Search for Higgs in Leptogenic Susy models

Simona Rolli (Tufts University)

with

Ketevi Assamagan (BNL)

Veronica Sanz (York University)

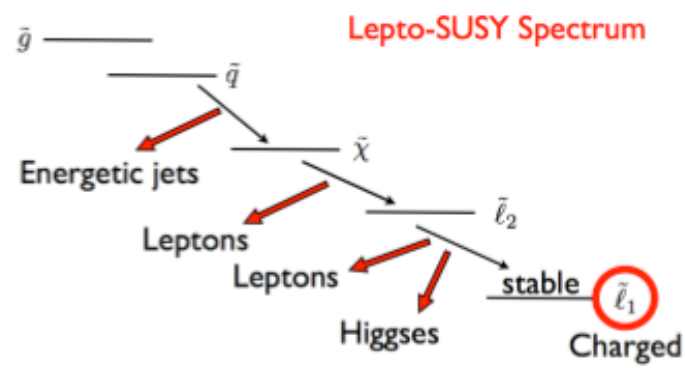
Wendy Taylor(York University)

Jorge A. Benitez (York University)

Sergei Checkanov (Argonne National Lab)

The model

- Leptogenic Supersymmetry
  - SUSY scenario characterized by cascade decays with copious lepton production;
  - Striking signatures that can be probed with just 1 fb^{-1} at LHC @7 TeV
    - Long-lived sleptons
    - Several Isolated leptons
    - Energetic jets
    - No MET
    - Copious Higgs production…

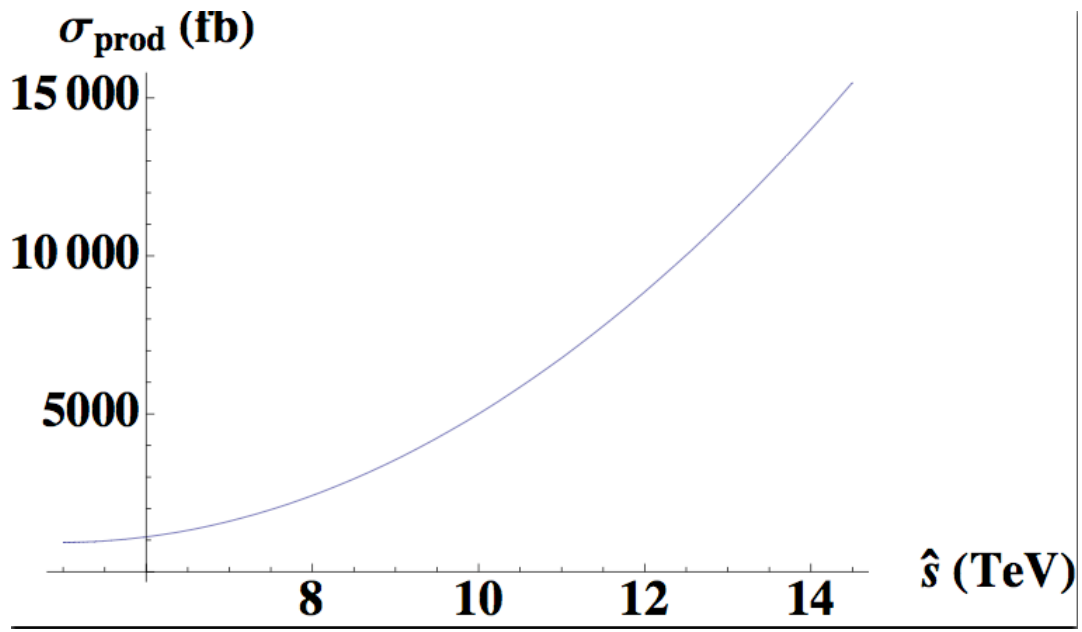


V.Sanz et al. Phys.Rev.D80:035010,2009.

The model (cont'd)

Input	m_3	2000 GeV		
	n_1	4.8		
	n_2	3.9		
	n_3	2.2		
	n_4	6.7		
	$\tan\beta$	10		
	$\mathrm{sgn}\mu$	$+$		
Output (GeV)	$m_{\tilde{g}}$	1938	$m_{\tilde{u}_L}$	949
	$m_{\tilde{\chi}_1^\pm}$	291	$m_{\tilde{u}_R}$	920
	$m_{\tilde{\chi}_2^\pm}$	676	$m_{\tilde{d}_L}$	952
	$m_{\tilde{\chi}_4^0}$	676	$m_{\tilde{d}_R}$	919
	$m_{\tilde{\chi}_3^0}$	353	$m_{\tilde{t}_1}$	920
	$m_{\tilde{\chi}_2^0}$	302	$m_{\tilde{t}_2}$	962
	$m_{\tilde{\chi}_1^0}$	271	$m_{\tilde{\ell}_L}$	248
	m_h	115	$m_{\tilde{\ell}_R}$	108
	$m_{H^\pm}$	387	$m_{\tilde{\nu}}$	236
	m_A	379	$m_{\tilde{\tau}_1}$	106
	m_{H_0}	379	$m_{\tilde{\tau}_2}$	249

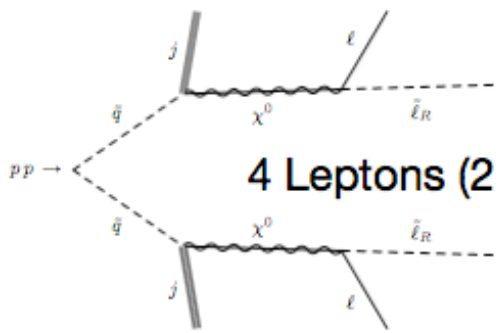
Table 1: A sample spectrum calculated with SUSY-HIT.



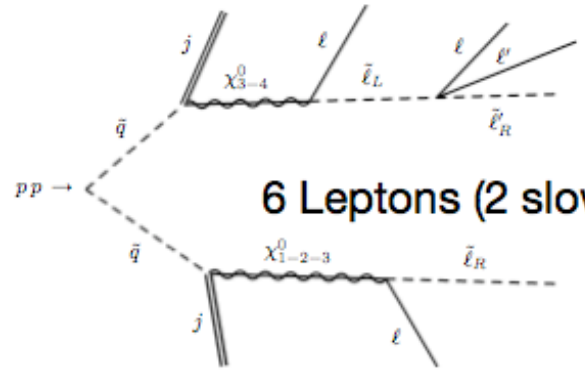
Cross section at 7 TeV of order 1400fb
No major sources of physics background
-- signal efficiency expected to be high

Final states Topologies

- Production mechanism: pair production of squarks
- Background: 2 jets + many leptons

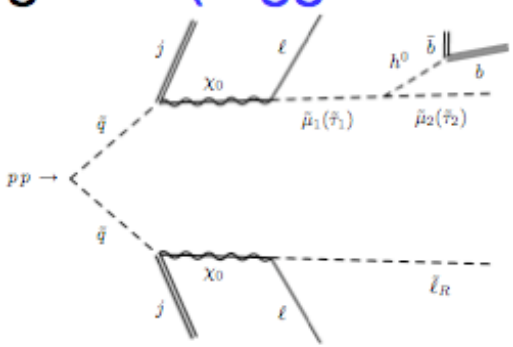


4 Leptons (2 slow)



6 Leptons (2 slow)

- Signal (Higgs Production)



Higgs in this scenario decays in bb pair

2 jets + 2 b-jets

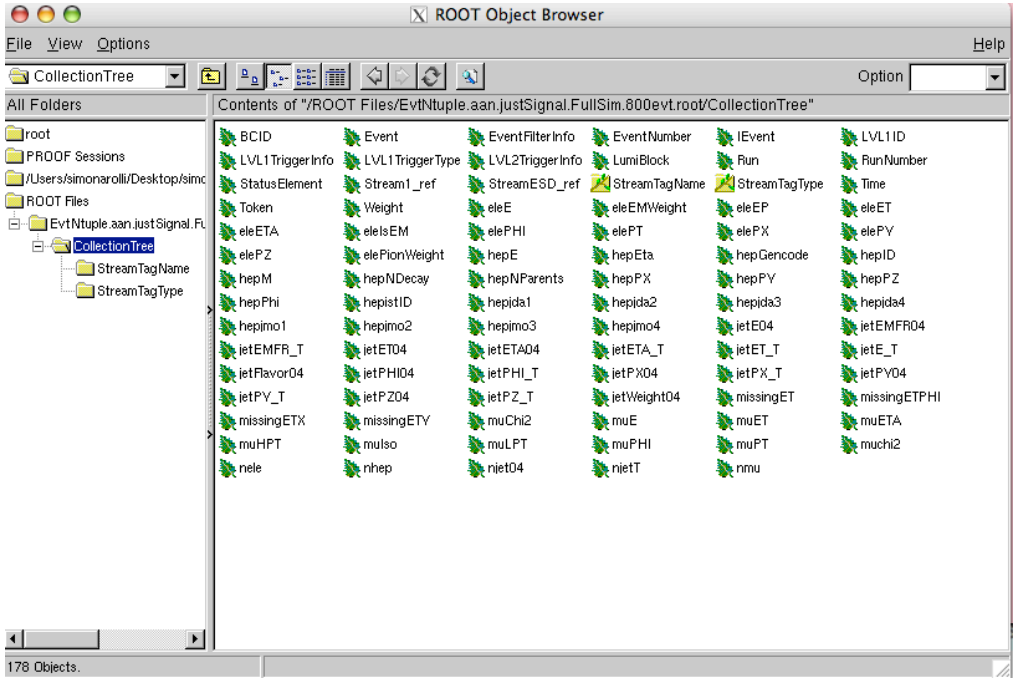
4 leptons

Analysis Strategy

- Given the presence of slow leptons, we can use a dedicated slow muon trigger
- Given the large jet multiplicity we require at least 4 jets in the event
- 2 of those jets should be b-tagged if searching for Higgs
- With these cuts, virtually NO SM background (as opposed to CMS that does not have a dedicated slow objects triggger)

Tools

- We are using a customized ntuple (Simona)
- Easy to add information and decouple from the the athena framework
  - Easy to add information and learn on the way what AOD really contains….



- We also use D3PD as produced for SUSY analyses (Jorge)

Event Cleanup

- Implemented pre-selection and Overlap Removal using:
  - UserAnalysisSelectionTool (Ketevi)
  - UserAnalysisOverlapRemovalTool (Ketevi)

- ToolSvc.UserAnalysisSelectionTool.ElectronIsEMFlag="Medium"
- ToolSvc.UserAnalysisSelectionTool.ElectronEtaWindowCut=False
- ToolSvc.UserAnalysisSelectionTool.ElectronEtaWindowCenter=1.445
- ToolSvc.UserAnalysisSelectionTool.ElectronEtaWindow=0.075
- #ToolSvc.UserAnalysisSelectionTool.ElectronIsolationEt=10.0*GeV // not available
- ToolSvc.UserAnalysisSelectionTool.ElectronPt=10.0*GeV
- ToolSvc.UserAnalysisSelectionTool.ElectronEta=2.5

- ToolSvc.UserAnalysisSelectionTool.MuonPt=10.0*GeV
- ToolSvc.UserAnalysisSelectionTool.MuonEta=2.5
- ToolSvc.UserAnalysisSelectionTool.MuonMatchChi2=100.0
- ToolSvc.UserAnalysisSelectionTool.MuonIsolationEt=10000.0

Cleanup Cuts

- ToolSvc.UserAnalysisSelectionTool.JetPt=20.0*GeV
- ToolSvc.UserAnalysisSelectionTool.JetEta=2.5
- ToolSvc.UserAnalysisSelectionTool.BJetLikelihood=-10.0

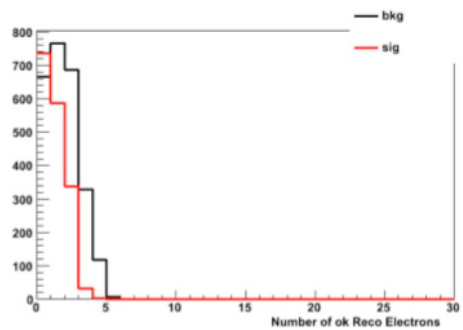
- ToolSvc.UserAnalysisSelectionTool.TauJetPt=20.0*GeV
- ToolSvc.UserAnalysisSelectionTool.TauJetEta=2.5

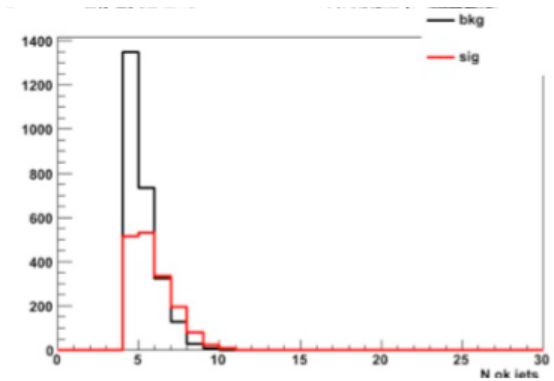
ToolSvc.UserAnalysisOverlapCheckingTool.OverlapDeltaR=0.2
ToolSvc.UserAnalysisOverlapCheckingTool.OverlapDeltaRWithJets=0.4

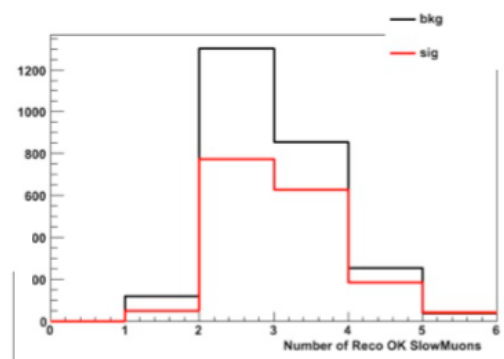
Final State Objects

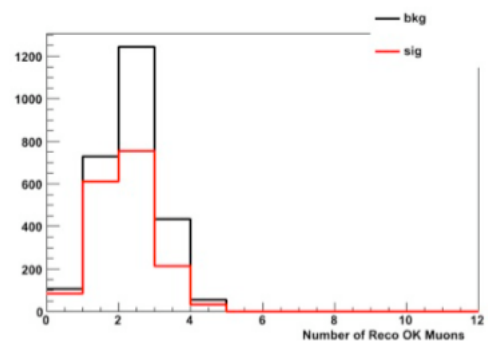
- Collections used:

```
ToolSvc.UserAnalysisPreparationTool.InputContainerKeys = [
   "ElectronAODCollection",
   "StacoMuonCollection",
   "TauRecContainer",
   "AntiKt4H1TopoJets",
   "PhotonAODCollection",
   "CaloCalTopoCluster",
   "TrackParticleCandidate"
  ]
```





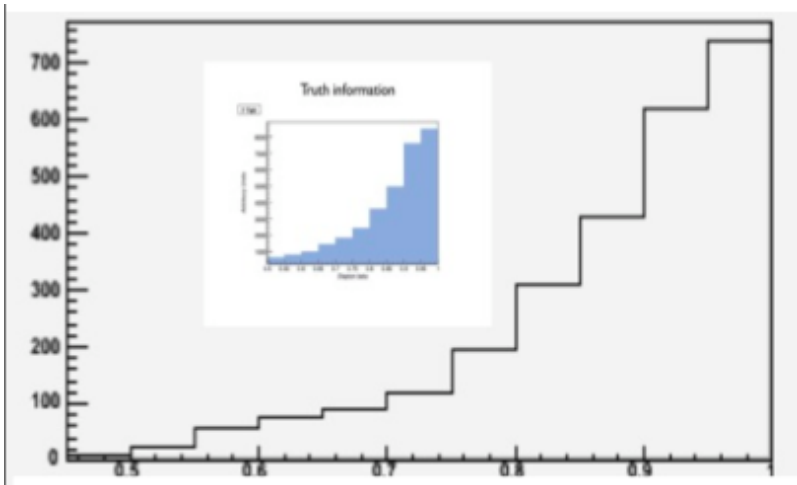




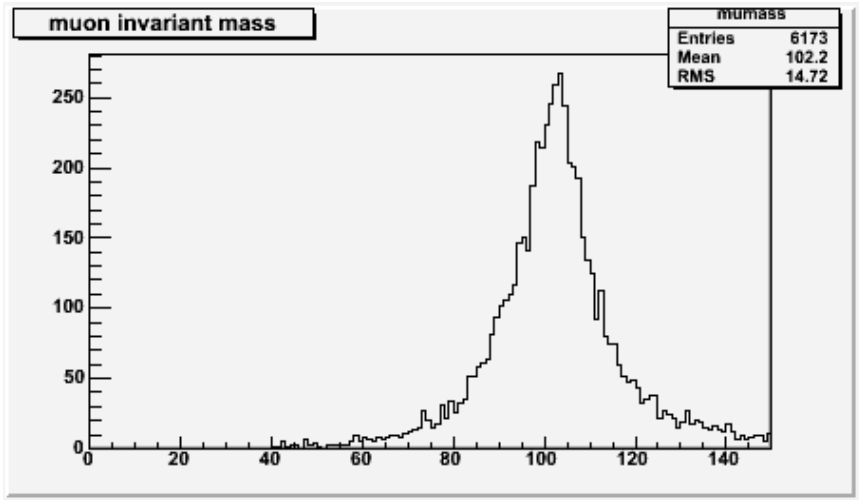
- Final state objects distributions
  - Lepton and jet multiplicity
- Trigger Efficiency (offline and simulated)
- Analysis cuts efficiency
  - Expected events
  - N(jets) ≥ 4
- Btgging
  - Preliminary Btag efficiency for Jet Probability and default SV0+IP3D Tagger

Trigger

- Possible to measure the mass and velocity of slow moving particles (β <1) directly.
- L1 -> Long lived particles are identified as muons
- L2 -> Algotithm measure the particle's velocity (β) using the time resolution panel of the RCP panel

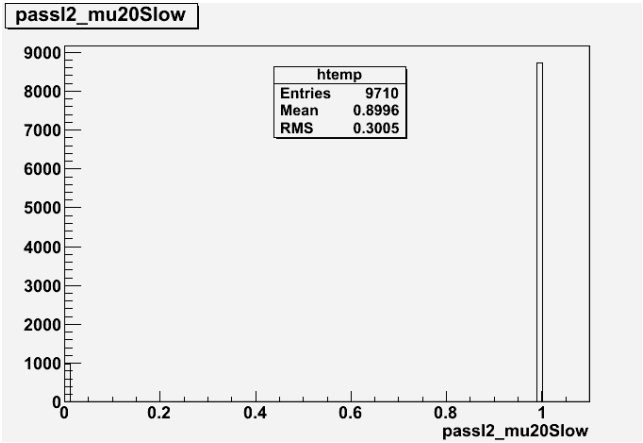


SlowMuon β Distribution



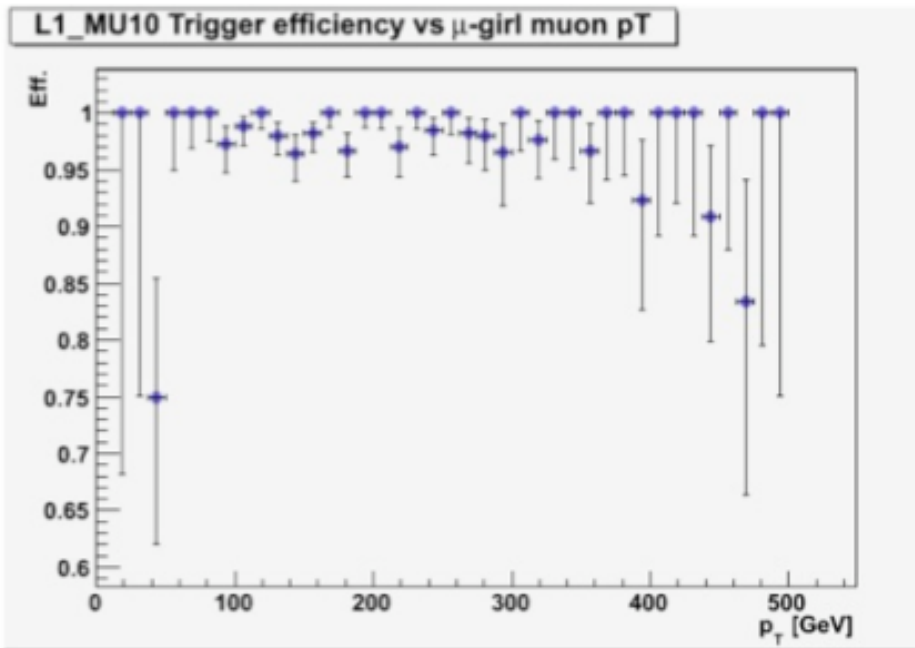
Offline Trigger Efficiency

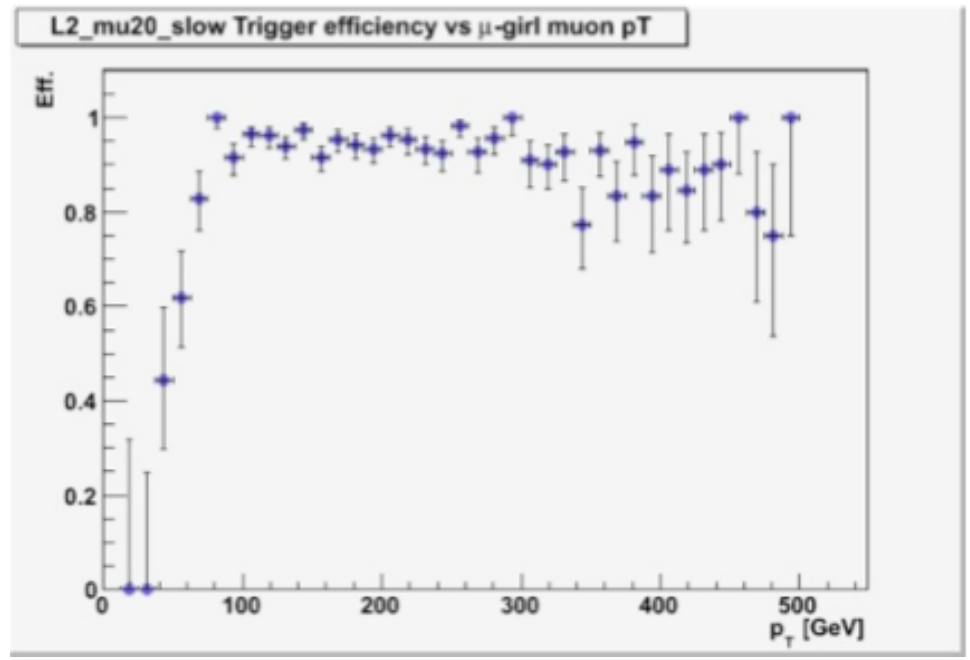
- Before Trigger Simulation, we select events with a single slow muon with PT > 25 GeV and $\beta > 0.5$
  - Signal only:2062/2402 = 85.8%
  - Background:6164/7308 = 84.3%
  - In agreement with trigger efficiency as from simulation (89.9%)
- Using Trigger Simulation, we looked at events passing L2_mu20_slow:
  - STAT Trigger Statistics on 9710 processed events
  - STAT Passed events for chain L2_mu20_slow 8735 (89.9588%)



Trigger Efficiency Turn-on

- L1 -> Long lived particles are identified as muons (L1_MU10)
- L2 -> Algorithm measure the particle's velocity (β) using the time resolution panel of the RCP panel. Low background rates. (L2_mu20_slow)





Event selection

Strategy
trigger on slow leptons, ask for high jet multiplicity, require b-tag

- Current Selection:
  - Trigger on 1 Slow Muon
  - Offline: 1 slow muon PT > 25, eta < 2.5
  - At least 4 jets with ET > 25 GeV eta < 2.5
    - Several jet multiplicity cuts to optimize S/B were tried before, now with preselection 4 seems ok
  - Following theory paper suggestion in disregarding the first 2 jets….
  - Jet 3 and 4 with btag weight cut > -3,-2,-1,0
    - Several tag weights used to calculated tagging efficiency and Rejection factor
  - JetProbability also investigated with JetProb cut at 0.1
- Calculated signal retention and background elimination (S/B)

How many events in $1fb^{-1}$?

- Assuming a cross section of 320 fb for Higgs-only events and 1080 fb for background

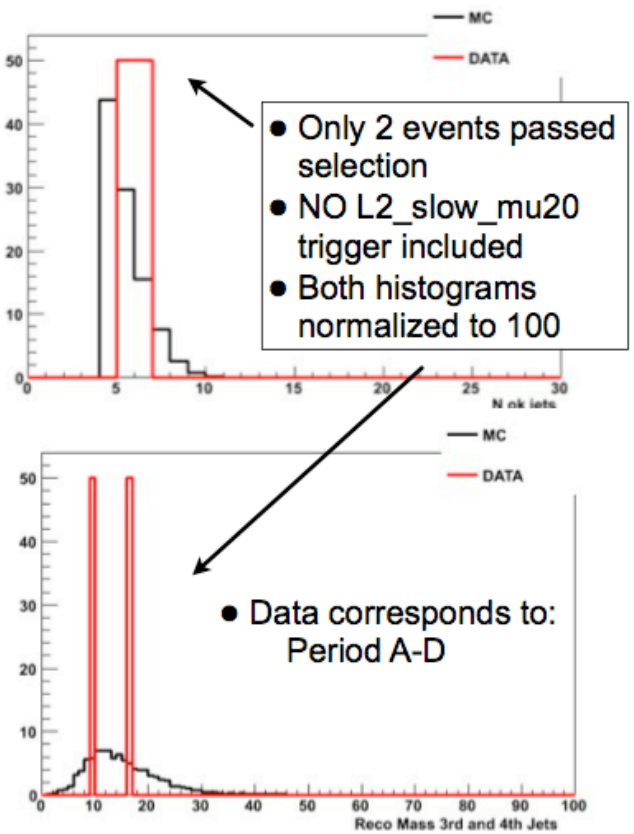
	Passing	Signal	Bkg
Trigger	85%	272	918
$\geq$ 4 jets	60%, 26%	192	280
4 jets with cuts	52%, 20%	166	216
2 bjets	11-6%, 1-0.5%	35 - 20	10-5

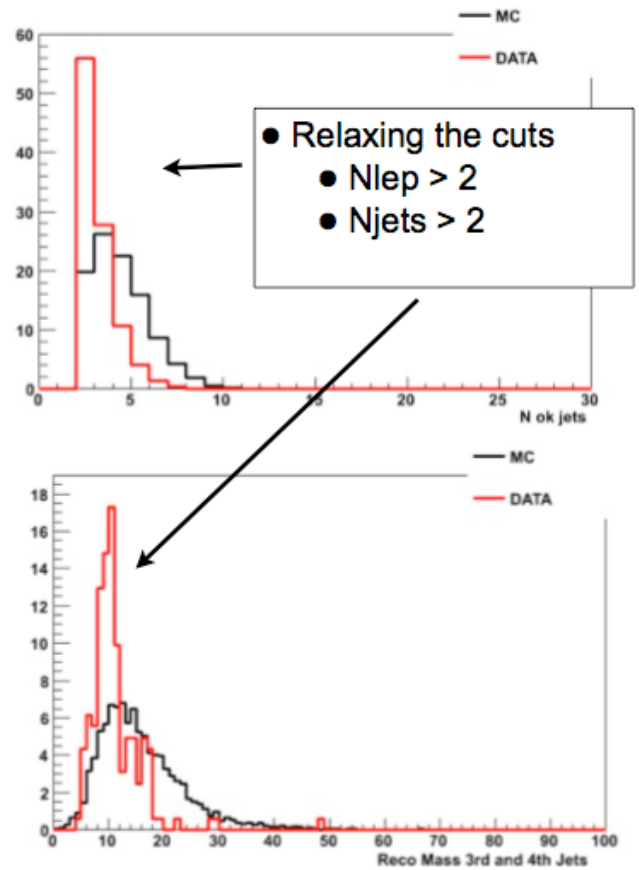
Conclusions on Rates

- Leptogenic production and decay of a SM-like light Higgs would happen with virtually no background from Standard Model (SM) sources and heavy flavor tagging can be used with relatively high efficiency to select the decay products of the Higgs.
- As more standard production modes of a light SM-like Higgs present prohibitive backgrounds for the LHC experiments at 7 TeV, this analysis is quite unique in that it can provide first evidence for a Higgs boson in the mass range favored by the current theoretical fits of electroweak data and with the statistical sample achievable at the end of 2011.

Preliminary Look at data

Unfortunately the slow muon trigger is not operational yet
So we looked at data passing the regular muon trigger





Btagging studies (Simona)

- Select the proper tagging cut for (SV1+I3PD cut) and Jet Probability

≥ 4 jets Signal

Weight Cut	Jet Prob < 0.1	W > -1	W > 0
ε(b)	68.8%	62.7%	54.7%
Mistag rate	4%	1.7%	0.07%

≥ 4 jets Background

Weight Cut	Jet Prob < 0.1	W > -1	W > 0
ε(b)	82%	64%	61%
Mistag rate	3%	1.4%	0.07%

B-tagging performance estimators

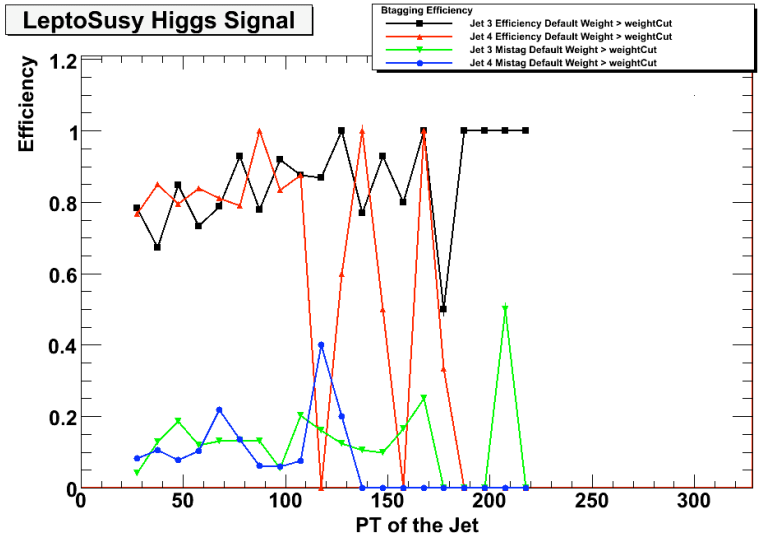
- B-jet efficiency ε_b as function of weight cut:
  - Denominator:
    - jets defined as b using MC truth
      - with fixed p_T and η cuts (p_T> 25 GeV/c, $|\eta|$<2.5)
  - Numerator:
    - ditto + cut on a tagging weight
- Light-jet rejection $R_u = 1 / \varepsilon_u$
  - R=100 means 1% mistag rate
  - light jets: u, d, s, g
- B-jet efficiency as a function of P_T and η
  - Denominator:
    - jets defined as b using MC truth
      - with fixed cut on weight (SV1 > 3, LHSig > 0.9, …)
  - Numerator:
    - ditto + cut on p_T and η

Weight Cut

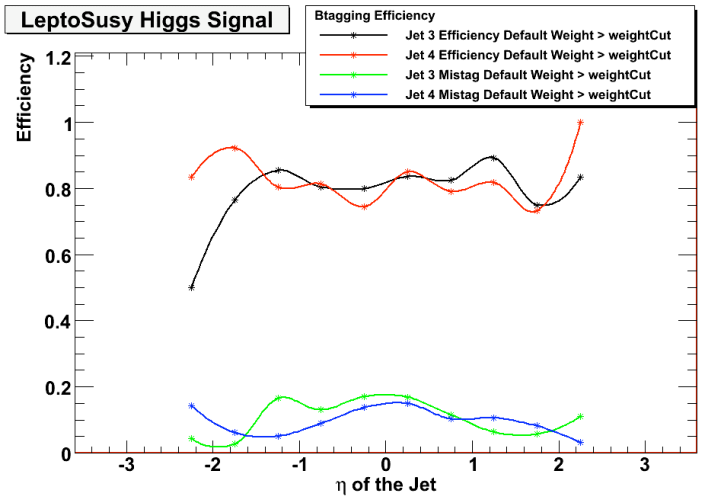
- From the b-tagging official page:
  (https://twiki.cern.ch/twiki/bin/view/AtlasProtected/BTaggingFAQ#Choosing_a_cut_value)
  - By cutting on the b-tagging weight, you choose a working point defining a certain b-tagging efficiency `eps_b` and a level of rejection of light jets `R_u`. This choice is very analysis-dependent (mostly via jet pT/eta spectra), therefore the b-tagging group does not recommend a cut. In addition, the relation between the cut value and `(eps_b, R_u)` is not univoqual: it depends on the sample, the release and the b-tagging calibrations.

- We did efficiency and rejection studies varying the cuts

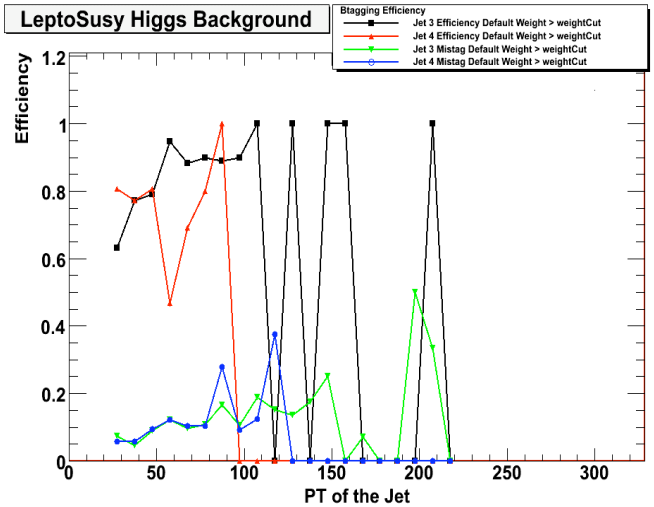
Efficiency and Mistag



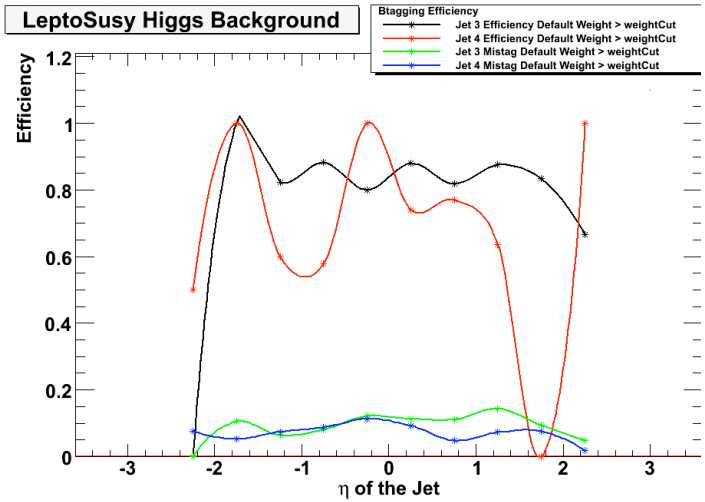
Signal



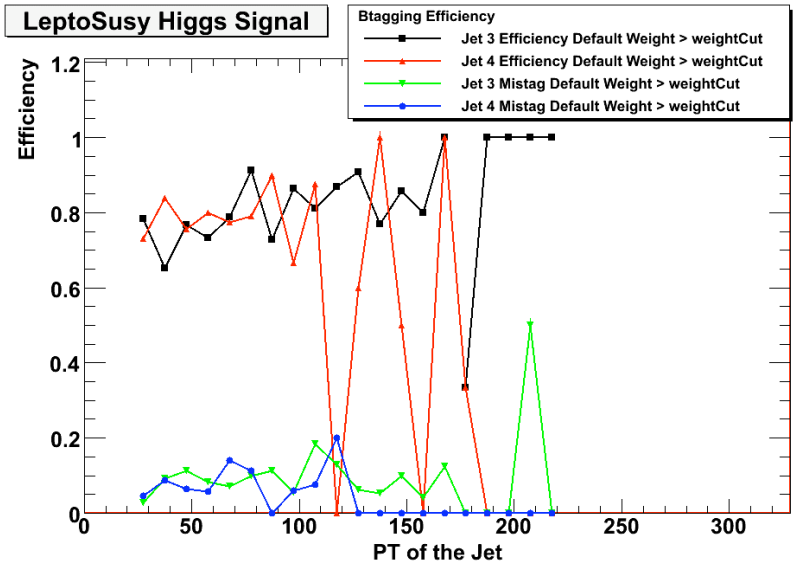
Weight > -1



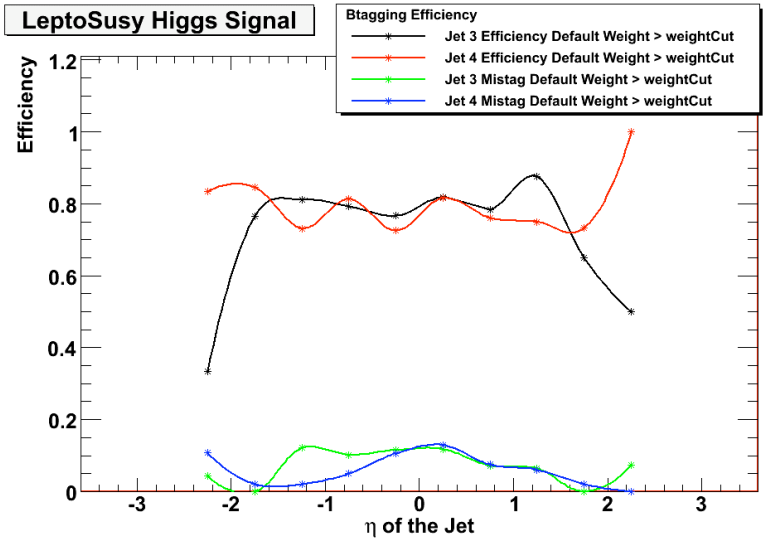
Background



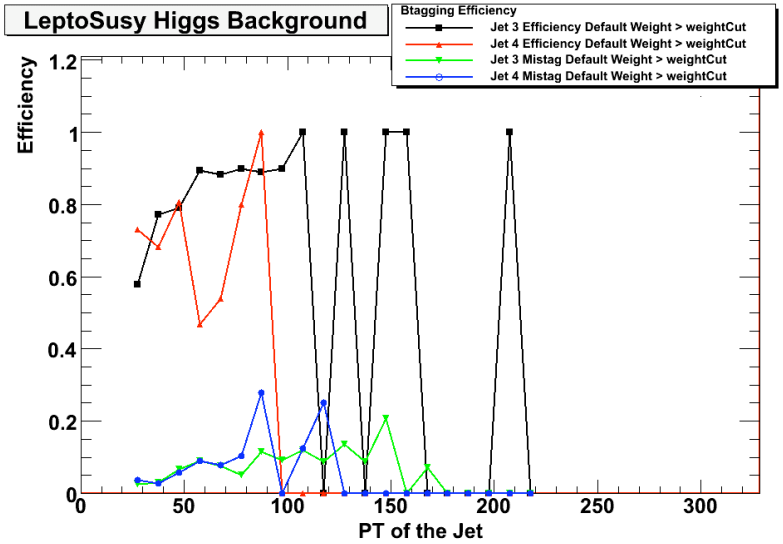
Efficiency and Mistags



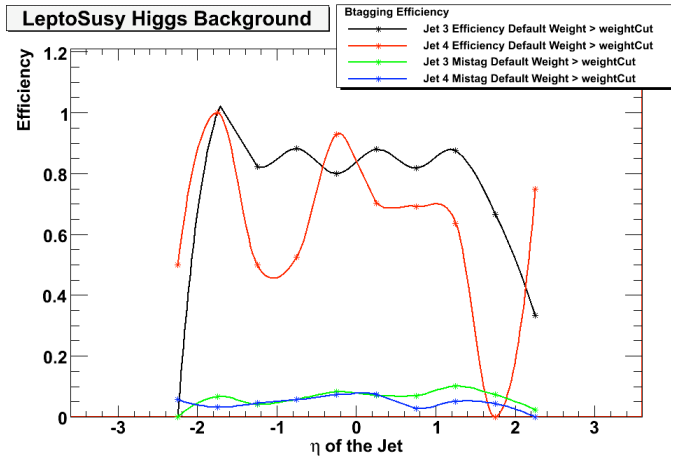
Signal



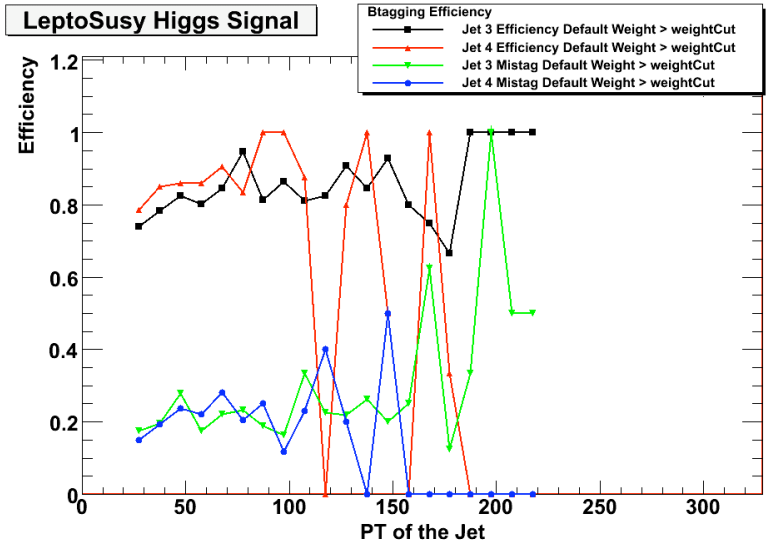
Weight > 0



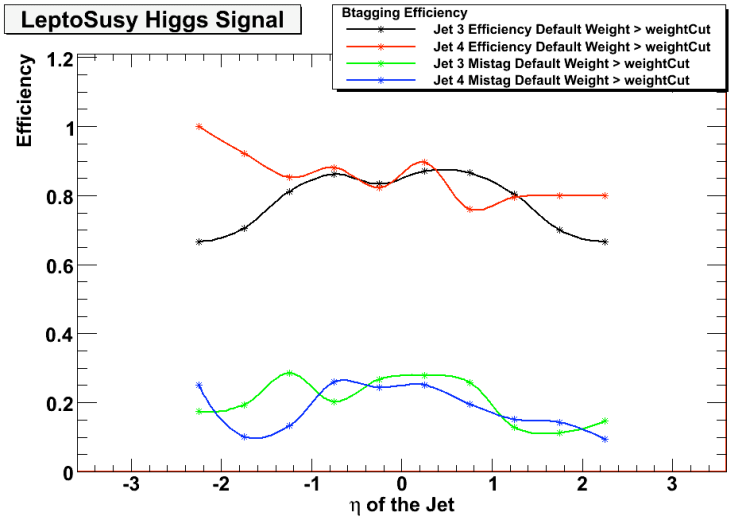
Background



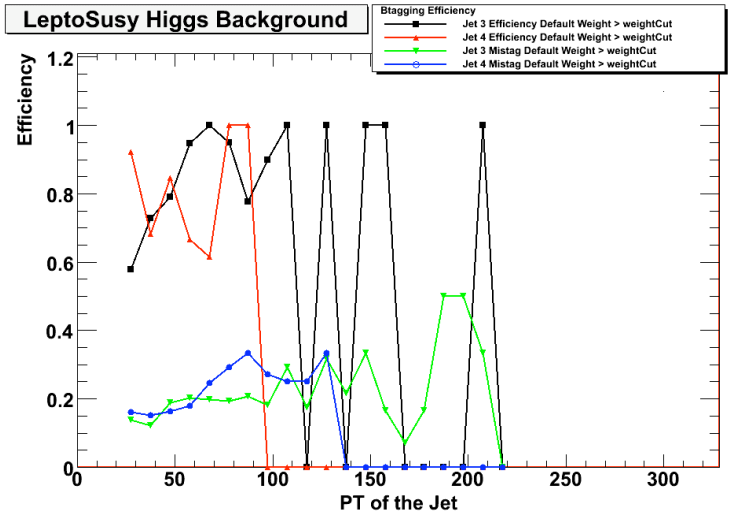
Efficiency and Mistags



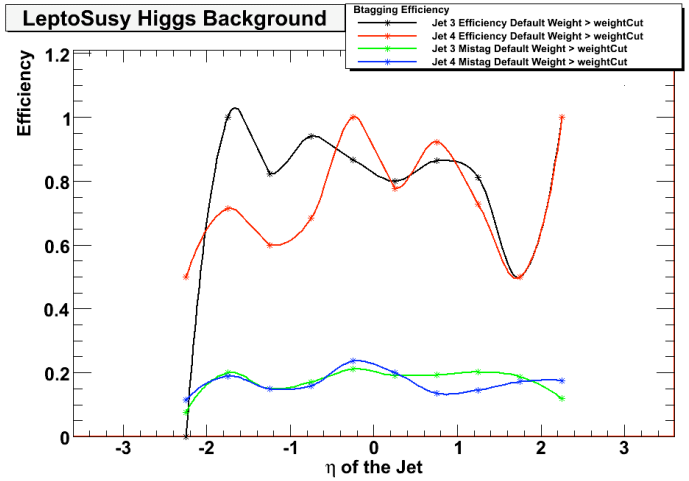
Signal



.Jet Prob < 0.1



Background



A closer look at Jet Probability

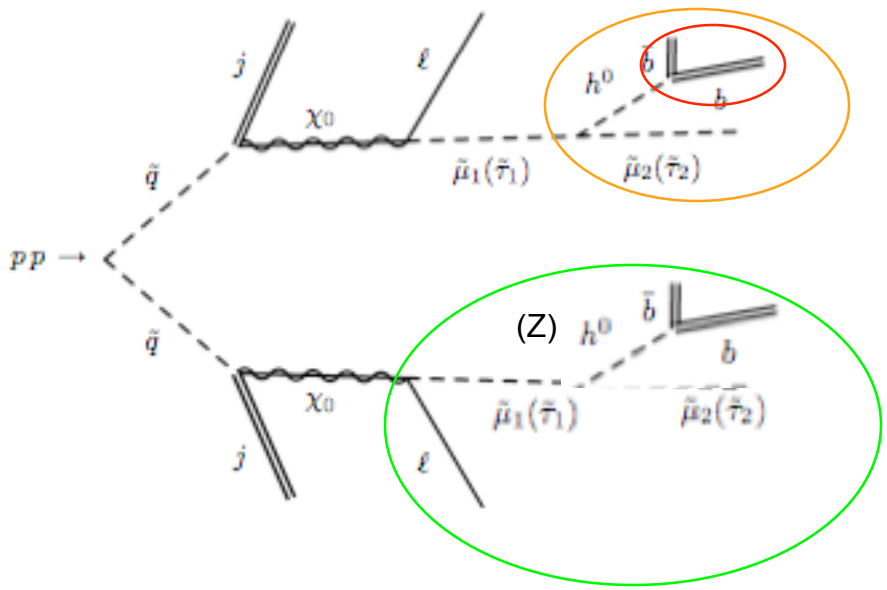
Since Jet Probability is one of the early data taggers, we looked at the behavior of Jet Probability for the third and 4th jets before and after applying the most SV1+I3PD cut to the same jets (we saw before that SV1+I3PD Weight > 0 gives a very high purity in terms of Truth Flavor (that we can check)

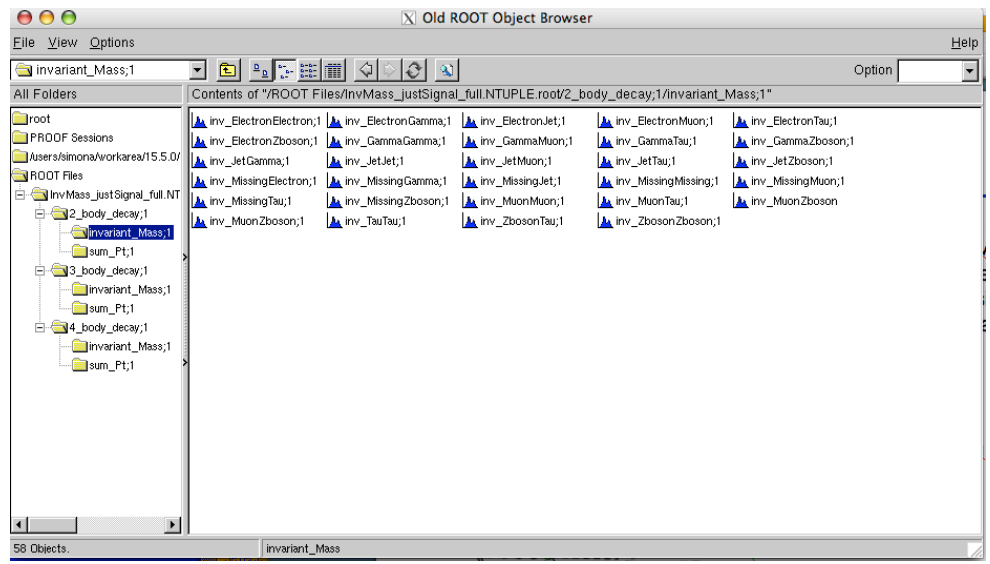
The idea is to find a good cut on JetPro (we selected < 0.1) to use such tagger independently from the others

We also note the difference between the signal (coming from Higgs) 3rd and 4th jet Jet Probability distributions and the background (spurious b-jets and mistags)

InvMass studies (Simona and S.Chekanov)

InvMass is a program that has been written at ANL to execute general searches using high E_T reconstructed objects (J.Boomsma & S.Cheknov)
It takes as input ntuple created by the PromptGamma package, which creates ntuples with up to 7 particle types stored in AOD/DPD, after using selection cuts defined by the user and performing an overlap removal. The package is now optimized for photon searches and we took it "as-is".

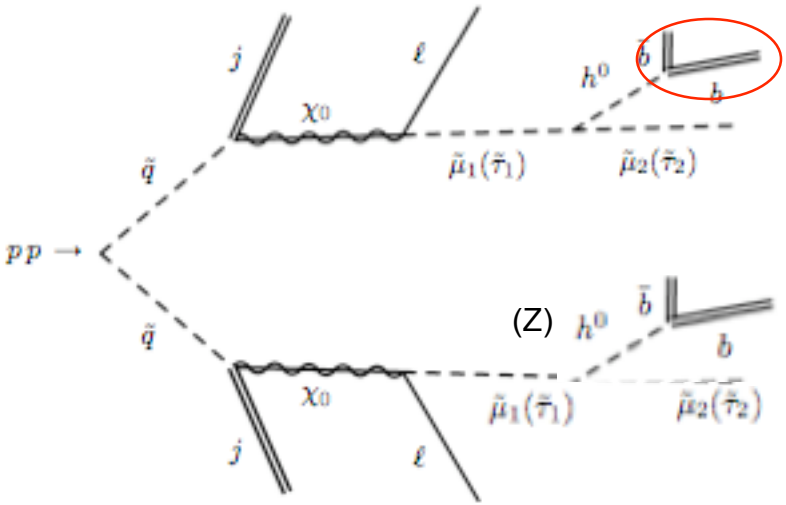


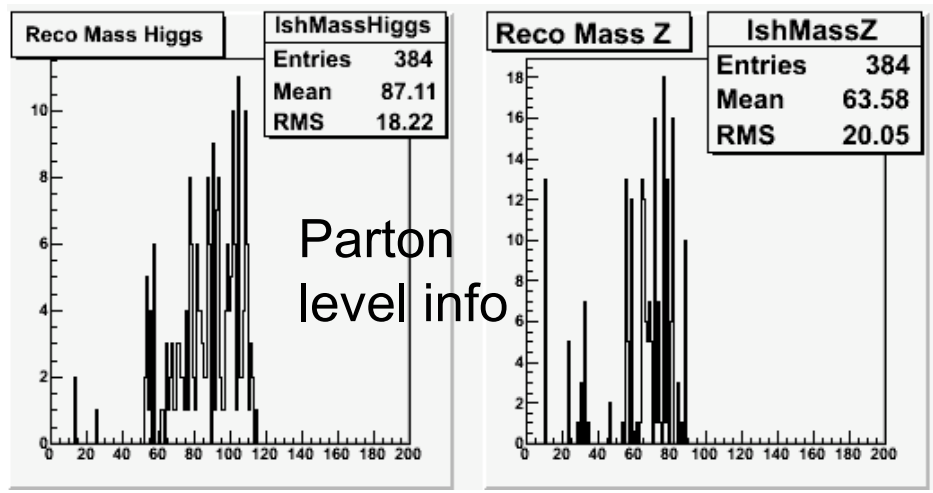


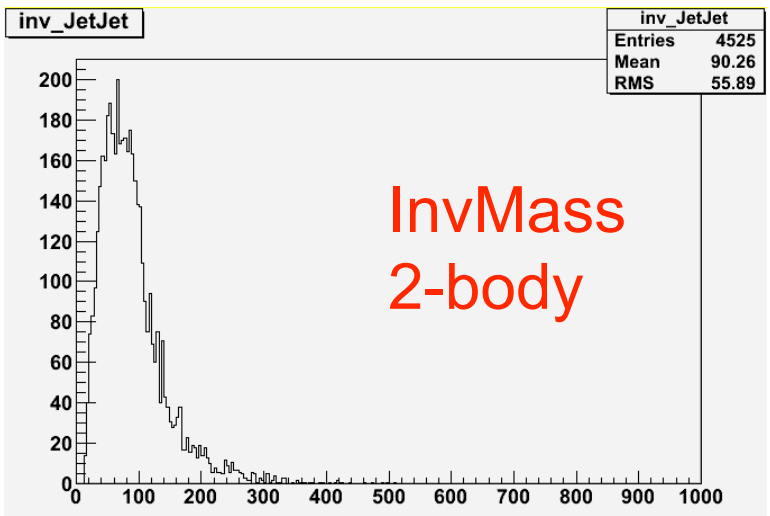
2-body JetJet
3-body JetJetMu
4-body JetJetMuMu(tau)

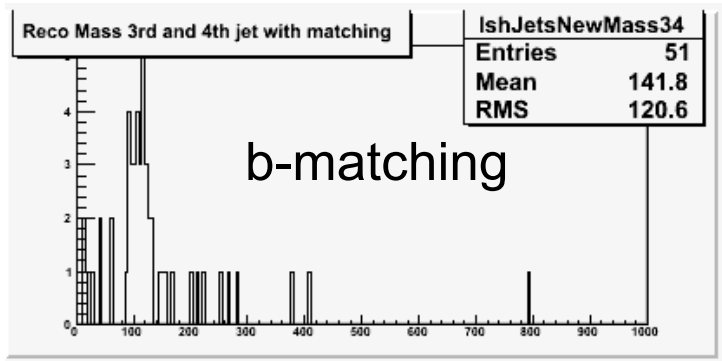
FullSim 2-body

10 TEV samples!

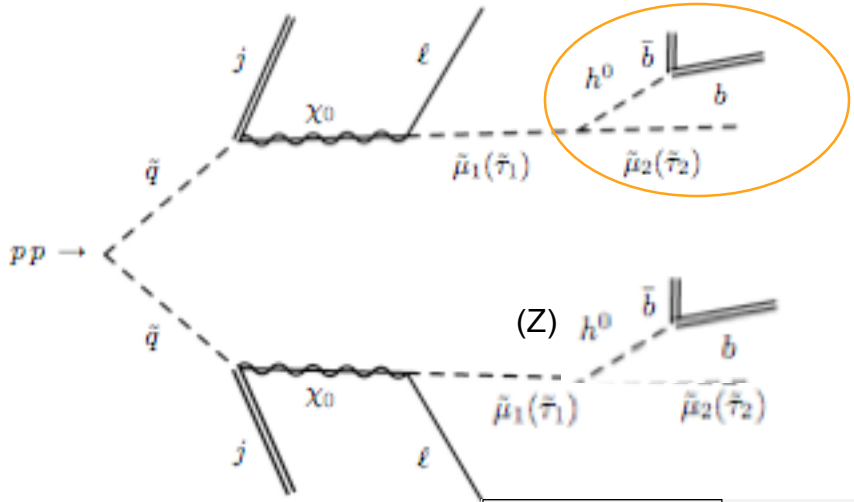


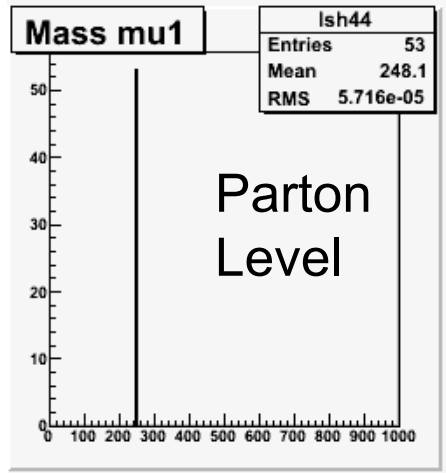


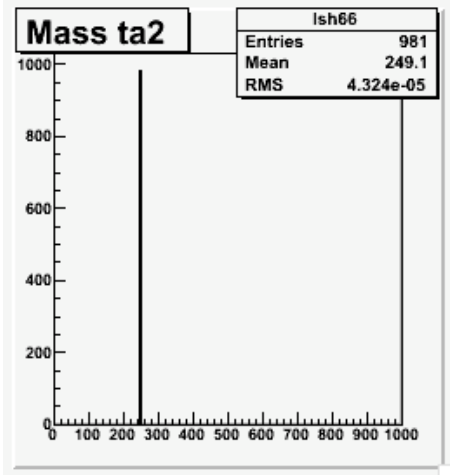


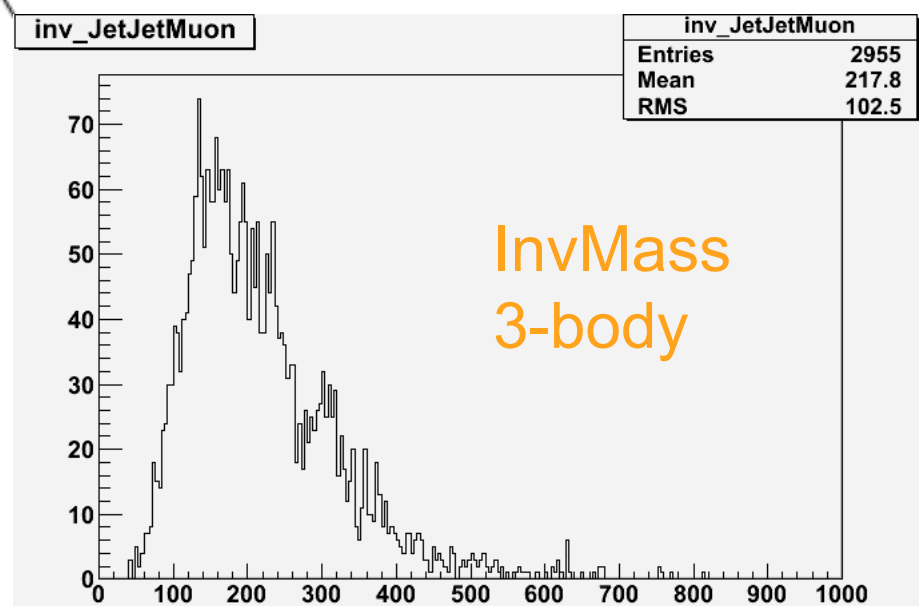


FullSim 3-body

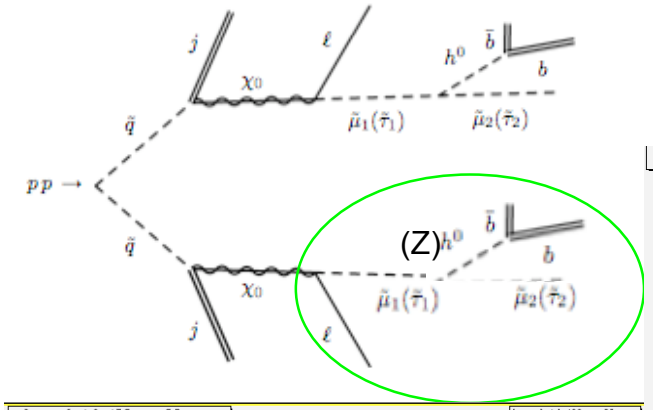


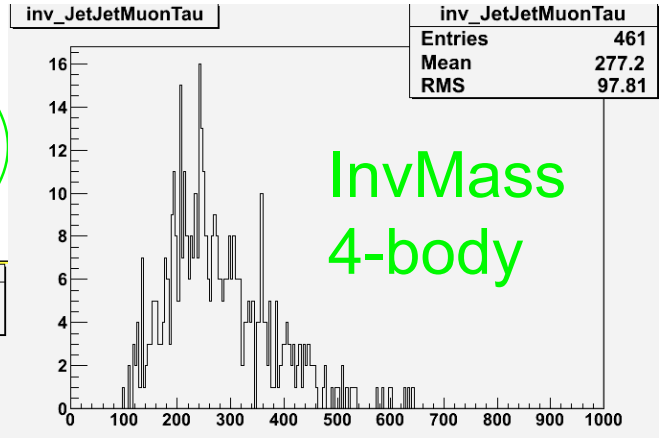


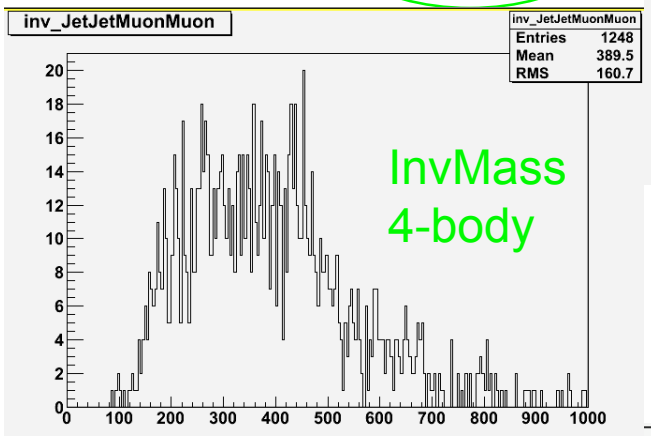


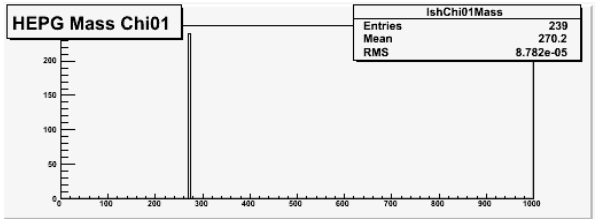


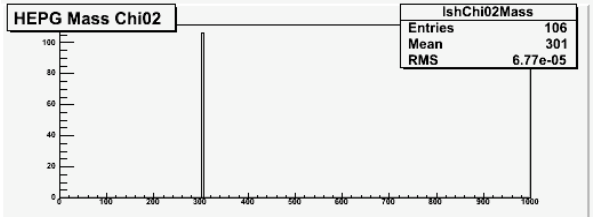
FullSim 4-body

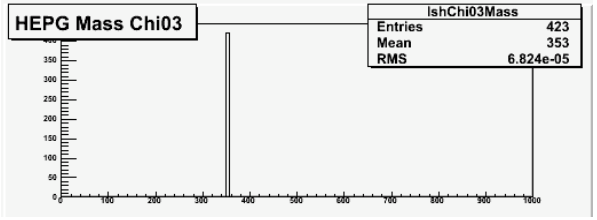


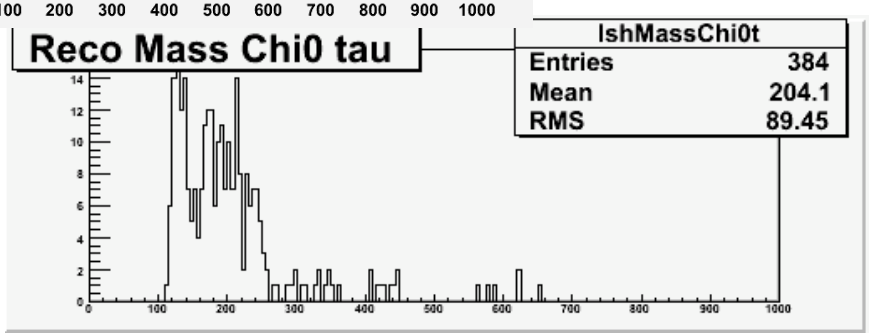


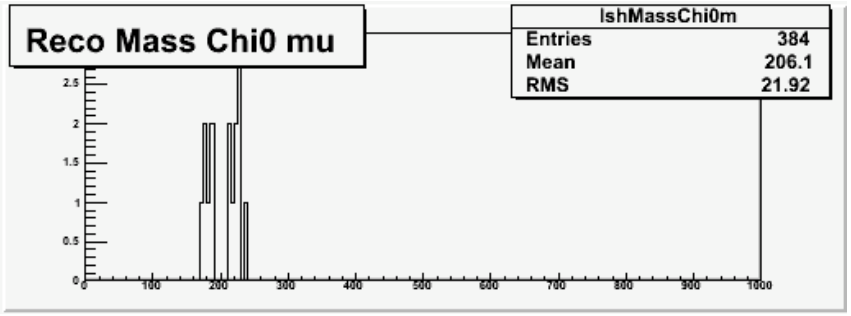












Inv Mass preliminary conclusions

- InvMass seems a suitable tool to look for resonances, and indeed we see structures in our sample
- The studies were very preliminary
  - Old sample
  - No cleanup
  - No slow muon collection and trigger selection
- We would be interested in using it further and implement the missing pieces for our analysis

Conclusions

- We have an interesting model to study
  - Leptogenic SUSY with large lepton/jet multiplicity signal and Higgs production
- We have developed tools to look at our events
  - evtNtuple
  - D3PD
  - Implemented clean-up and preselection cuts
- We have a preliminary analysis strategy
  - Expected number of events
- We have looked at b-tagging efficiency as function of PT and eta
  - SV1+I3PD Weight
  - Jet Probability
- We have looked at the possibility of using InvMass searches code (Argonne)
  - Need to implement the slow muon recognition
  - Possible base for a signature based analysis?
- We need data!
  - Trigger operational in the next few weeks…

Presentations

- S.Rolli HSG5 working group, September 2009
- S.Rolli Argonne Analysis Jamboree, January 2010
- S.Rolli Argonne Physics Meeting, September 2010
- J.A. Benitez HSG5 working group, September 2010

Short Term Association

- Wendy Taylor, S.R. and Ketevi Assamagan co-signed a request for a short term association to ATLAS on bhealf of Prof Veronica Sanz (June 2010)
- Short term association was approved at ATLAS CB of October 8th.

Proposal for ATLAS Short-Term Association
for Dr. Veronica Sanz

Ketevi Assamagan, Simona Rolli, and Wendy Taylor

June 16, 2010

In this proposal, we request that Dr. Veronica Sanz be considered for a *short-term association* with ATLAS. Dr. Sanz is an Assistant Professor in theoretical particle physics at York University, Toronto, Canada. The existing ATLAS group at York University is led by Dr. Wendy Taylor, and is associated with the ATLAS TRIUMF institutional cluster. Dr. Sanz is interested in collaborating with Dr. Taylor's group, and with ATLAS members Dr. Ketevi Assamagan and Dr. Simona Rolli, on a search for Lepto-SUSY at ATLAS. Dr. Sanz is uniquely qualified to contribute to this analysis, as she developed the phenomenology of Lepto-SUSY, as described in her paper *Leptogenic supersymmetry*, Phys. Rev. **D80**, 035010 (2009).

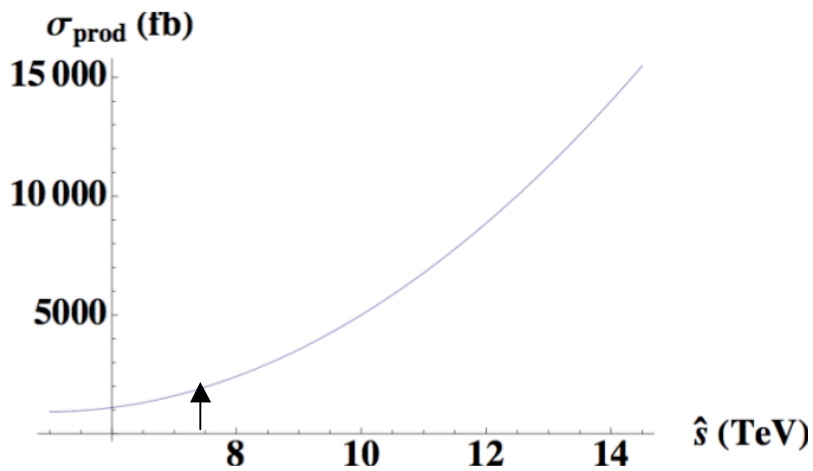
The DØ and CDF experiments at the TeVatron have excluded a light Standard Model (SM) Higgs with a mass in the range 162-166 GeV/c^2. If the SM Higgs is light, the dominant decay is to $b\bar{b}$, which is plagued by QCD backgrounds, whereas decays to clean final states such as diphotons or ditaus are very rare. This is also the case in most extensions of the SM. As a result, the discovery of a light Higgs at the LHC may require high statistics and a good understanding of the detector. However, if the Higgs to $b\bar{b}$ decay were accompanied by multiple leptons in the final state, suppression of the QCD background could be very effective, making an early Higgs discovery possible.

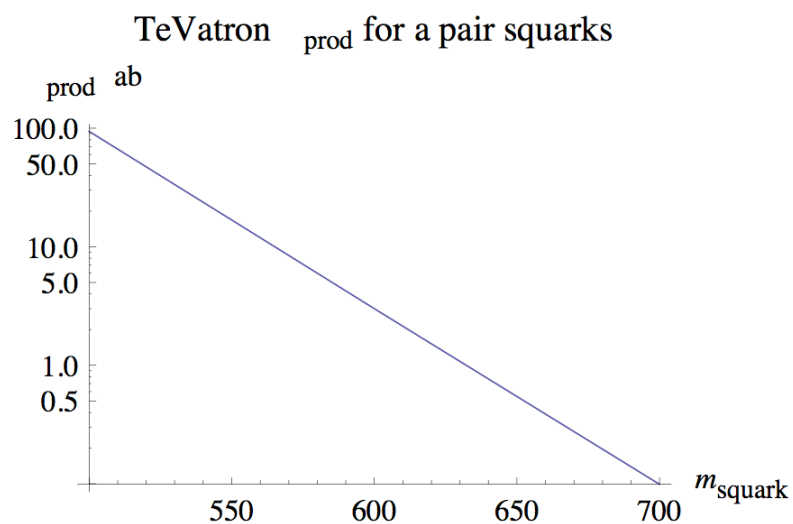
Leptogenic supersymmetry is a class of supersymmetric models that yield a complex state of Higgs bosons plus multi-leptons. In the Lepto-SUSY model, Higgs bosons produced in 7-TeV proton-proton collisions would decay predominantly to $b\bar{b}$ in association with two high-p_T jets, two high-p_T leptons and two sleptons. This characteristic signature of a Higgs decay to $b\bar{b}$ produced in association with six isolated high-p_T objects provides a very attractive scenario for an early Higgs discovery at the LHC. Since the supersymmetric cascade decay is initiated by heavy squarks, the total cross section of the Lepto-SUSY signal is 1.5 pb at 7 TeV, but less than 1 fb at the TeVatron.

Preliminary Lepto-SUSY studies indicate that a Higgs discovery could

1

Cross Section:LHC vs Tevatron





- 1) 7 TeV pp
  - Production cross section: 1.45 pb (240fb for Higgs).
    - q-q initial state is 70%, q-antiq is 20% and g-g is 10%.
- 2) 2 TeV ppbar
  - Production cross section is 159.8 ab (attobarns)
    - q-anti q is 159.5 ab (99%).

L2_mu20_slow

S. Bressler, S. Tarem, S. Vallecorsa

SUSY Trigger meeting - 22/03/2010

- mu20_slow is part of the physics menu
- It has been specifically designed to trigger on heavy long lived charged particles
- It modifies standard muon triggers to measure β
  - Recover the cases in which no inner detector track is associated to muon spectrometer hits
    - low β candidates or charge flipping R-Hadrons
  - Improve efficiency for low β in EF

- It has very low bkgd rates at 10^{31} and 10^{34}
- It can be activated as soon as RPC and MDT timing are well calibrated