Search for MSSM neutral Higgs, h_0/A, boson decaying in muon pair in mass region < 130 GeV: Methods & Sample

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Outline

- Motivation bb h_0/A $\rightarrow$ $\mu^+ \mu^-$ studies (25/05/2005) S.G. presentation, ATLAS-PHYS-2003-015, June 2003.
- Methods
- Software & Generators
  - Simulation, Reconstruction, Analysis.
- Sample
  - Signal, Background
- Reconstruction features
  - muon reconstruction
  - b-tag

MSSM

Constrained:

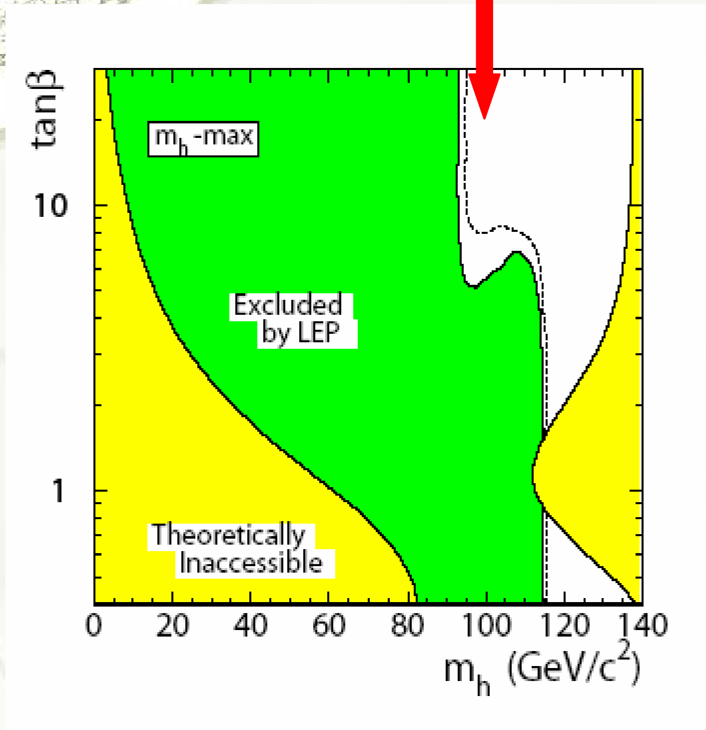
- Two Higgs doublets $\rightarrow h_0$, H, A, H^+, H^-
- Two neutral Higgs bosons A, CP-odd, and h_0 the lightest CP-even.
- Large loop corrections depend on SUSY parameters: M_{susy}, M_2, μ, **tan β**, A, $\mathbf{m_A}$, m_{gluino}
- $A = 6^{1/2} M_{susy}$, $|\mu| \ll M_{susy}$ for maximal top mixing

Past & future

Excluded:

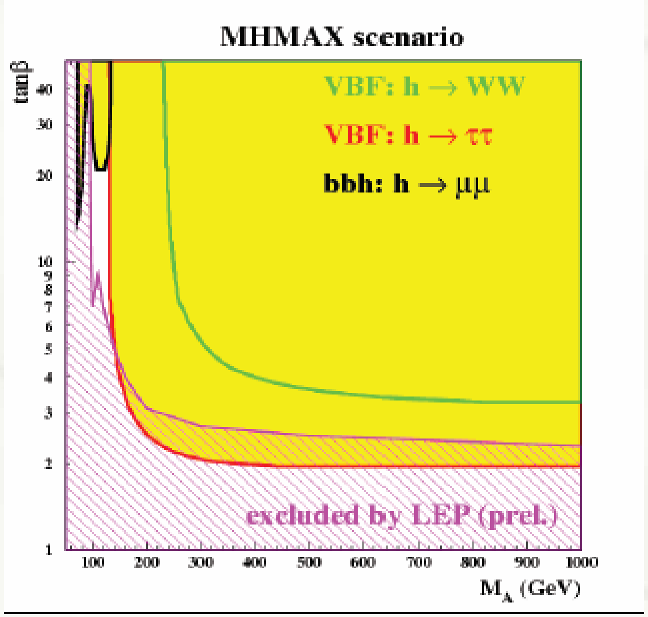
$m_{h0} < 92.9\ GeV^2/c$ $m_A < 93.4\ GeV^2/c$

tanβ 0.9 – 1.5



LHWG-Note 2004

$L_{int} = 30\ fb^{-1}$



Markus Schumacher
June 2004, SUSY04, Tsukuba

MSSM parameters

- M_{susy},sfermion mass at EW scale
- M_2, $SU(2)_L$ gaugino mass at EW scale
- m, supersymmetric Higgs boson mass parameter.
- tan b, the ratio of the two Higgs fields doublets
- A_t, a universal trilinear higgs-squarks coupling at EW scale. It is assumed to be the same for up-type squarks and for down types quarks. X_t,X_b stop and sbottom mixing parameters
- m_A, mass of CP-odd Higgs boson.
- M_{gluino}, it affects loop corrections for stop and bottom

M_h^{max} scenario

- **It is designed to yield the maximum value of m_{h0} can reach 135 GeV**
- A negative search of h_0 boson in such scenario implies the exclusion of the model

•M_{susy} =1000GeV
• $\mu = -200$
• M_2 =200 GeV
•$X_t = A_t - \mu \cot\beta = 2M_{susy}$
•$M_{gluino} = 0.8\ M_{susy}$
•**M_A =4 -1000 GeV**
•**$\tan_b$ =0.4 -50**

Pythia jargon:
Top trilinear coupling
RMSS(16)=2440.
Bottom & tau trilinear coupling default value

Motivation

- The h_0 Supersymmetric Higgs Boson discovery in the channel **bb h_0/A** $\rightarrow$ $\mu^+ \mu^-$ in the region of high tan $\beta \sim 15$–50 and $m_{h0} \sim 100$ -130 GeV.

- In a large region of interesting parameter space

A and h_0 are indistinguishable

$m_A - m_{h0} \sim 0.1$ - 3 GeV (mass range 95-130 GeV)

$\Gamma_A - \Gamma_{h0} \sim$ 0.1- 2 GeV (mass range 95-130 GeV)

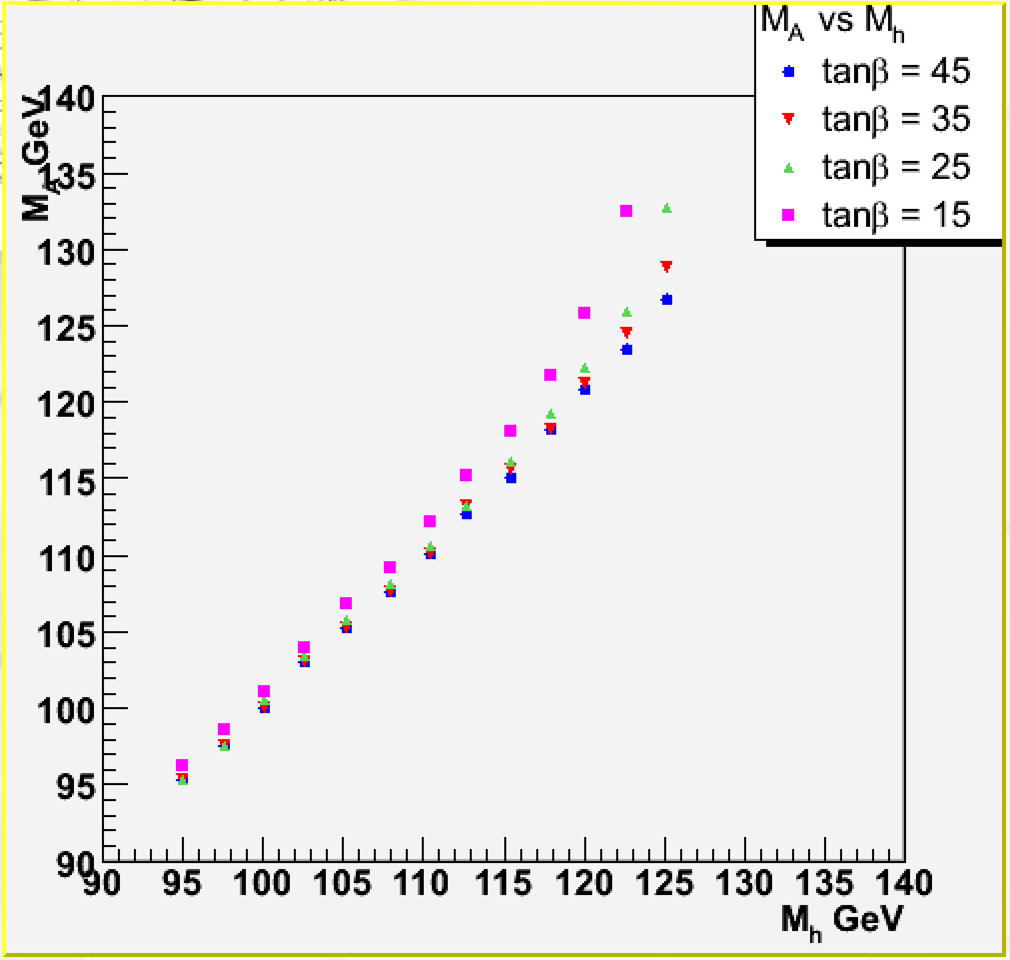
$\sigma_A \sim \sigma_{h0}$ 0.1- 0.2 pb

➢**Search for supersymmetric neutral Higgs h in the decay $\rightarrow \mu^+ \mu^-$ in ATLAS detector at LHC.**

Simonetta Gentile, Mercedes Paniccia, Paolo Violini, ATLAS-PHYS-2003-015, June 2003.

M_A and M_h below 130 GeV

Pythia 6.226



- The mass

M_A , M_h boson are very close

- The width

$\Gamma_A \approx \Gamma_h$

- The cross section:

$\sigma_A \approx \sigma_h$

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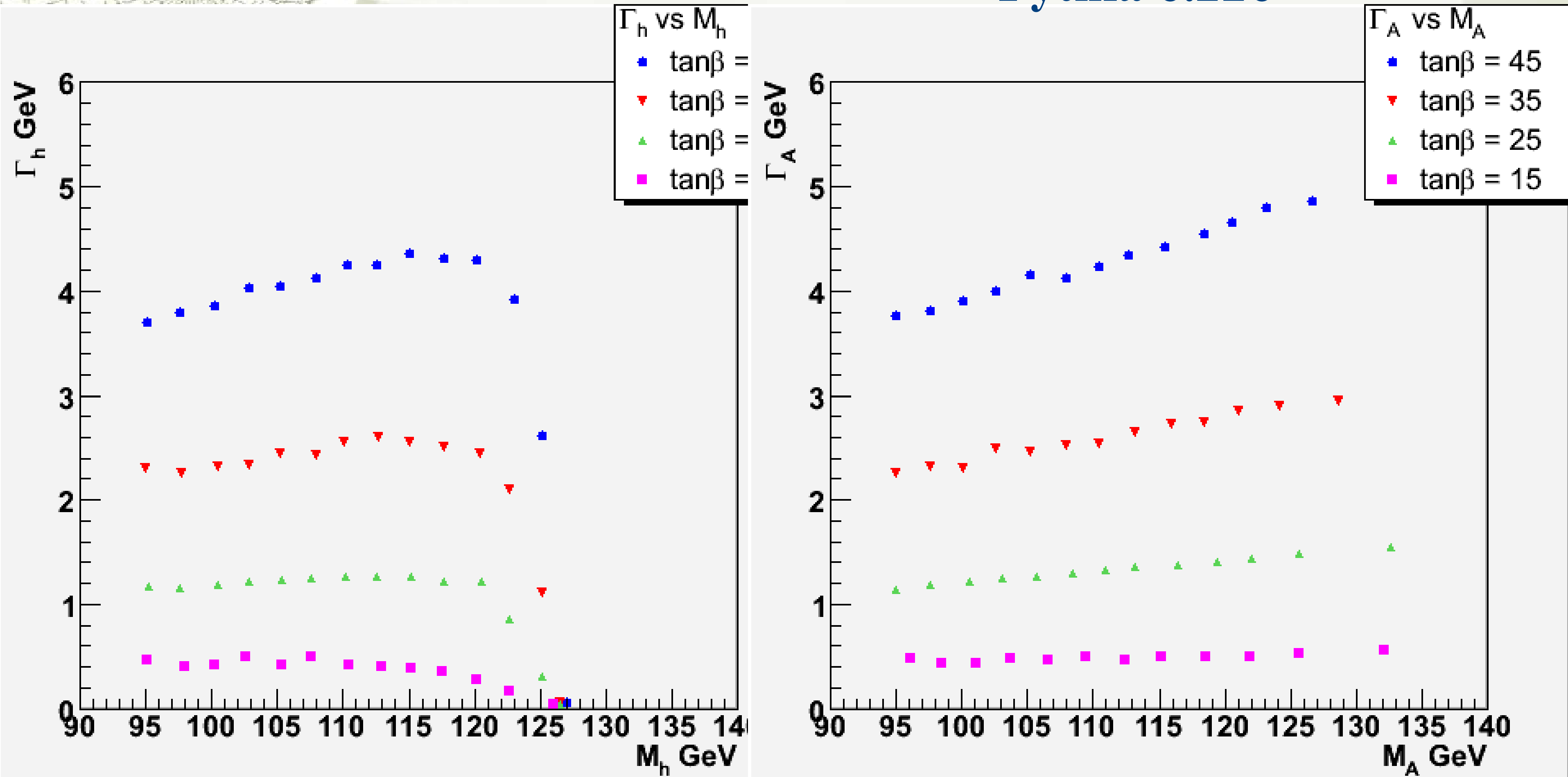
The width: Γ_h, Γ_A

Pythia 6.226



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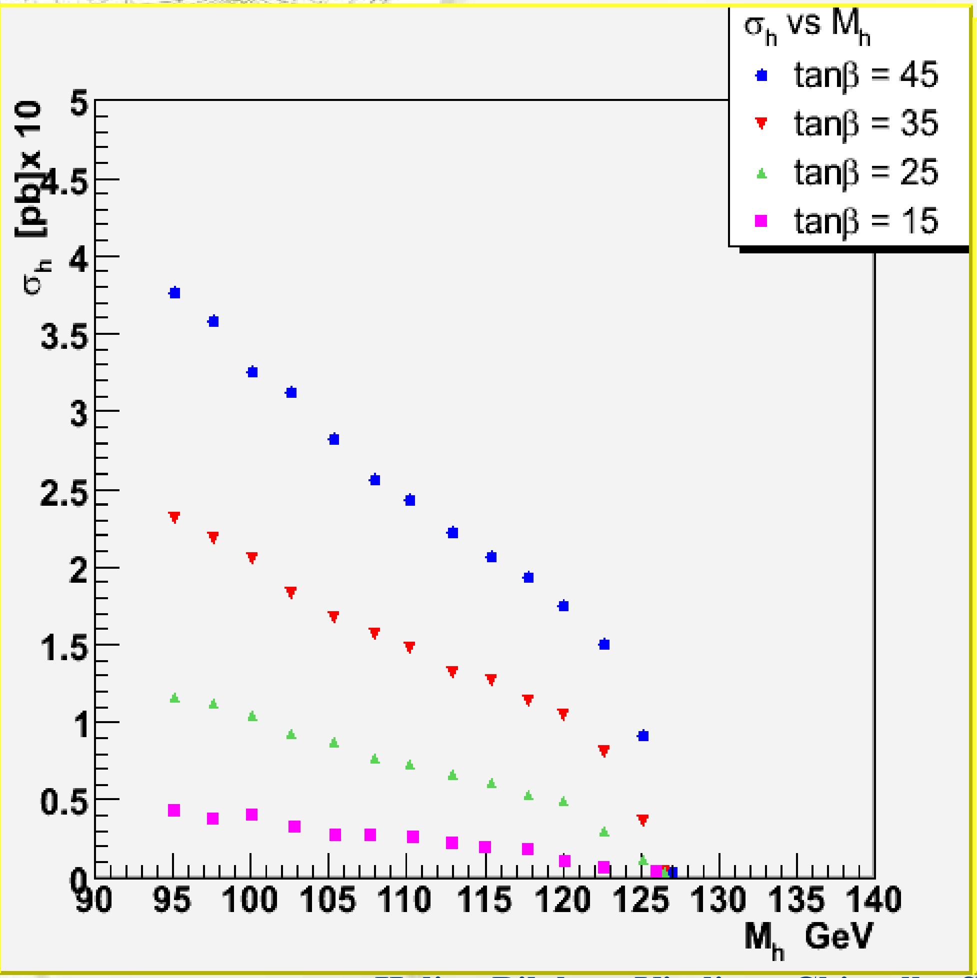
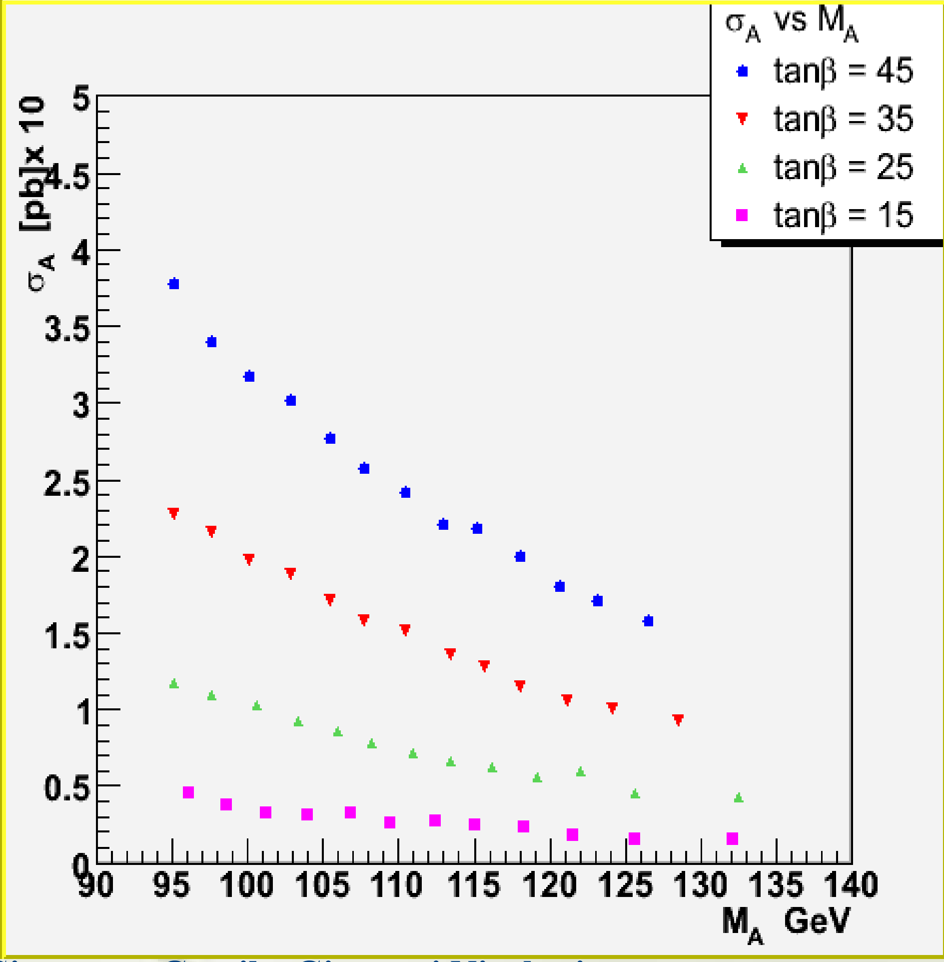
The cross sections: σ_h σ_A

Pythia 6.226





Signal & background proces

- **Signal**
  Pythia 6.226

  $h_0 \rightarrow \mu^+ \mu^-$ and bb
  $A \rightarrow \mu^+ \mu^-$ and bb

  $\sigma \sim$ 0.2 - 0.01 pb (even lower)

- **$Z/\gamma^* \rightarrow \mu^+ \mu^-$ and bb**
  σ*br($Z \rightarrow \mu^+ \mu^-$ and bb) (Pythia 6.226)
  AcerMC (v.2.3) interfaced with Pythia 6.2 (hep/ph0405247).

  $\sigma \sim$ 22.8 pb

- **($Z/\gamma^* \rightarrow e^+ e^-$ and bb for bg subtraction)**
- **tt $\rightarrow W^+ W^-$ bb $\rightarrow$ bb $\mu\nu$ $\mu\nu$**
  σ(tt) *br(t$\rightarrow$ bW)*br(W $\rightarrow \mu\nu$)*br(t $\rightarrow$ bW)* br(W $\rightarrow \mu\nu$)

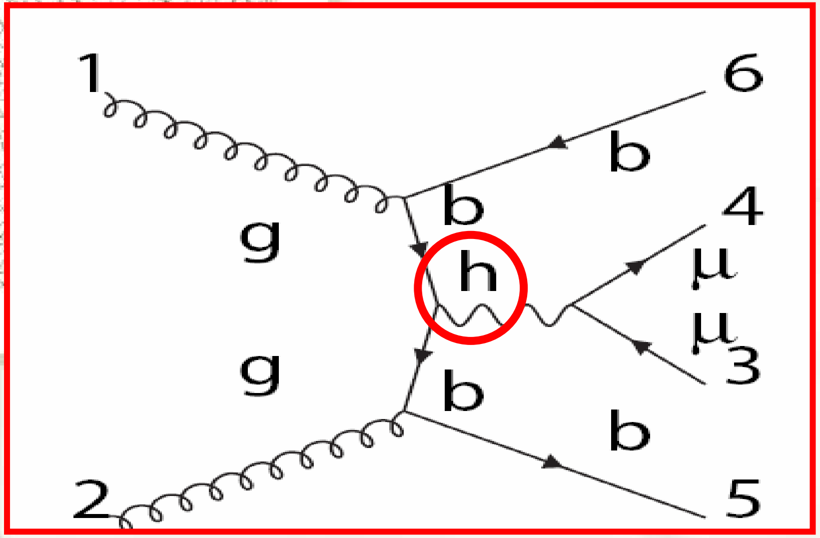
  Missing energy in the event

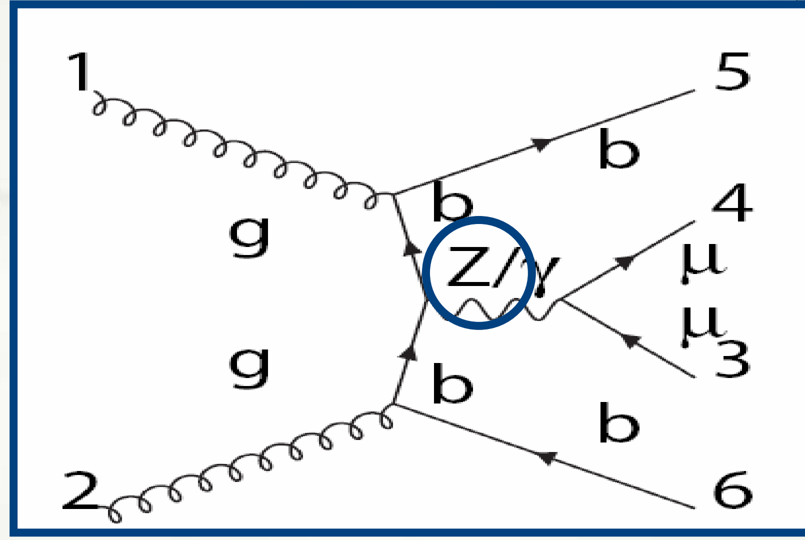
  $\sigma \sim$ 5.70 pb

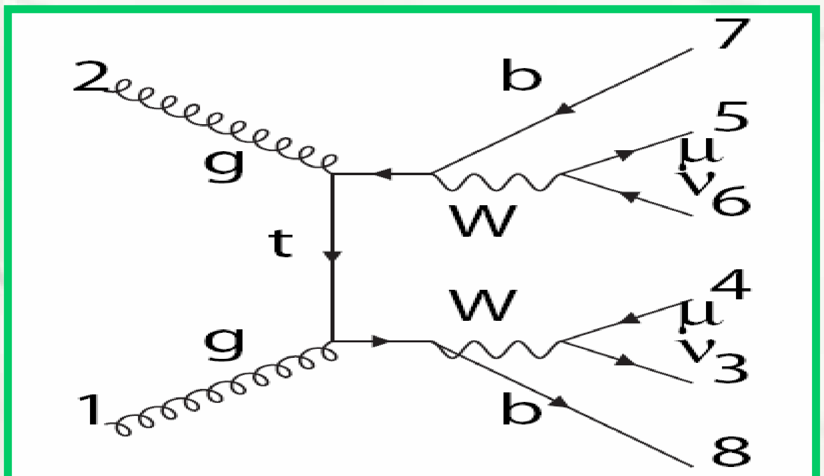
- **ZZ $\rightarrow \mu^+ \mu^-$ and bb :**
  σ*br(Z $\rightarrow \mu^+ \mu^-$) σ*br(Z$\rightarrow$ bb)
  Same order of magnitude of signal.
  Reduced by kinematical cuts.

  $\sigma \sim$ 0.13 pb

Signal & background







- **h_0 bb→ $\mu^- \mu^+$bb**
- **Zbb → $\mu^- \mu^+$ bb**
- **tt missing energy**

Final state
2 b-jets and
2 μ (or 3-4)

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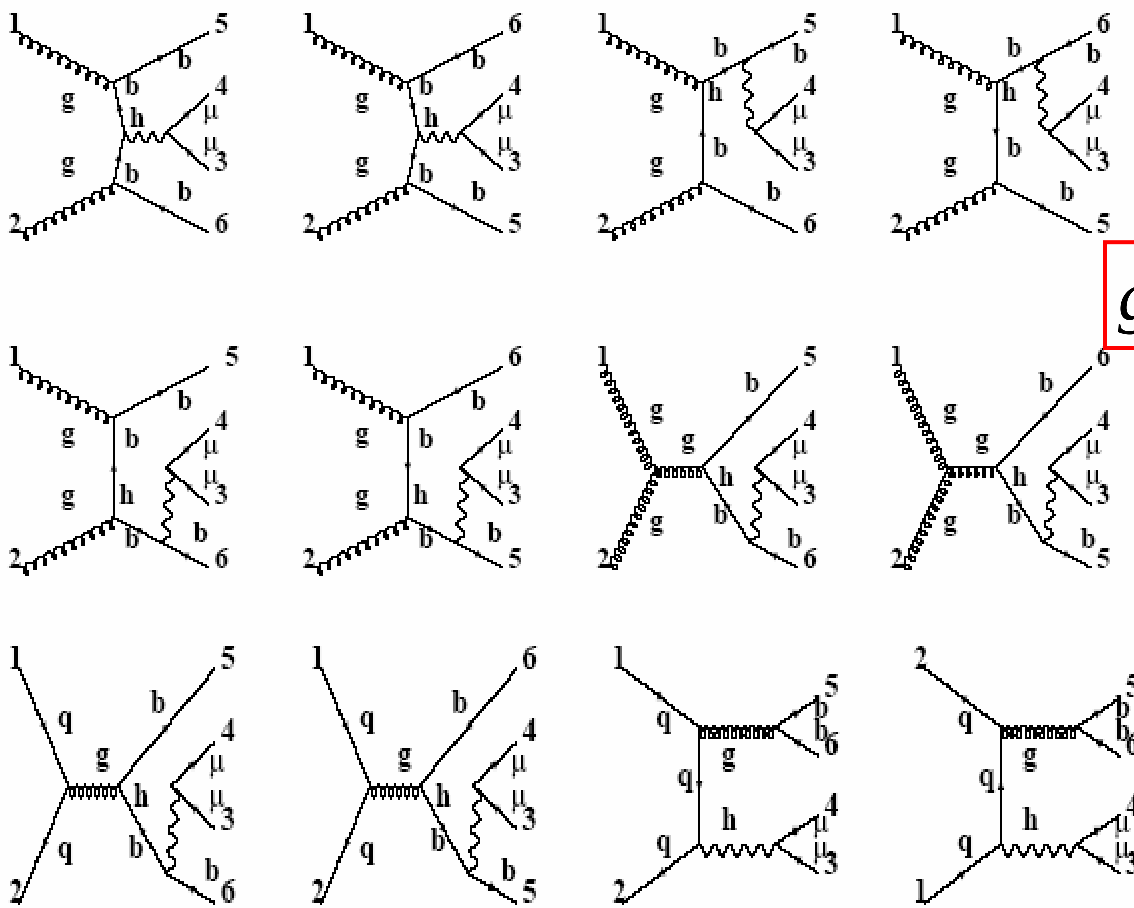
Higgs Meeting 14 December 2005,CERN.

h_0 production



$$gg \to hb\bar{b} \to \mu^+\mu^- b\bar{b}$$

$$q\bar{q} \to hb\bar{b} \to \mu^+\mu^- b\bar{b}$$

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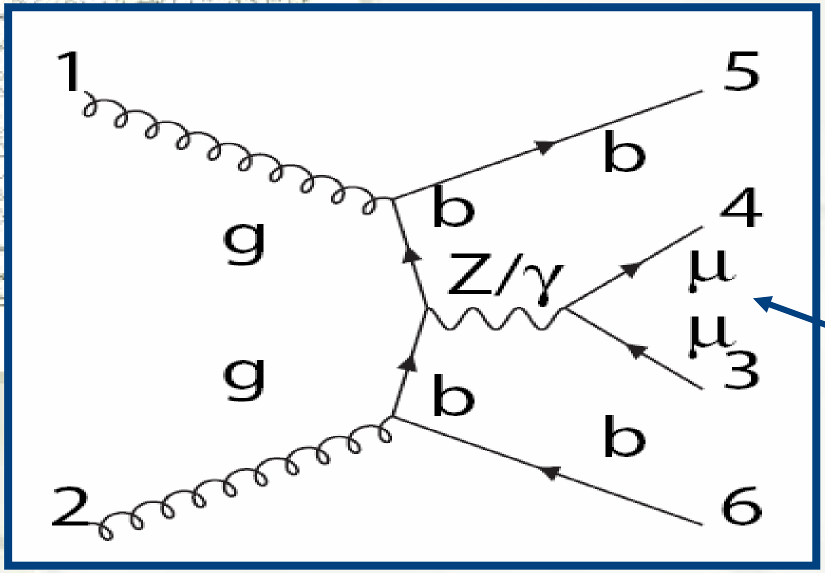
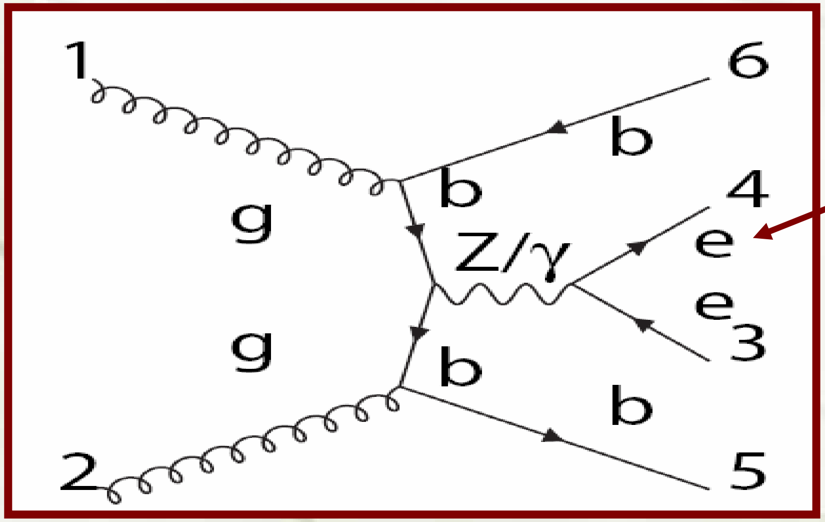
Higgs Meeting 14 December 2005,CERN.

Background Subtraction Method





Precise Knowledge of background is crucial

- Experimental method proposed based on $Z \to \mu^+ \mu^-$ and $Z \to e^+ e^-$
- Relying on experimental data
- **Br($h_0 \to e^+ e^-$) neglegible**

$$\propto \left(\frac{m_{\mu}}{m_{e}} \right)^2$$

- **Different Inner Bremhstrahlung**

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Sample

Data taking scenario:

$$\int Ldt = 30\ fb^{-1}$$

- Signal **$h_0 \rightarrow \mu^+ \mu^-$** and bb : 8 points tan β[15,50]
  13 point of mass: m_A [95,130]

- Signal **A** $\rightarrow \mu^+ \mu^-$ and bb : 8 points tan β[15,50]
  13 point of mass: m_A [95,127]

- **bbZ** $\rightarrow bb\mu^+ \mu^-$
- **tt** $\rightarrow$ **W^+W^-bb** $\rightarrow$**bb** $\mu\nu\mu\nu$
- **ZZ** $\rightarrow \mu^+ \mu^-$ **bb**

← **New**

Test point:

tanβ =45 , m_{h0} = 109.25 GeV, Γ_{h0} = 3.31 GeV, σ_{h0} = 0.20 pb

tanβ =45 , m_A = 110.30 GeV ,Γ_A = 4.28 GeV, σ_A = 0.23 pb

Software Release & Sample

- Generation Athena 9.0.4 - Pythia (v.6.226) - Acer (v. 2.3)
- Simulation, Digitalization, Reconstruction Athena 10.0.1
- Analysis based on CBNT (root –ntuples).
- **Final study in L_{int} =30 fb^{-1} scenario**.
- Aim : signal MC x L_{int} x10
- : background MC x L_{int} x (5-10).
- Sample of **used events in this presentation** $\int L dt = 30\ fb^{-1}$
- **Technical problem: since 11 October most of dig/recostruction jobs fail for Database problem.**

Software Release & Sample

process	L=30fb^{-1}	gen	simul	recon	**This presentation**
h_0	**up to ~ 15 10^3 each point**	**Up to ~ 150 10^3 each point**	**~800.000**	**~100.000**	Test point **6000**
A	**up to ~ 15 10^3 each point**	**Up to ~ 15 10^3 each point**	**~800.000**	**~100.000**	**Test point 7000**
Zbb	**680000**	**3.4 10^6**	**3.4 10^6**	**~3.410^6**	**340.000**
ttbb	170000	1.8 10^6	1.3 10^6	~ 1.0 10^6	170000
ZZ	**3800**	**1.0 10^5**	**1.0 10^5**	**~ 1.0 10^5**	**3800**
Zee		**75000**	**75000**	**~ 50000**	

back ground studies

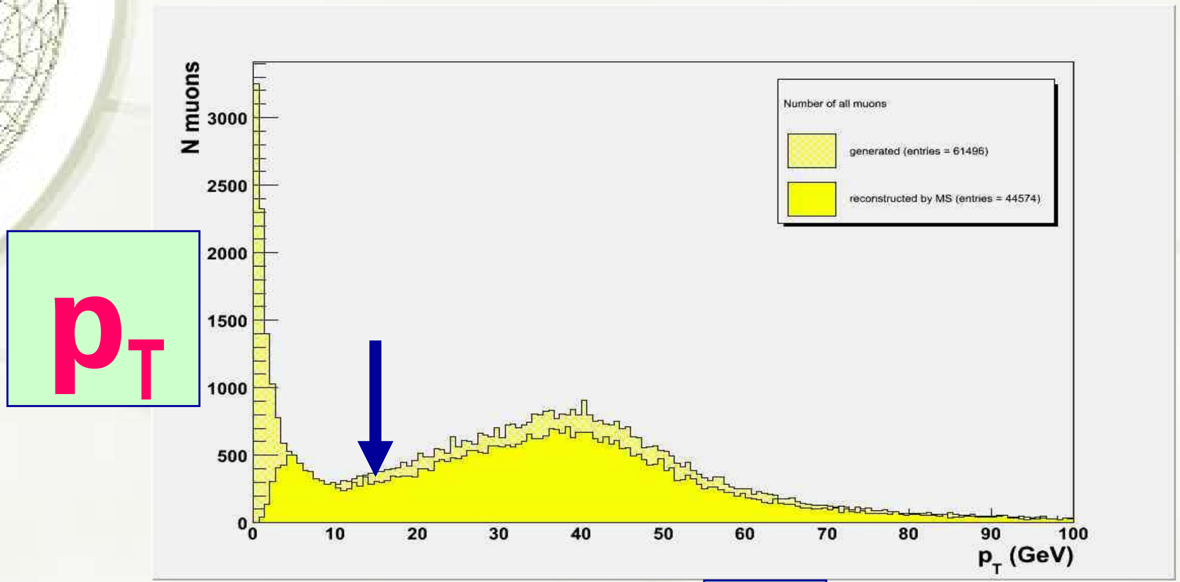
Reconstruction performances

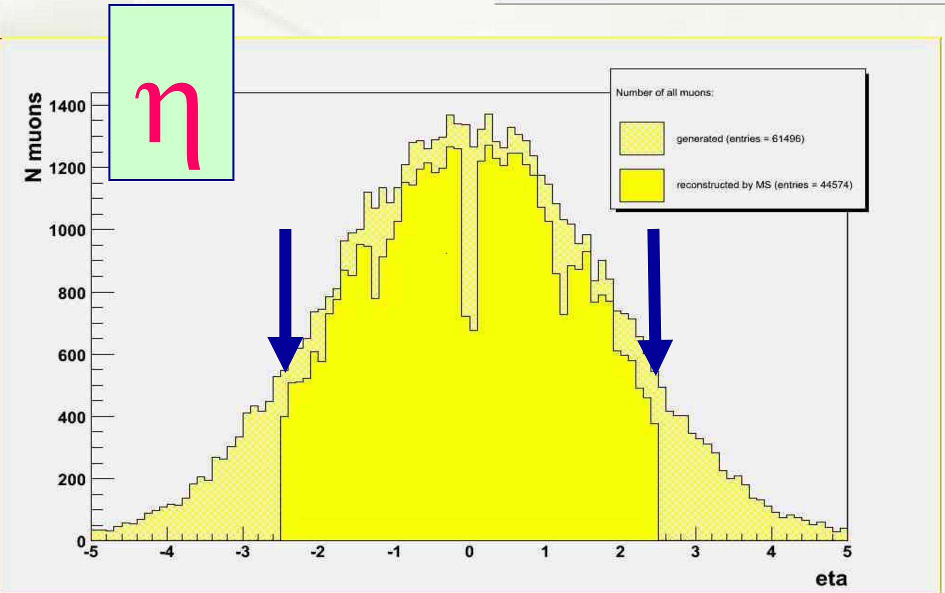
The two critical point of this analysis are:

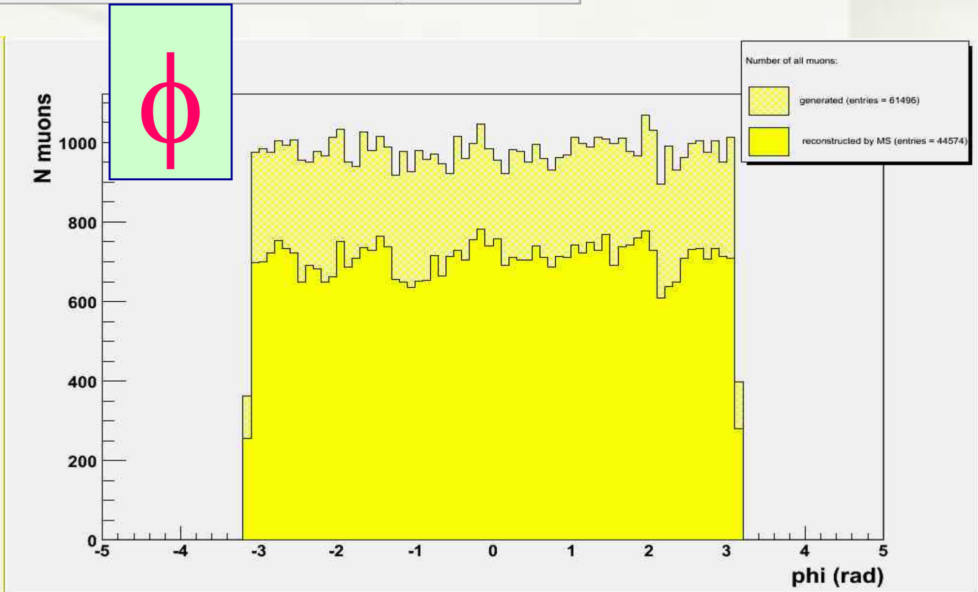
- Muon reconstruction: efficiency & mass resolution (from a student work Enrico Pomarico)
- b-tag

They deserve a preliminary study.

Combined muon reconstruction

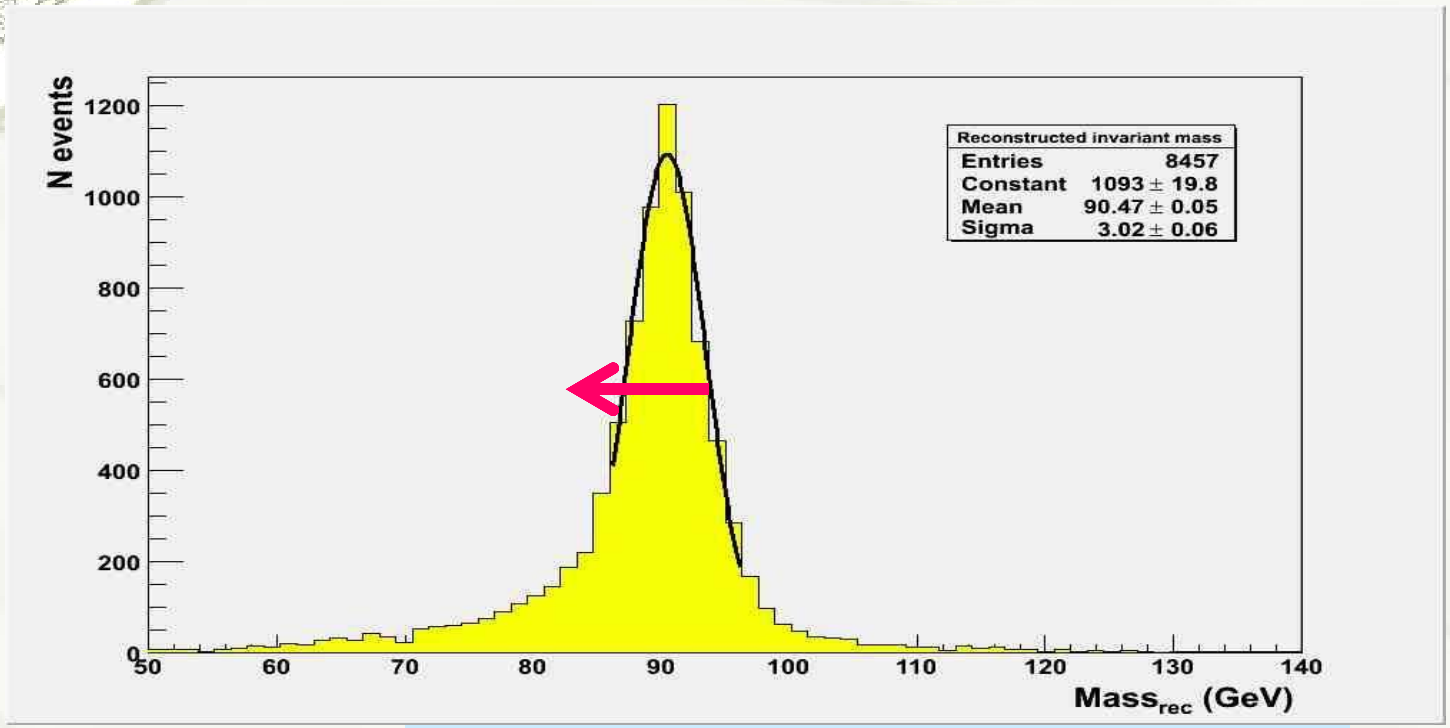






Reconstructed invariant mass

Only 2 μ opposite charge: $|\eta| < 2.5$ $p_T > 15$ GeV.



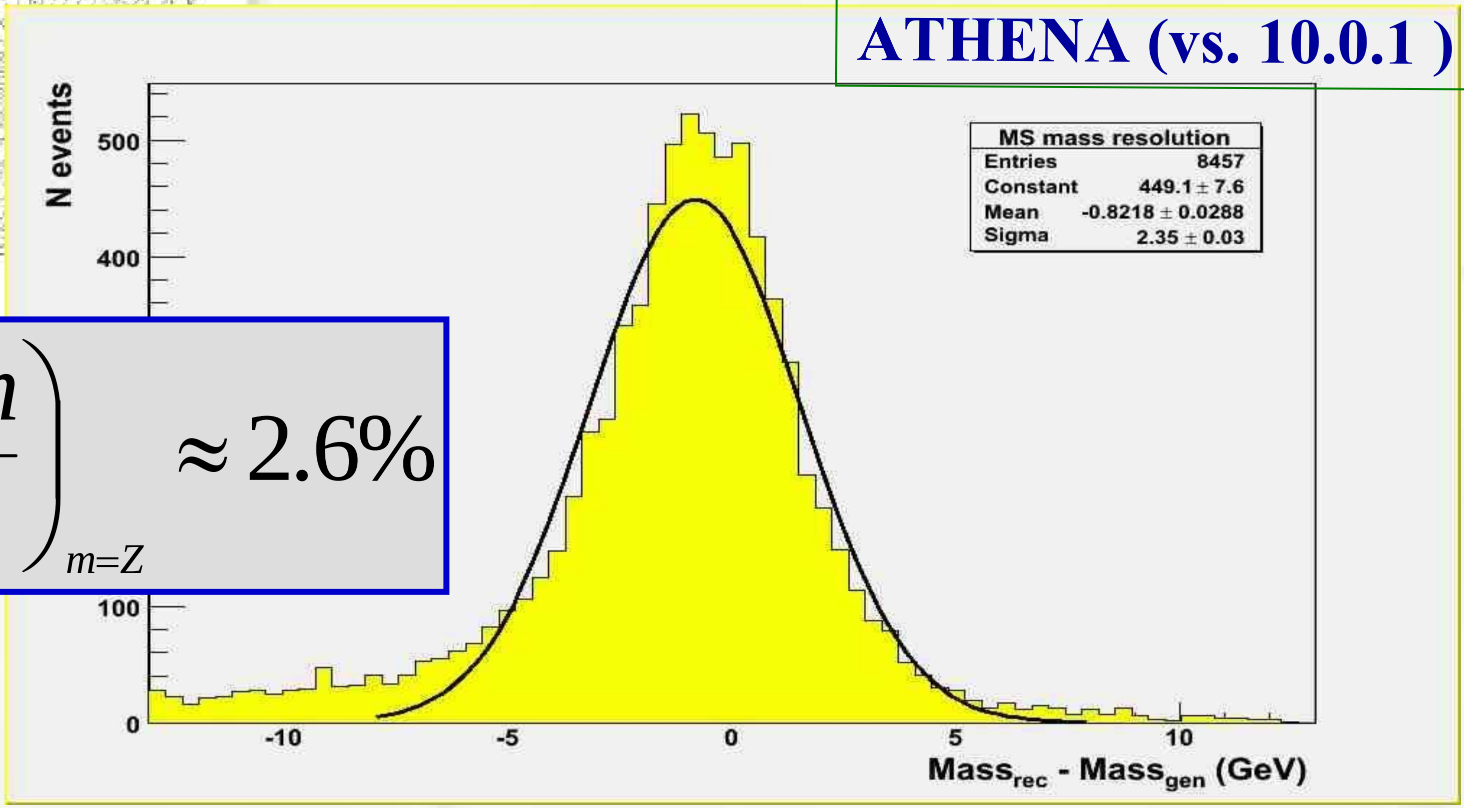
gaussian fit :

$M_{rec} = 90.47 \pm 0.05$ GeV

$\sigma_{rec} = 3.02 \pm 0.06$ GeV

Mass resolution combined reconstructed muons

ATHENA (vs. 10.0.1)



$$\left(\frac{\Delta m}{m}\right)_{m=Z} \approx 2.6\%$$

Gaussian fit:

$$\overline{M_{rec} - M_{gen}} = -\,0.82 \pm 0.03 \text{ GeV}$$

$$\sigma_{RES} = 2.35 \pm 0.03 \text{ GeV}$$

Author:
Enrico Pomarico
bachelor student

b-tagging

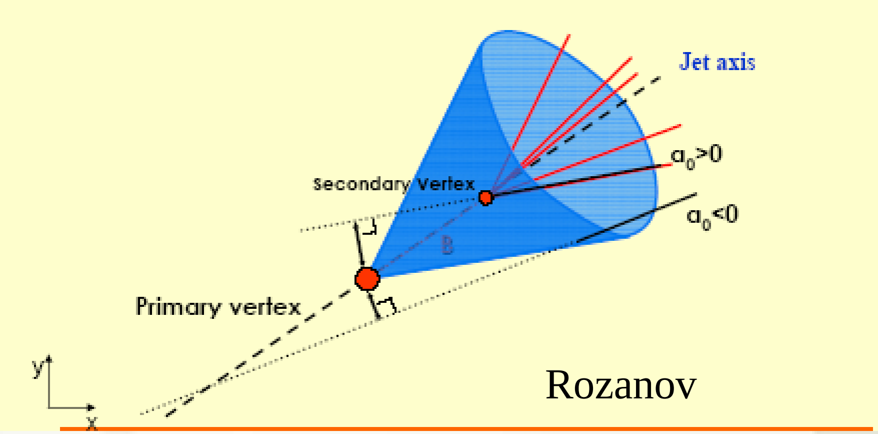
The b-jet tag is an crucial part of this work

few algorithms are available in ATLAS

- **3D** based on transverse (2D) and longitudinal (+1D) impact parameter
- **SV2** 3D impact parameter + information on secondary vertex (as energy, fraction tracks, mass)

•Efficiency of b-jet tagging ε_b

•Rejection of light jets (udsc) R_j

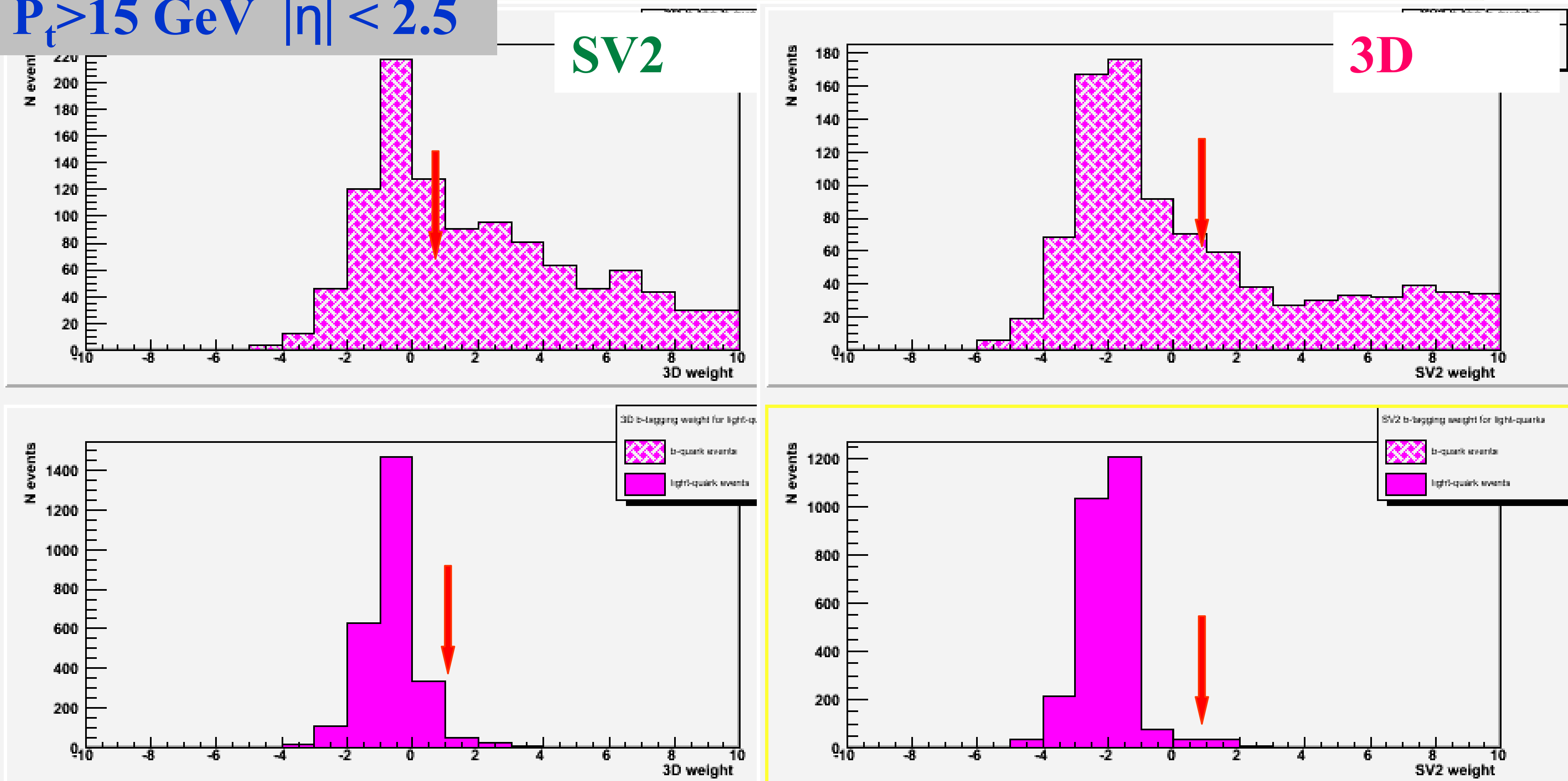


Thanks to Vadim Kostyukhin

b-tag on bbh_0

$$\Delta R = \sqrt{\Delta\eta^2 + \Delta\varphi^2} = 0.7$$

$P_t > 15$ GeV $|\eta| < 2.5$



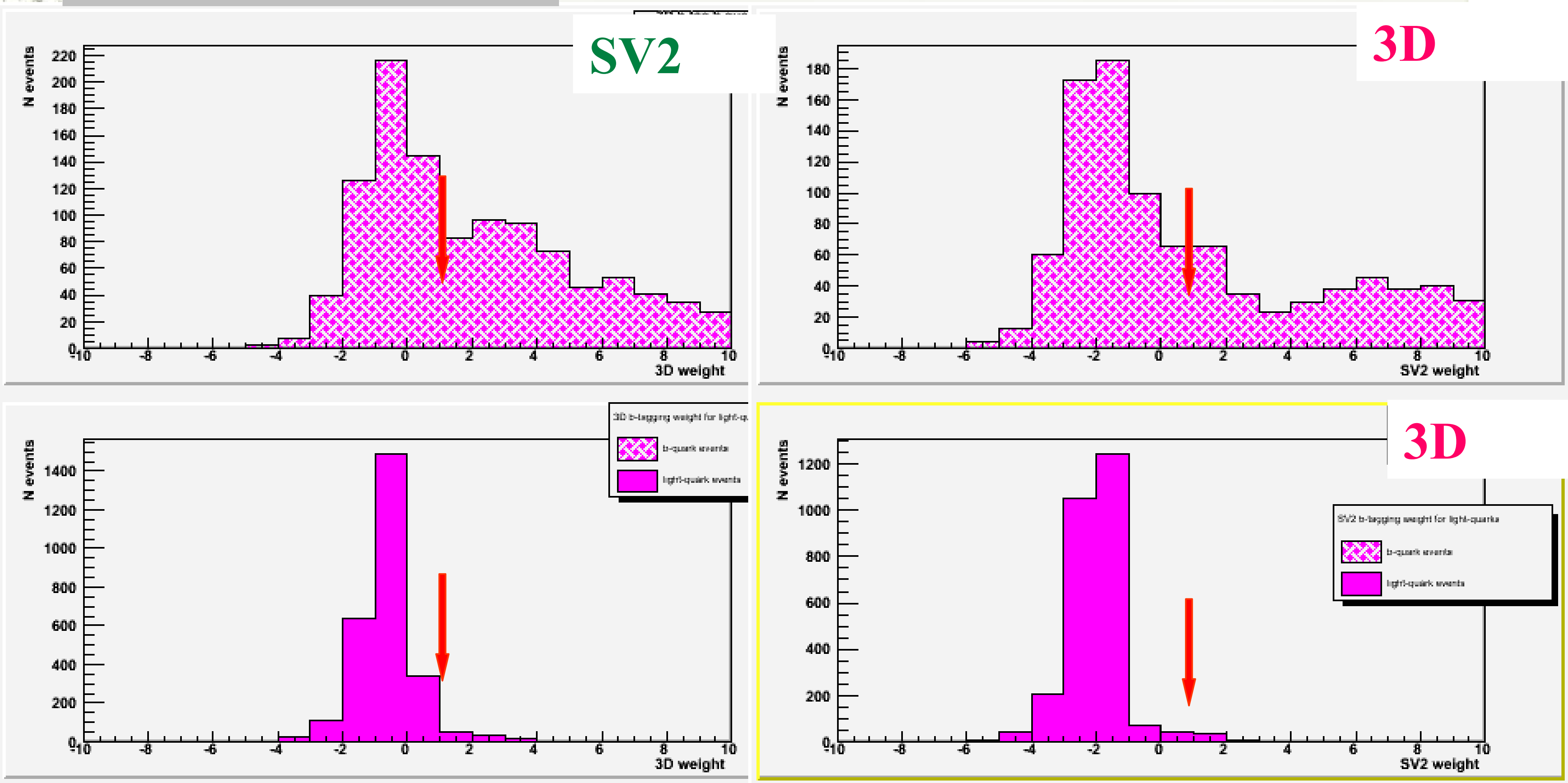
- Efficiency of b-jet tagging ε_b: **49% SV2 , 55% 3D**
- Rejection of light jets (udsc) R_j **:71 SV2, 27 3D**

Weight cut 1

b-tag on bbh_0

$$\Delta R = \sqrt{\Delta\eta^2 + \Delta\varphi^2} = 0.4$$

$P_t > 15$ GeV $|\eta| < 2.5$



- Efficiency of b-jet tagging ε_b: **50% SV2 , 54% 3D**
- Rejection of light jets (udsc) R_j **:58 SV2, 26 3D**

Weight cut 1

btag -performance

- ΔR =0.7 weight =1

Algorithm	ε_b	R_j
SV2	**49%**	**71**
3D	55%	27

- ΔR =0.4 weight =1

Alghoritm	ε_b	R_j
SV2	50%	58
3D	54%	26

- ΔR =0.7 weight =2

Alghoritm	ε_b	R_j
SV2	**46%**	**219**
3D	49%	52

- ΔR =0.4 weight =2

Alghoritm	ε_b	R_j
SV2	46%	200
3D	49%	50

b-tag

- No major improvement in changing cone width (ΔR=0.7, ΔR=0.4); natural choice ΔR =0.7 (default value ATHENA (vs. 10.0.1).
- A study vs. weight cut w = 2 brings to better R_j for light quarks at price of b-tag efficiency.
- The study has been done on h_0bb sample and Zbb with similar conclusions.
- Warning: these efficiency have been evaluated "*à la mode* "of b-tagging group, for comparison performance

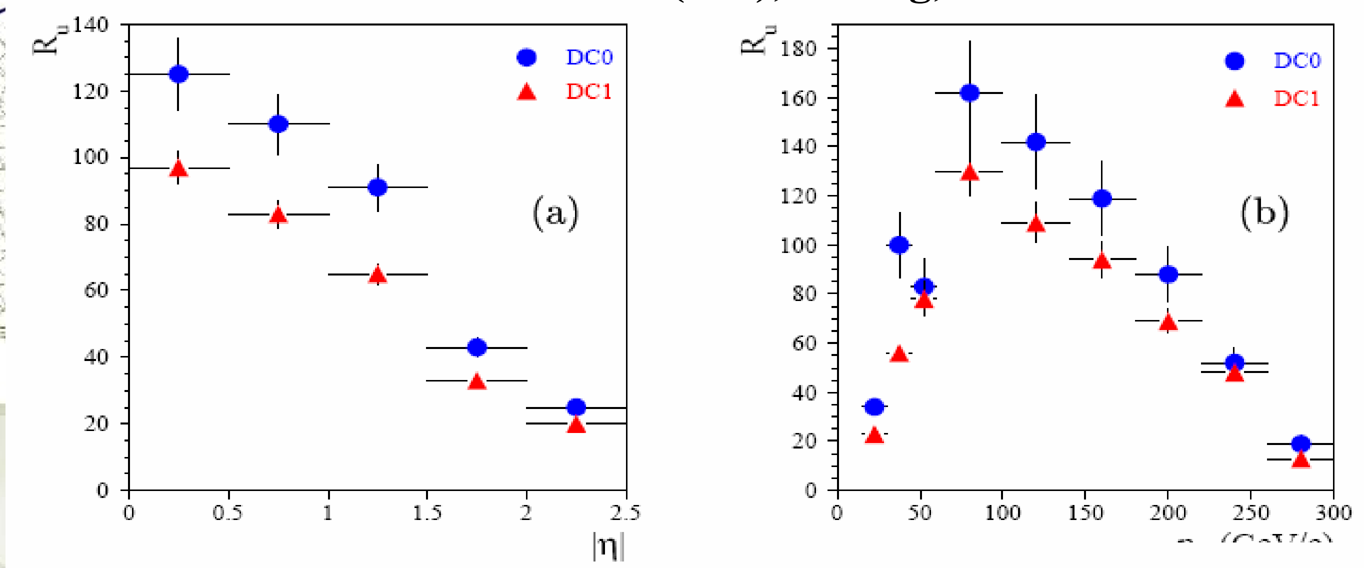
no b-quark in a cone ΔR=0.6 around light quark jet

p_T>15 GeV $|\eta|$< 2.5 , at least, 1 track in jet

- SV2 algorithm is more promising: **good b tag efficiency**: ε_b, and **better rejection factor for light quarks** :Rj **Provisional choice SV2 alghoritm (cut weight 1)**

b-tagging at different P⊥ & η

WH(400), 2D-alg, 60% eff.



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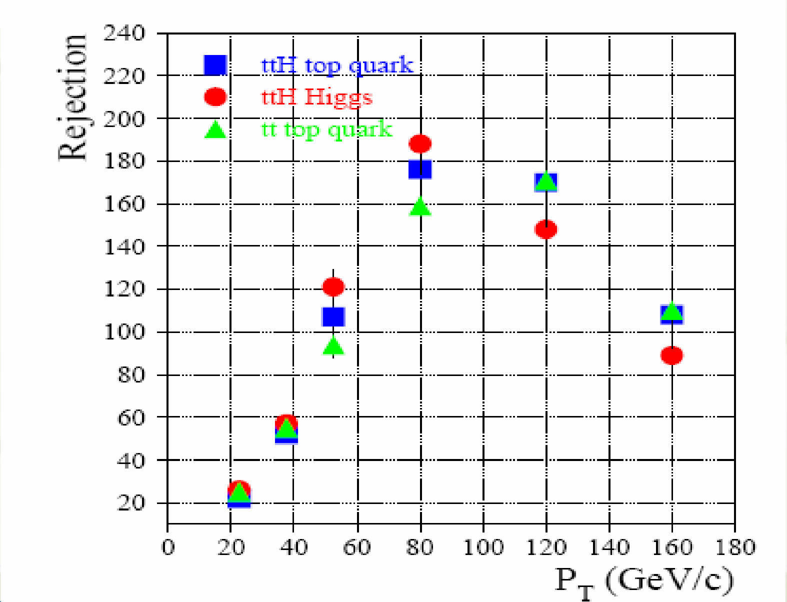
ATL-PHYS-2004-006,
"b-tagging with DC1 data"



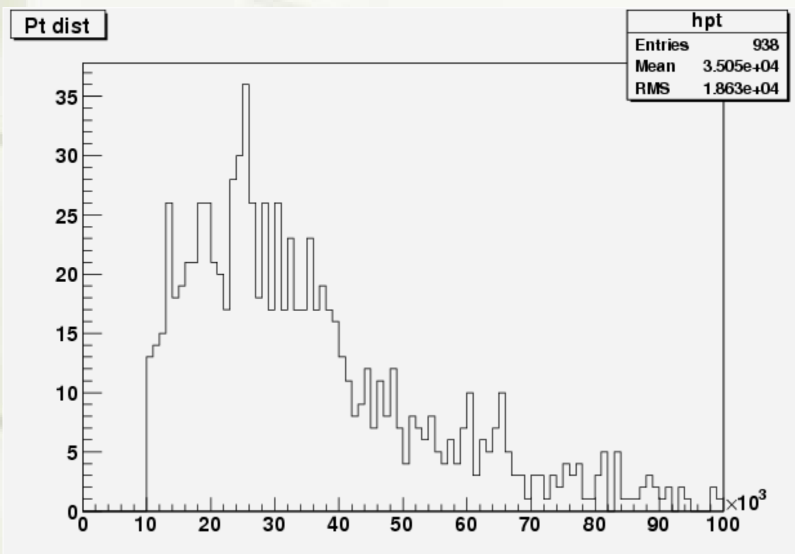
"Bad" regions for b-tagging:

1. **$P_\perp$<40 GeV**
2. **$P_\perp$>250 GeV**
3. **|η|>2**

Example: $h_0$bb system

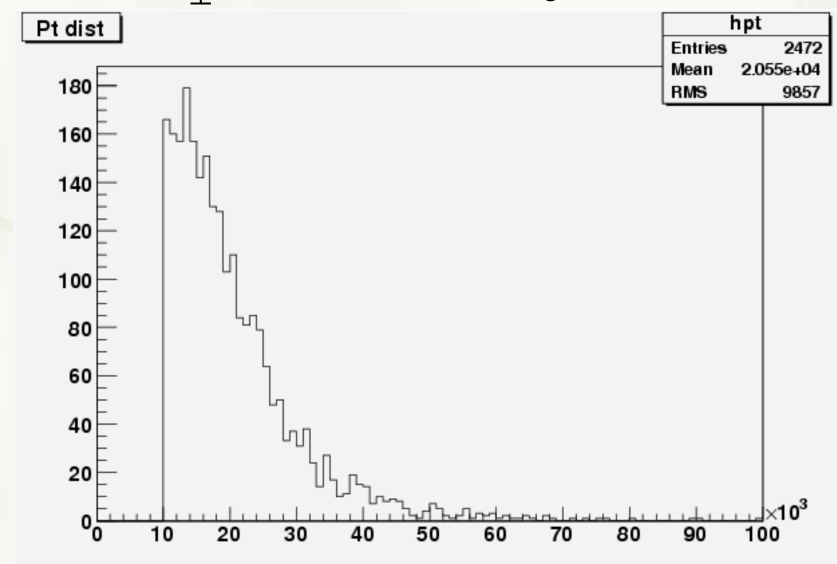
- The h_0 Supersymmetric Higgs Boson discovery in the channel **bb** **h_0** $\rightarrow$ $\mu^+ \mu^-$ in the region of high tan $_b$ ~ 20 and mh_0 ~ 110 GeV .

$P_\perp$ of labeled b-jets



MeV

$P_\perp$ of labeled u,d,s-jets



MeV

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$h_0 bb$ system

Number of "good" tracks in jet

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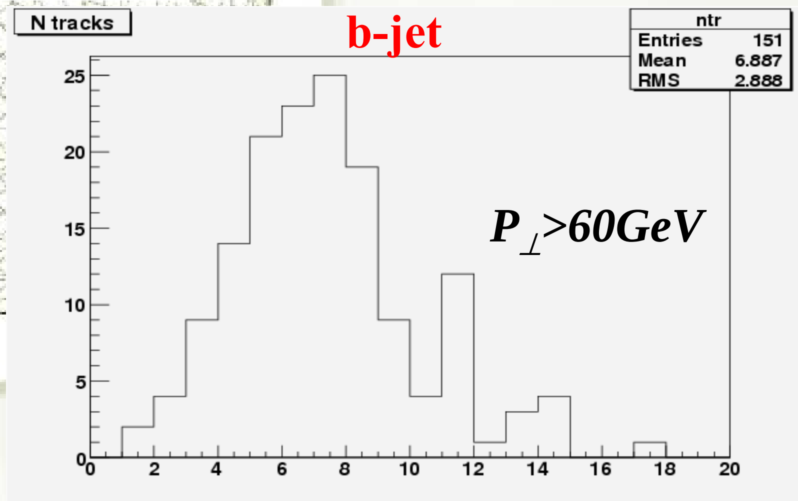

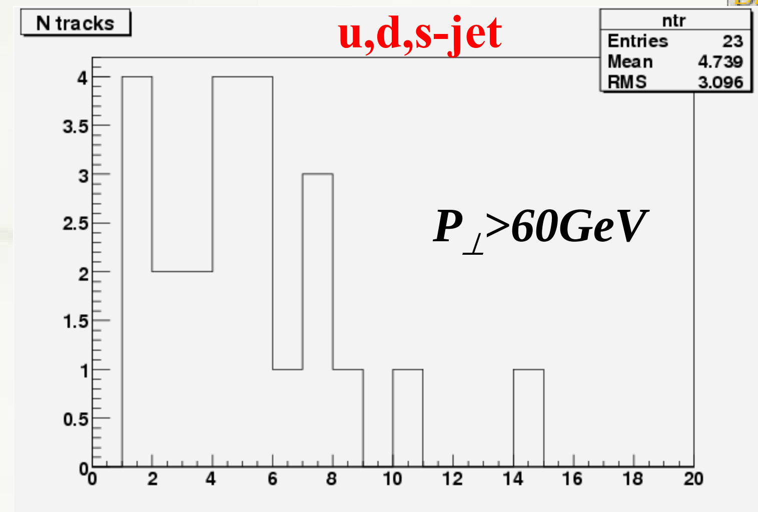

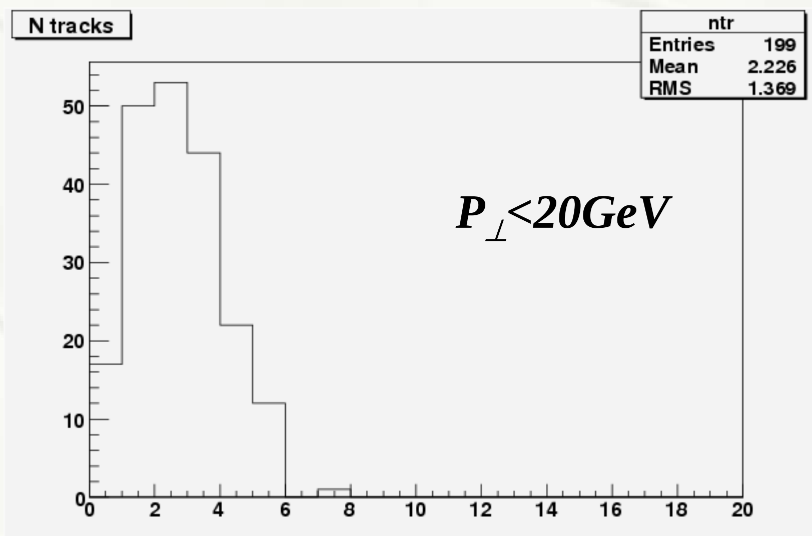

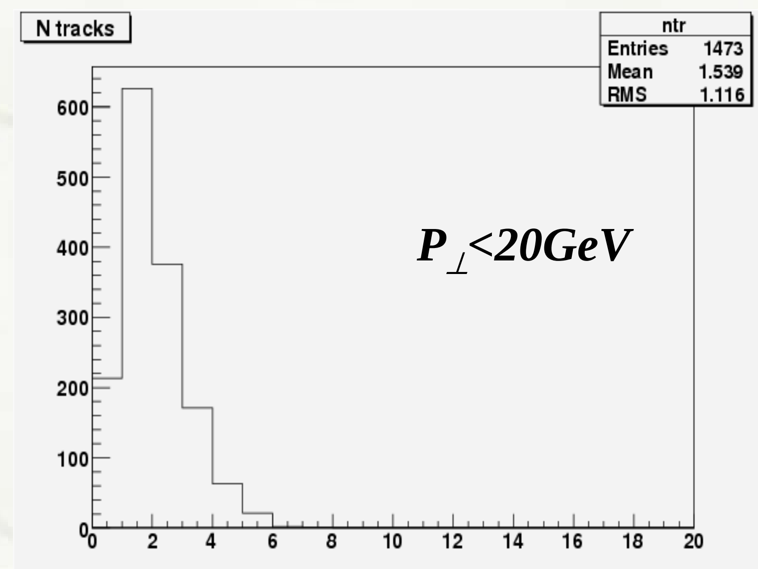

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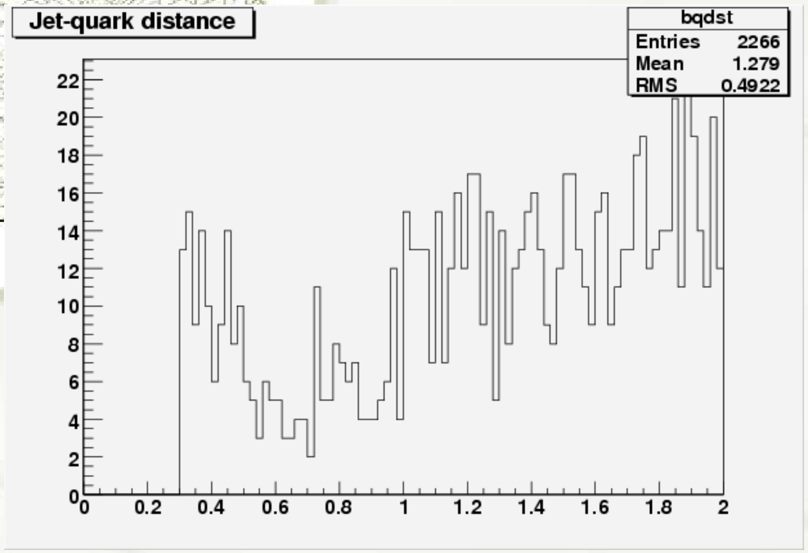
h_0bb system light jet rejection

Jet-bquark distance, jets marked as u,d-jets, $P_\perp$<30 GeV



Still problem with labeling in CALO jets reconstruction. Safe jet-bquark distance for labeling is 0.5!!!
Default in RecExCommon will be changed.

Rejection $N_{track\_in\_jet}$>0, 10<$P_\perp$<20 GeV, WgtSV2>2, BqDst>0.5 180 (210 with N_{tr}=0 jets)

to limit occasional coincidence between light jet and b-quark directions.

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Further study on b-tag

1. B-tagging performance (contrary to TDR expectation 100 at 60% everywhere) is NOT UNIFORM.
2. Regions with very low performance are:
   1. *$P_{\perp}$>250 GeV*
   2. *$P_{\perp}$<40 GeV* ⬅
   3. *$|\eta|$>2*
3. One should be careful when applying the "real" b-tagging because b-tagging efficiency curve modifies the P⊥ and η distributions of jets and thus changes the kinematical properties of events.
4. For the moment there is no any easy way to recuperate efficiency of b-tagging in "bad" regions. More work is needed.

Vadim
Kostyukhin
25/10/2005

Conclusions

- MSSM h_0/A Higgs bosons have been generated, simulated and recontructed in $\int Ldt = 30\ fb^{-1}$ data taking scenario. Ten times the statistics is aimed for 8 points tan b[15,50] 13 point of mass: m_A [95,130]
- Muon recontruction efficiency & mass resolution at Z peak have been studied $\left(\frac{\Delta m}{m}\right)_{m=Z} \approx 2.6\%$
- Preliminary b-tag studies have been performed

•Efficiency of b-jet tagging ε_b: **49% SV2 algorithm**

Weight cut 1

•Rejection of light jets (udsc) R_j **:71 SV2 algorithm**