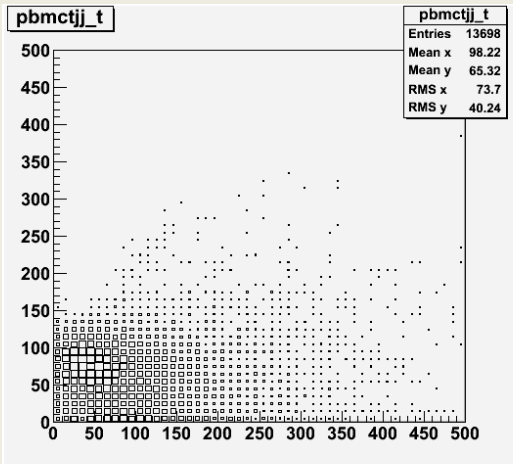
$$M^2_{CT}(v_1, v_2) \equiv [E_T(v_1) + E_T(v_2)]^2 - [\mathbf{p}_T(v_1) - \mathbf{p}_T(v_2)]^2$$

The variable M_{cT} has an upper limit as a function of p_b:

$$M^{max}_{CT}(l_1 l_2) = 80.4 GeV$$

$$M^{max}_{CT}(b_1 b_2) = 135.0 GeV$$





$$p_b = \left| - p_T(l_1) - p(l_2) - E_T^{miss} \right|$$

Italian 2011 SUSY Activities

Common Activity and Analysis scheme

- D3PD Slimming on GRID maintainig only the branch useful to the SUSY analysis.
- Cutflow production
  - •Different code developed in order to produce cutflow. Continuous crosscheck of results.
- Short Weekly Meetings

Analysis scheme

- Use plain SUSY D3PD n-tuples
- Thinning n-tuples on GRID
- Skimming, if necessary, on GRID
- Use of SUSYTools which contain the standard object definitions and analysis officially approved code

Lecce Activity

Muon Triggers as main task

Efficiencies

- needed in all 2 lepton analyses (OS,SS,FS)
- needed in 1-lepton analyses too
- used also in searches for long lived particles (displaced vertexes)

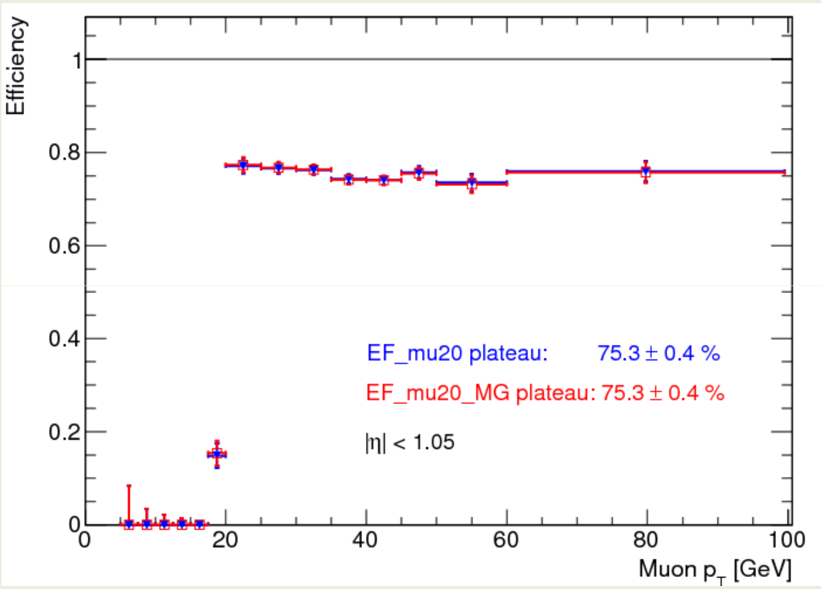
Recovery of <20 GeV muons

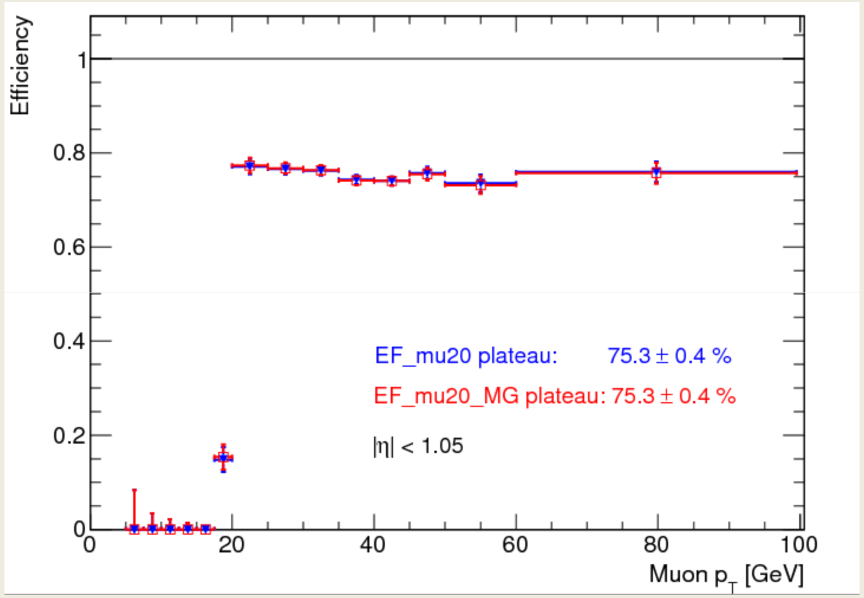
- Recent studies on Trigger EF_mu15_mu10_EFFS to improve on 2MU10 inefficiencies
- Test and validation of all primary muon trigger according to the evolving of ATLAS trigger menu.

Z/γ^* Background Studies

Lecce Activity (Muon SUSY trigger studies)

Efficiency studies performed using MCP guidelines and SUSY GRL to provide useful results to SUSY groups





- Results obtained for MSonly Muon Signature used in searches for long lived particles (displaced vertexes)
- Support/interaction also with other BSM groups
- **Plots and text already provided for SUSY 1-lepton note on 2011 data**

Pavia Activity (top background studies)

OS SR optimisation (in particular kinematic top rejection)
Re-optimisation of OS top background evaluation

The generalization of the work proceed in two directions:

1) Better definition of the selection cuts.

2) Optimization cuts, to define a better control region for the top wrt last year.

An essential element of this program is to understand, from the consideration of the kinematics of the top high EtMiss, how to select the jet to be used in the algorithm of top-tagging.
A detailed study is ongoing, already showing that the jet with the higher pt in the Signal Region (EtMiss > 150 GeV) is a jet from QCD radiation 40% of the time.

Pavia Activity (Flavour subtraction)

Within the 2-leptons flavor subtraction analysis a detailed study related to the systematics uncertainties on leptonic efficiencies (beta) is performed.

$$S = \frac{N(e^{\pm}e^{\mp})}{\beta\left(1-(1-\tau_e)^2\right)} - \frac{N(e^{\pm}\mu^{\mp})}{1-(1-\tau_e)(1-\tau_\mu)} + \frac{\beta N(\mu^{\pm}\mu^{\mp})}{\left(1-(1-\tau_\mu)^2\right)}$$

- Uncertainties on the trigger efficiencies have a negligible effect on the predicted same flavour excess.
- Instead, more important is the correct estimation of the reconstruction efficiencies and of their uncertainties.
- Results are obtained on MC samples.

Studied systematic uncertainties on leptonic efficiency ratio coming from:

1) The effect of MC generator $\Delta S_{sys}(\beta_{gen}) = 1.05 * 10^{-4}$
2) The effect of radiation (ISR and FSR) $\Delta S_{sys}(\beta_{IFSR}) = 6.97 * 10^{-4}$
3) The effect of the dilepton MC production process (ttbar or Z) $\Delta S_{sys}(\beta_{process}) = 0.022648$

Plans

- The flavour subtraction analysis is limited by the observed statistical uncertainty, while systematics are small.

- The operative work foresees the repetition of the analysis on release 16, a completion of systematics studies and MC analysis with new samples (dibosons, single top, W...) and a data-driven estimate of S, useful for the validation of the MonteCarlo value of S.

Milano Activity (Background ttbar estimation)

For SUSY two leptons paper on the 2010 data, the estimate on Top background has been provided in collaboration with Pavia.

Similar analysis on 2011 data is ongoing

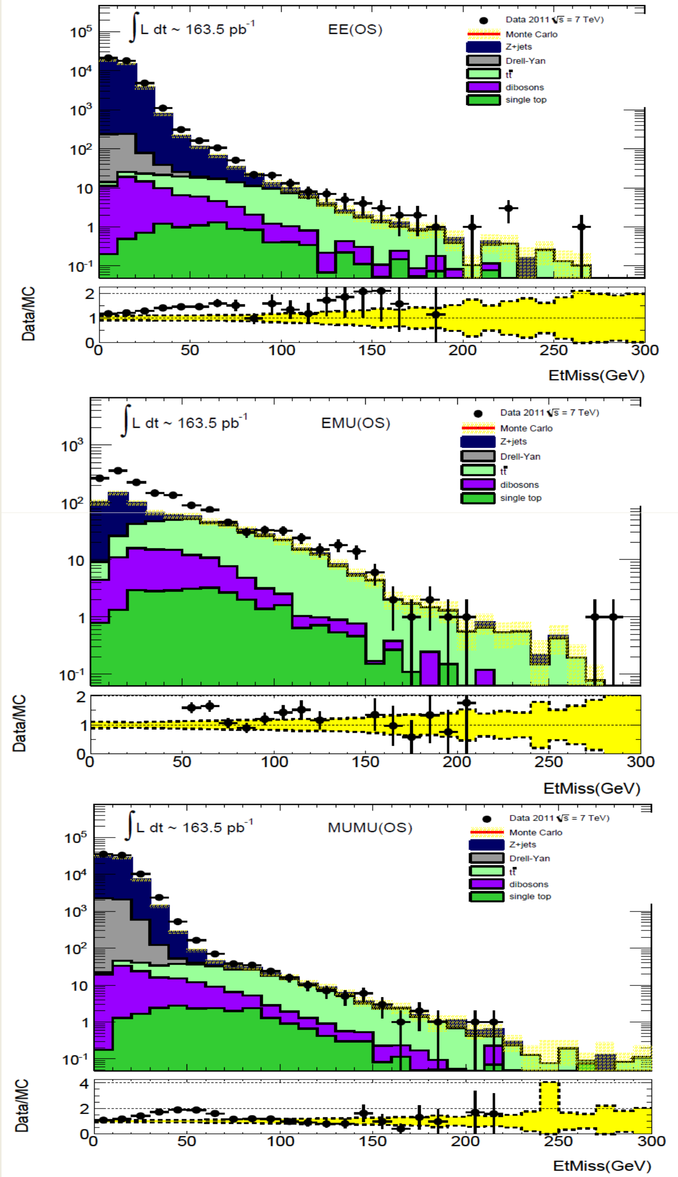
Provide estimate for top PLHC

This activity is complementary to the Pavia technique for short-term improvements in top estimate.

Milano Activity (Data analysis)

Activity on Data Analysis

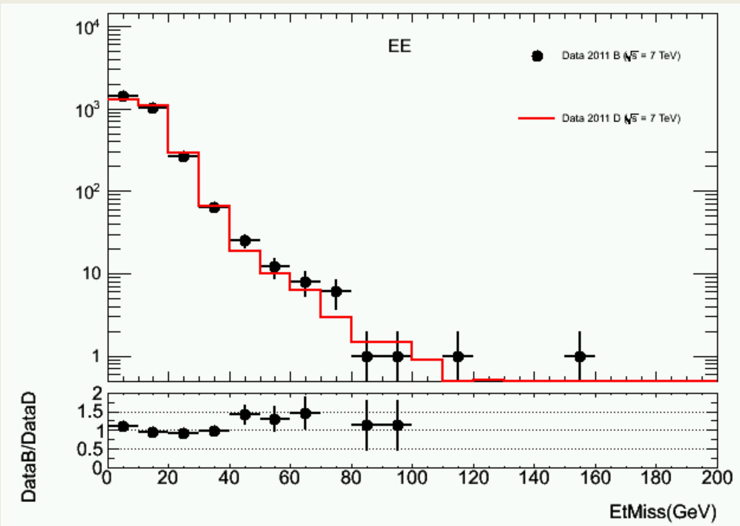
- Follow (and contribute to) the objects selection strategy
- Analyze the data as they arrive (like a factory) and compare periods with different operating conditions.
- Understanding the effects of pileup on the background composition in low and moderate EtMiss regions.
- Active participation in the development of the code of D3PD SUSY slimming.

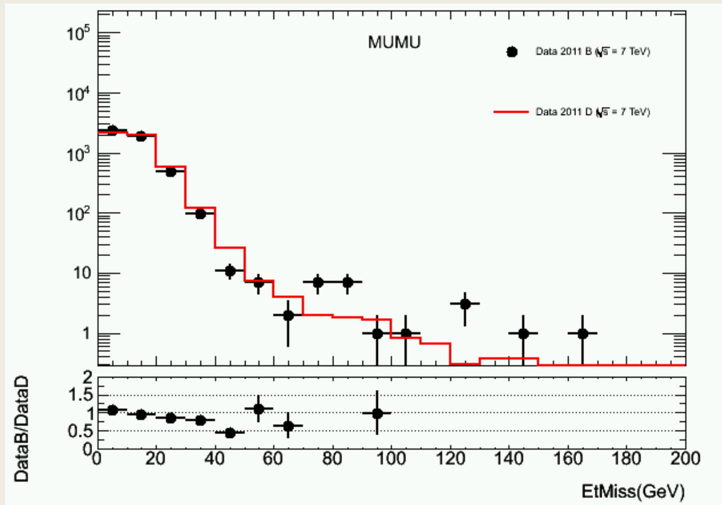


Milano Activity (Data analysis)

For what concern the significance and limit studies, the main goals are:

- Combining the results of the channels OS, SS, and three leptons.
- Produce plots for publications.
- Enter the number of events observed in the control regions as explicit parameters in the statistical tools (to constrain systematics.)
- Being able to manage the dependence of the uncertainties on different PDF.





Udine Activity and plans

- Is currently focused on the estimation of measurement uncertainties of the background processes, especially on ttbar, single top, and dibosons Ztautau, within well defined signal and control regions for the study of the background top.
- Contribute to writing/maintaining the code for D3PD slimming.
- Run over the various grids (MSUGRA/PhenoGrid) and compute exclusion contours, try to be model independent by limiting the production to gg or qq only.

Conclusions

- ❖ The Italian group plays a key role inside the ATLAS 2-Leptons SUSY group, but significant contributions are also provided to the broader SUSY group.

- ❖ We are present in all aspect of SUSY analyses and produce results regularly.

- ❖ Excellent collaboration (and competition ..) with the other partecipanting groups.

We are working hard to mantain the leading role acquired in 2010

With MANY MANY MANY thanks to the SUSY Italian Groups for the help, support and for this opportunity

Bonus Tracks

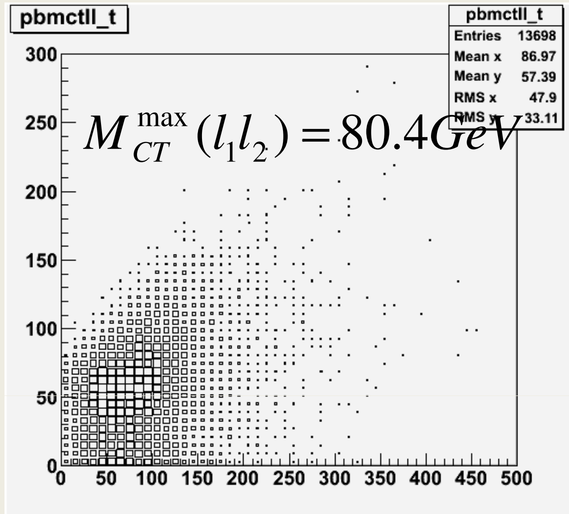
Two possible variables: $M_{CT}(ll)$ vs p_b and $M_{CT}(bb)$ vs p_b

$$M^2_{CT}(l_{1,}l_2) \equiv [E_T(l_1)+E_T(l_2)]^2 - [p_t(l_1)-p_t(l_2)]^2$$

$$p_b = \left| - p_T(l_1) - p(l_2) - E_T^{miss} \right|$$

$$M_{CT}^{\max}[p_b] = M_{CT}^{\max}[0](r+\sqrt{1+r^2}) \qquad r \equiv P_b / 2m(t)$$

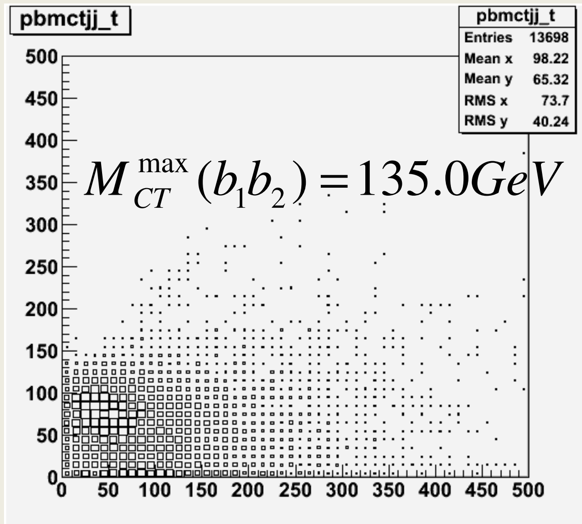
$$M_{CT}^{\max}(l_1 l_2) = \frac{m^2(W)-m^2(\nu)}{m(W)}$$



$$M^2_{CT}(b_{1,}b_2) \equiv [E_T(b_1)+E_T(b_2)]^2 - [p_t(b_1)-p_t(b_2)]^2$$

$$p_b = \left| - p_T(l_1) - p(l_2) - p(b_1) - p(b_2) - E_T^{miss} \right|$$

$$M_{CT}^{\max}(b_1 b_2) = \frac{m^2(t)-m^2(W)}{m(t)}$$



Pavia Activity (New variables for top rejection)

700 pb-1, add Z veto

Additional requirements: require at least 2 jets with pt>20 GeV, and m(ll) outside of the 80-100 GeV window

Sample	$E_T^{miss} > 150$ GeV	$E_T^{miss} > 150$ GeV+cuts
$t\bar{t}$	86.239 ± 6.898	1.936 ± 1.046
Z/γ+jets	11.540 ± 4.254	1.441 ± 1.441
W+jets	0.000 ± 0.000	0.000 ± 0.000
Diboson	5.878 ± 0.374	0.186 ± 0.050
Single top	3.739 ± 1.569	0.000 ± 0.000

Diboson background disappears, cannot say anything
About Z, since before Z veto a single event was left in MC

The statistics of MC background is insufficient for 700 pb-1 analyses!

Pavia Activity (New variables for top rejection)

Light neutralino, 700 pb-1

Consider points on the diagonal and light neutralino case

Run	m(gl) (GeV)	m(sq) (GeV)	2l tot	$E_T^{miss} > 100$	$E_T^{miss} > 100$ +cuts	$E_T^{miss} > 150$	$E_T^{miss} > 150$ +cuts
114939	310	300	8976.8	4794.58	437.24	2147.71	256.904
114947	410	400	2160.57	1571.34	354.823	1021.87	229.552
114955	510	500	629.401	510.009	157.5	387.127	129.297
114963	610	600	199.791	176.385	60.3491	151.075	55.0196
118945	710	700	65.6623	60.3204	25.0451	51.8058	22.7493
118957	810	800	23.6024	21.6945	9.57817	19.4845	9.0009

Good chances up to 800 GeV, can further increase Etmiss

Light neutralino, 700 pb-1 Z veto

Consider points on the diagonal and light neutralino case

Run	m(gl) (GeV)	m(sq) (GeV)	$E_T^{miss} > 150$	$E_T^{miss} > 150$ +cuts
114939	310	300	2147.71	177.151
114947	410	400	1021.87	205.389
114955	510	500	387.127	113.285
114963	610	600	151.075	48.6942
118945	710	700	51.8058	21.2479
118957	810	800	19.4845	8.34783

Small decrease in efficiency

Pavia Activity (New variables for top rejection)

Compressed spectrum, 700 pb-1

Run	m(gl) (GeV)	m(sq) (GeV)	2l tot	$E_T^{miss} > 100$	$E_T^{miss} > 100$ +cuts	$E_T^{miss} > 150$	$E_T^{miss} > 150$ +cuts
114940	310	300	9366.31	3643.57	262.237	1304.99	73.965
114948	410	400	2055.36	964.069	72.4287	402.501	43.588
114956	510	500	554.304	284.51	16.3056	148.252	14.7494
114964	610	600	170.592	85.3307	3.66974	41.9126	1.2276
118946	710	700	62.7339	35.1029	2.3509	17.7663	1.09622
118958	810	800	25.7876	14.2002	1.04685	6.42689	0.575801

As expected low efficiency of top rejection cuts also for signal

Pavia Activity (Flavour subtraction)

Results

- Without MET cuts, for 34.3 pb-1:

For ttbar

n(ee) = 20.185699

n(eμ) = 53.408493

n(μμ) = 36.112682

S = 1.38 ± 0.67

- In the signal region (MET>100GeV), for 34.3 pb-1:

For ttbar

n(ee) = 3.580224

n(eμ) = 9.787506

n(μμ) = 6.686218

S = 0.16 ± 0.28

For Z+jets

n(ee) = 0.173649

n(eμ) = 0.

n(μμ) = 0.452718

S = 0.57 ± 0.20

For SU4

n(ee) = 5.441449

n(eμ) = 9.564414

n(μμ) = 10.152800

S = 5.55 ± 1.34