Jet reconstruction in LHCb searching for Higgs-like particles

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(on behalf of LHCb Collaboration)

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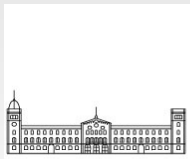

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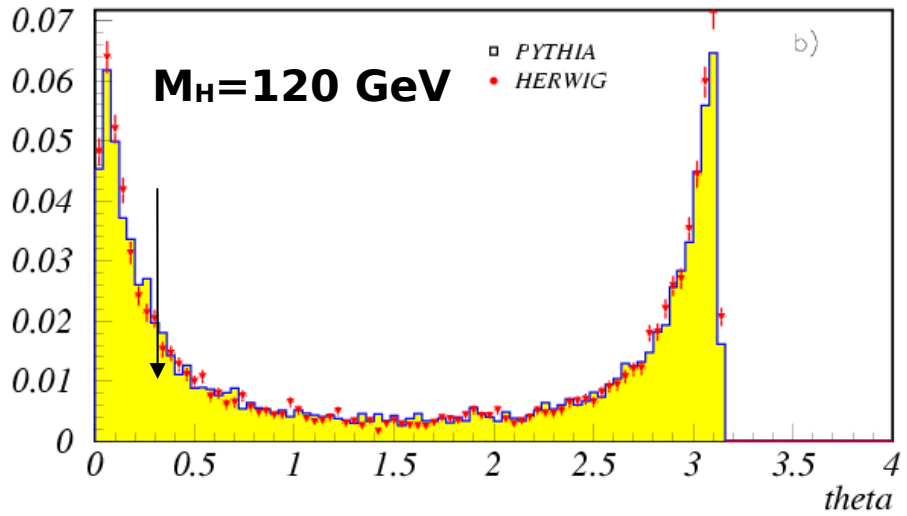
Motivation

Jet reconstruction is important for searches of particles involving b-jets and displaced vertices since LHCb has a very good b-quark trigger and identification, and will be well calibrated with the large number of B mesons.
Jets reconstruction is used in:

- **Standard Model Higgs** of light mass going to $b\bar{b}$

Precision EW fits give
M_H = 126 +73/-48 GeV
M_H < 219 GeV at 95% C.L.

~30% SM Higgs events are in LHCb acceptance

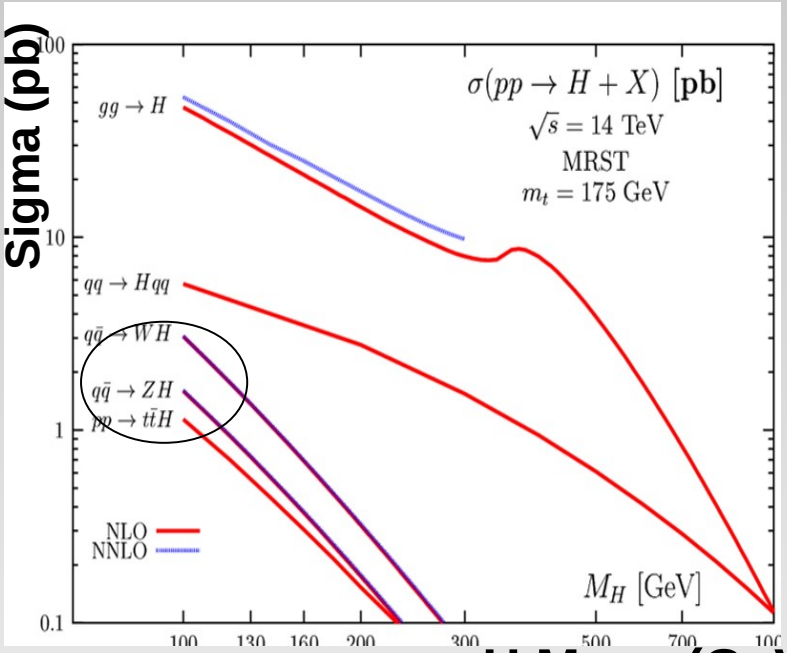


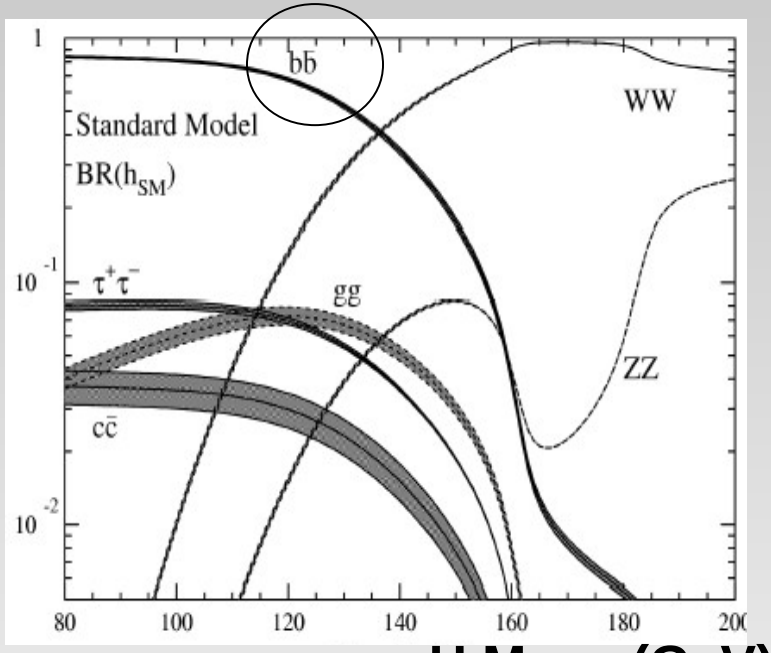
- **Hidden Valley Models**
- **SUSY models with long lived neutralinos**

This is a field of search which is outside the main LHCb scope, still the potentialities of the detector are worth being investigated

• Standard Model light Higgs

If one considers the associated Higgs production HW, HZ, for a SM Higgs:





$b\bar{b}$ dominant at low masses

SM predicts ~3 pb of HZ+HW at M_H=120 GeV -> about 100 evts in one year LHCb data

LHCb has good possibilities in triggering, reconstructing and tagging b-jets

LHCb has a very restricted forward acceptance

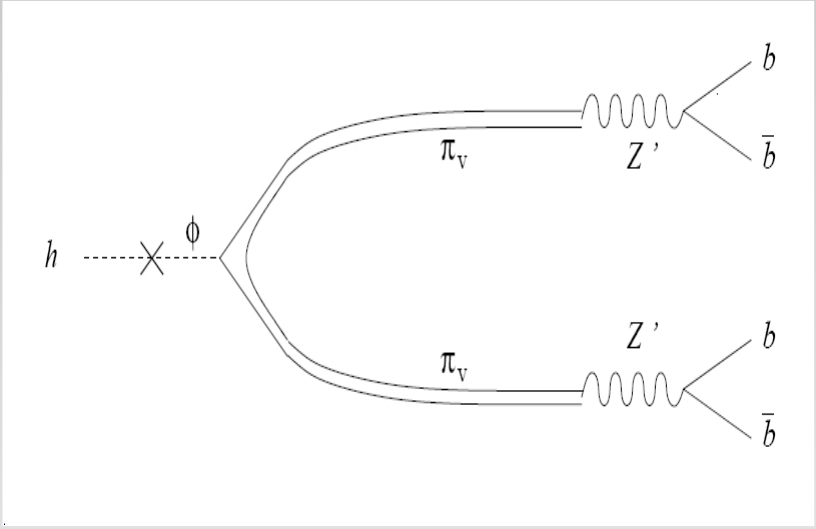
• Hidden Valley phenomenogical models

Sectors with non-abelian gauge group which couple weakly to the standard model via higher dimension operators

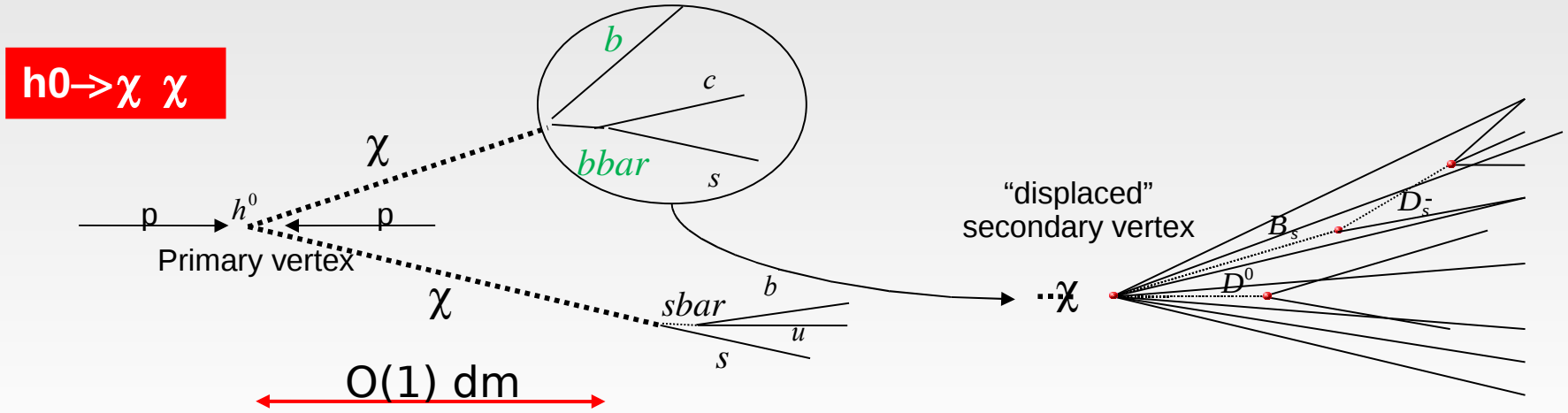
- several, possibly long-lived, v-hadrons, with masses typically of the order v-confinement scale Λ_v

- some v-hadrons may be stable, providing dark matter candidates and missing energy signals, while others decay to neutral combinations of SM particles

- decay lifetimes can vary over many orders of magnitude producing displaced vertices in the detector



• MSSM with R-parity violation models (hep-ph/0607204)



LHCb Overview

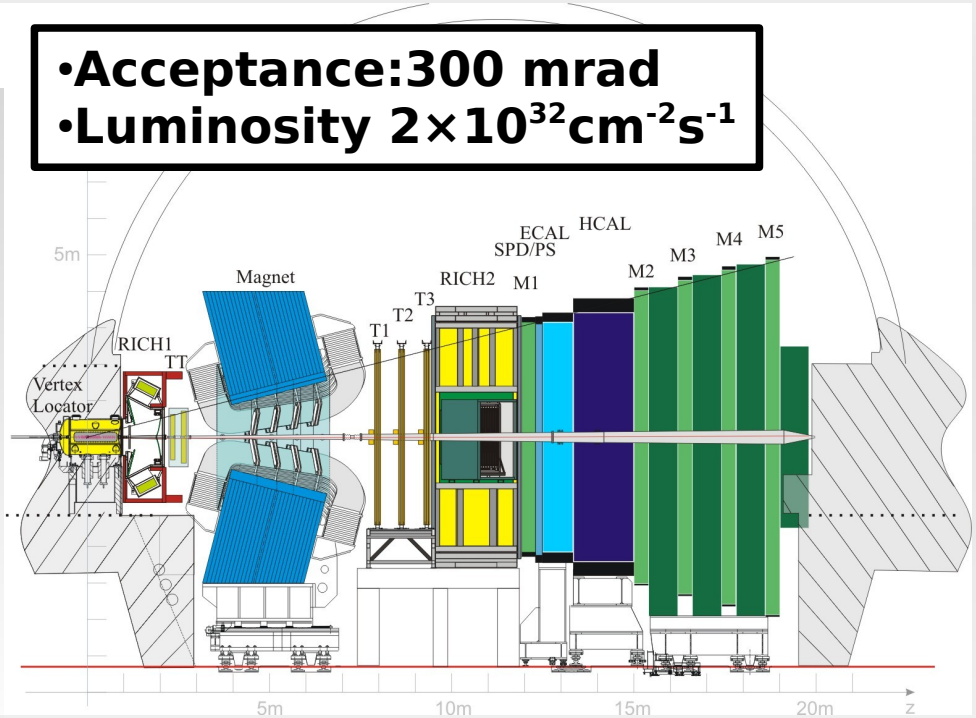
Single arm spectrometer
$B\bar{B}$ production correlated and peaks in the forward-backward direction

Produced B mesons are highly boosted
Average B momentum ~80 GeV

Access to all B mesons with huge statistics
even though $LHCb_{lumi} = LHC_{lumi}/50$
10^{12} $b\bar{b}$ pairs per year

✔ LHCb is good to find secondary vertices
✔ LHCb is good to select "prompt" muons

•Acceptance:300 mrad
•Luminosity $2\times10^{32}cm^{-2}s^{-1}$

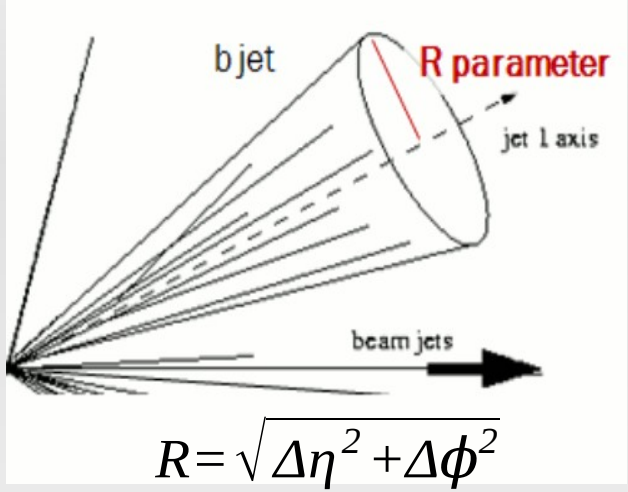


Precision Vertexing:
- Primary vertex resolution
  ~**10μm** transverse plane and
  ~**60μm** in the longitudinal direction
- Impact parameter resolution
  σ_{IP}=**14μm+35μm/pT**

Muon ID: ε = **89%** MisID=**2.3%**
Electron ID: ε = **94%** MisID=**0.7%**

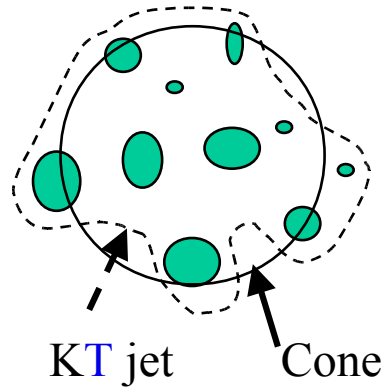
Jet algorithms

Nearness in angle
⇒Cone Algorithm.



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

Nearness in relative transverse momentum
=> Kt algorithm.



Reconstruction

Matching tracks and electromagnetic clusters

Use track and calorimetric information to build 4-MOMENTA

2 B-seeds from 2-tracks secondary vertex

B-seed finding

Cone algorithm with B-seed

2 b-jets/event created

B-jets

2-seed algo

Kt jet algorithm

B-jet tagging

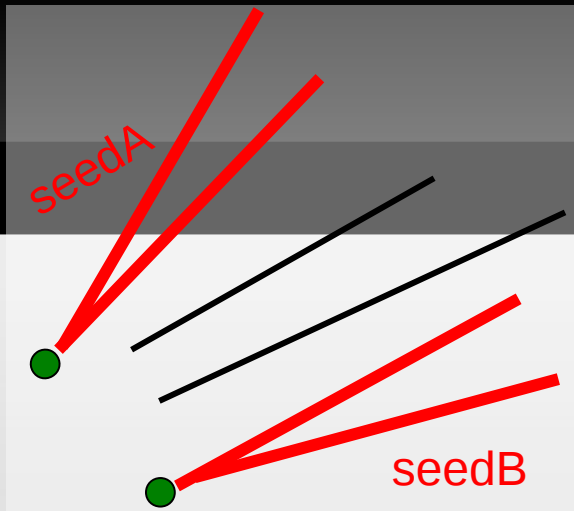
B-jets

Ideally 2 tagged jets/event

Kt algo

For R=0.5 ~15 jets/event reconstructed

LHCb Seed algorithm



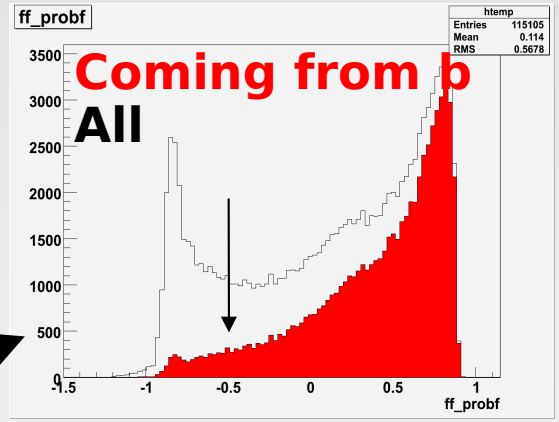
Track selection: build a 2-track vertex using cuts on

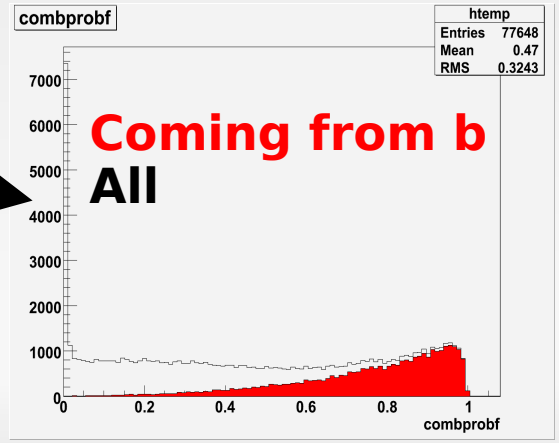
- χ^2 of tracking
- P>2 GeV
- IP/σ > 2.5, 2.8 (wrt **Primary Vertex**)
- Pt >0.6, 0.8
- K_S candidates are excluded in the mass window M=[0.490;0.505] GeV

Seeds selection. Select seeds on the base of a classifier using kinematic variables of tracks

Double-seed selection. Pairs of seeds are passed to a second classifier, pick up the best seeds pair candidate according to classifier output.

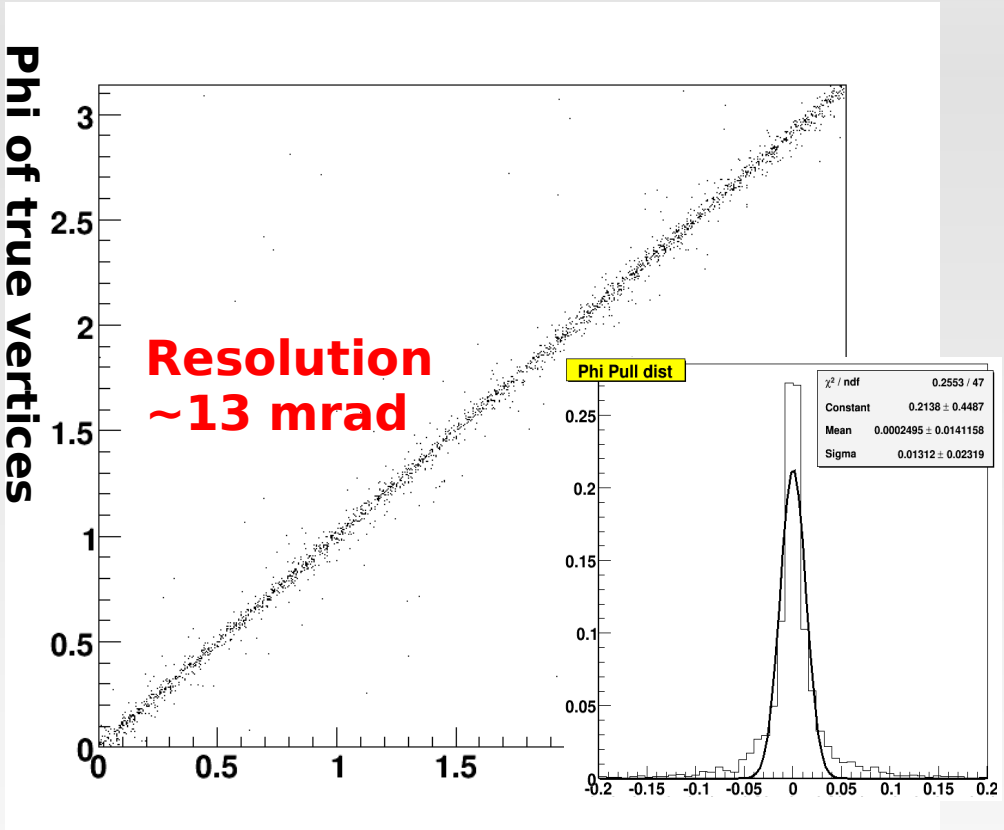
Jets construction. Other particles are added to form a jet if particle belongs to a cone of ΔR=0.7

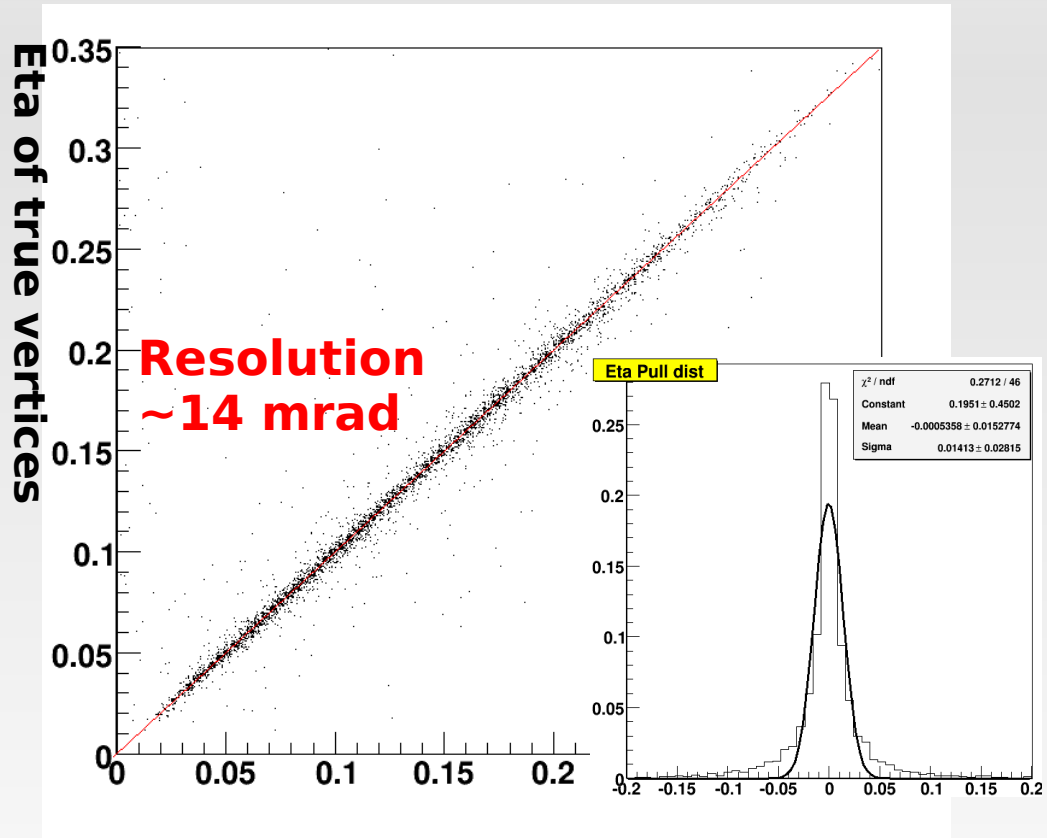




LHCb Seeds selection

HW, HZ Monte Carlo events generated with M_H=120 GeV and a lepton of Pt > 10GeV within the acceptance



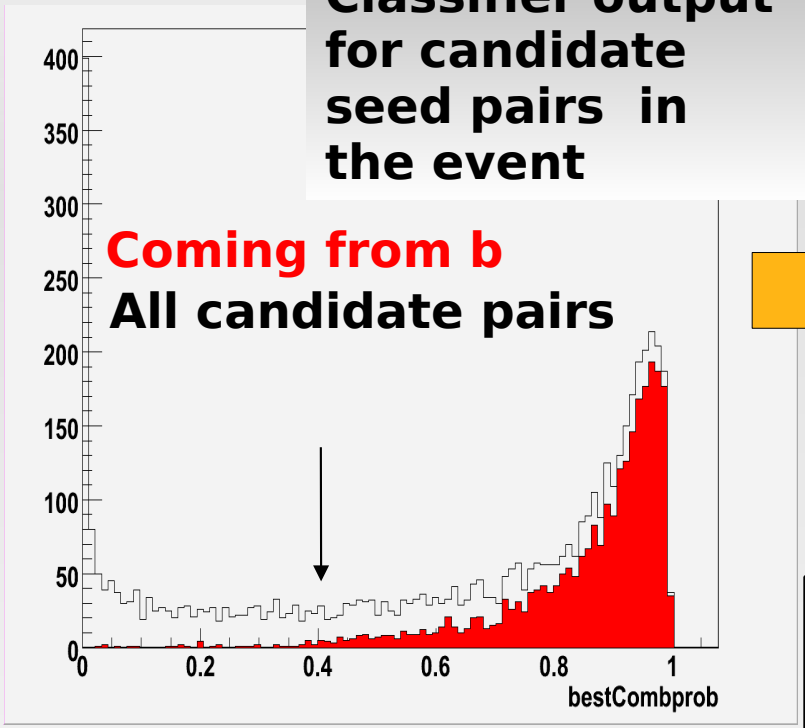


ϕ and η correlation between reconstructed and true vertices

- No biases seen in the reconstructed jet direction

LHCb double-seed selection

Classifier output for candidate seed pairs in the event



%	Prob>0.4
ε_{vis}	24.6
ε_{rec}	8.4
purity	72.3

numbers include trigger efficiency and muon/electron reconstruction

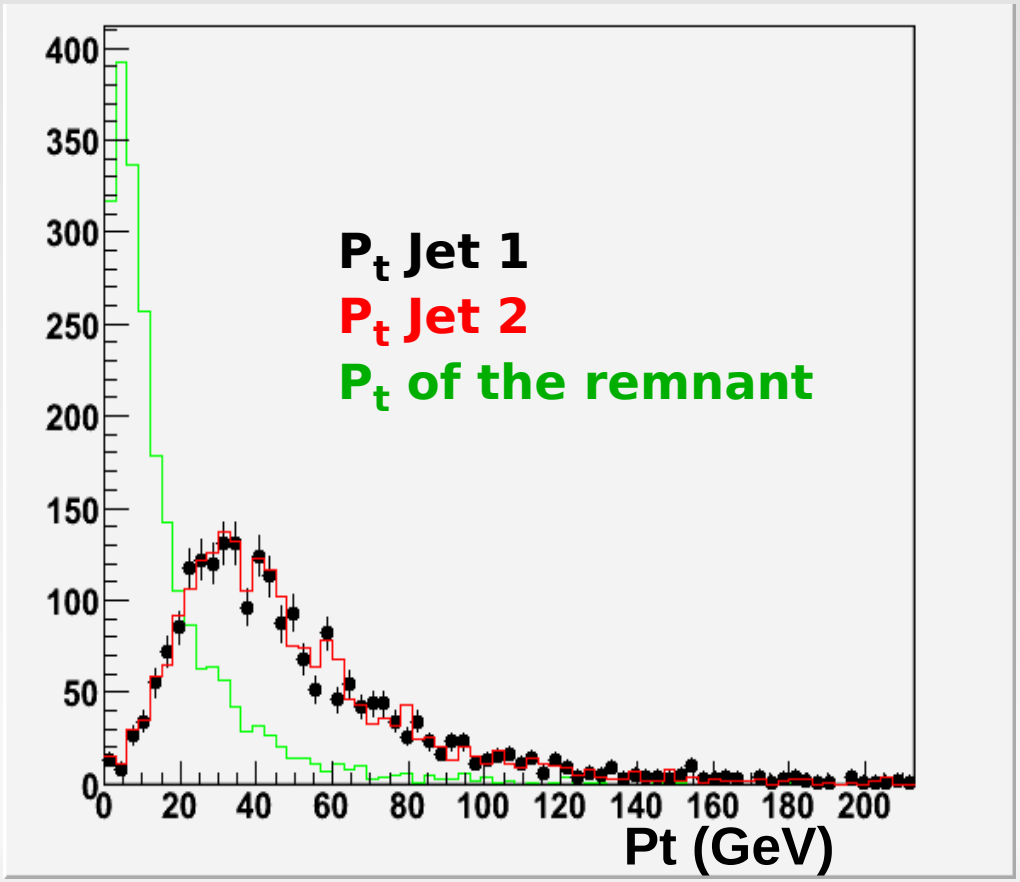
ε_{vis}: fraction of selected evts among visible true evts.
ε_{rec}: fraction of evts that have a reco seeds combination over the total number of evts
purity: fraction of true seeds combination over the number of reco evts

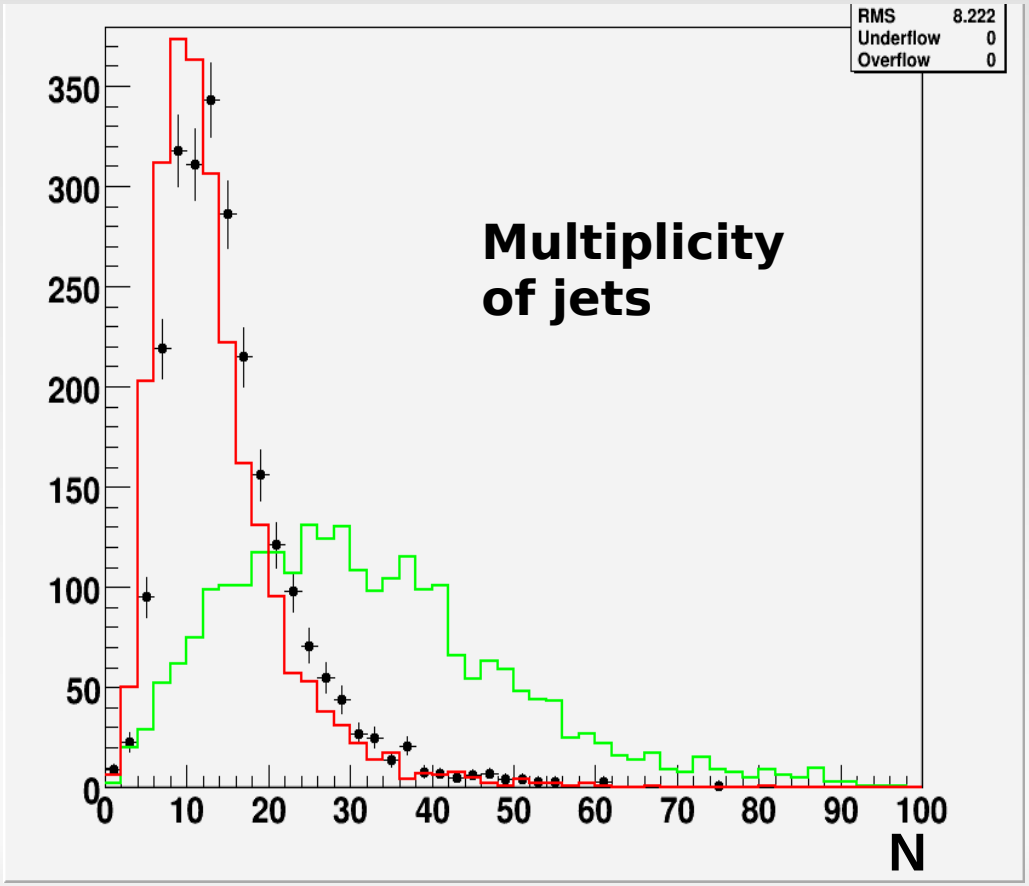
Visible true evts: evts with 4 well reconstructed tracks (2 from each B, ~25% of the total of generated events).

Jets construction

HW, HZ Monte Carlo events generated with M_H=120 GeV and a lepton of Pt > 10GeV within the acceptance

Once candidate pair of seeds is reconstructed, charged and neutral tracks are added to the cone of ΔR=0.7 built around seeds directions

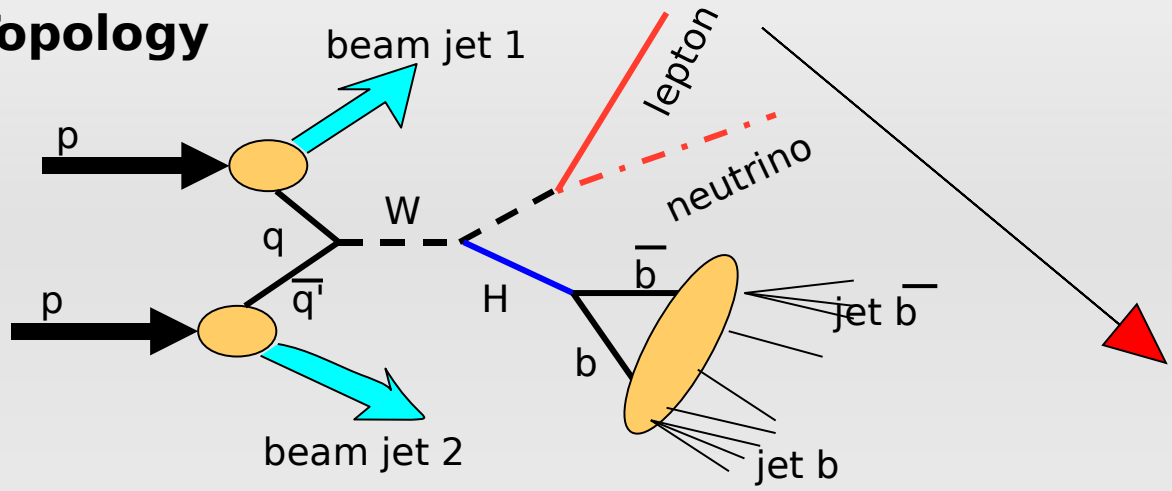




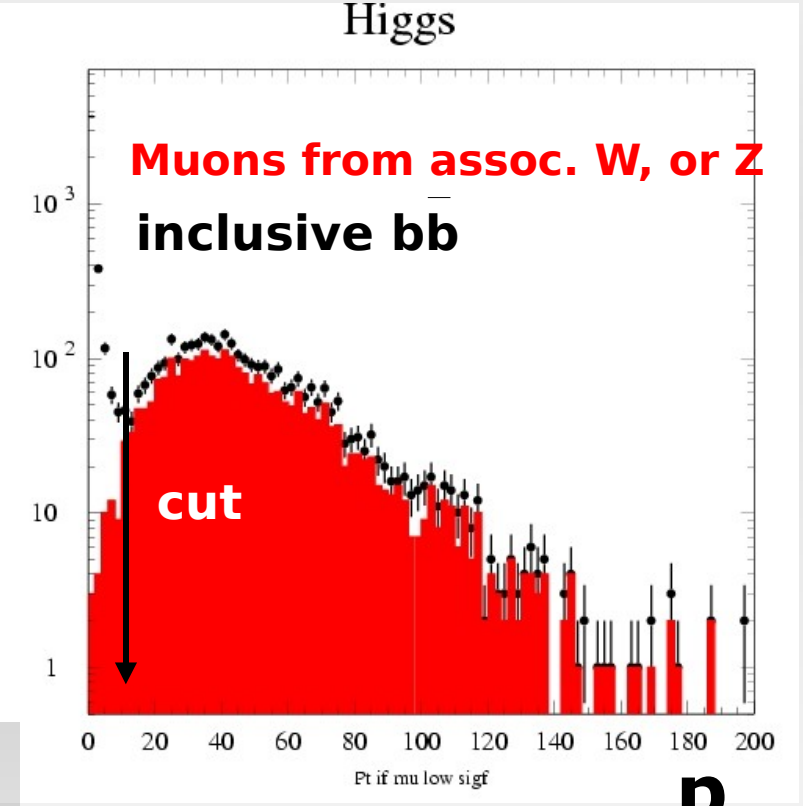
• High Pt lepton from W or Z boson is not included in jets

Light Higgs decay

Topology



- Selection: large Pt prompt lepton (Pt > 10GeV | IP/σ < 3) to tag W,Z
- Reconstruction of 2 jets in LHCb acceptance

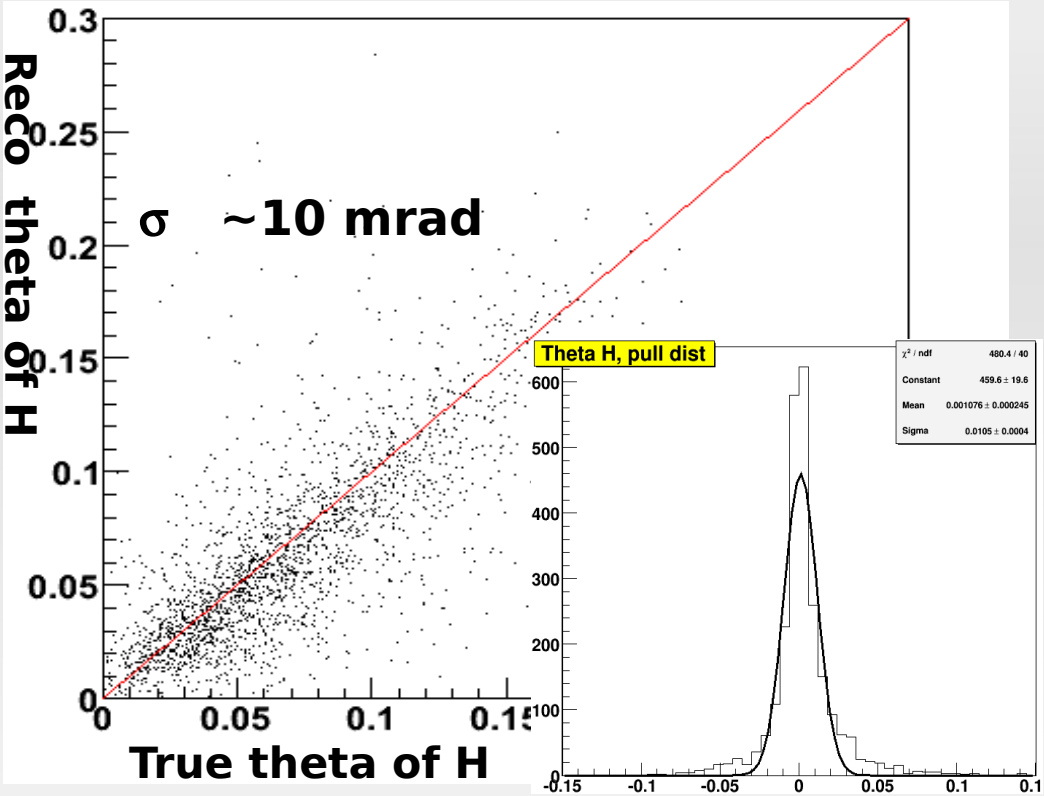


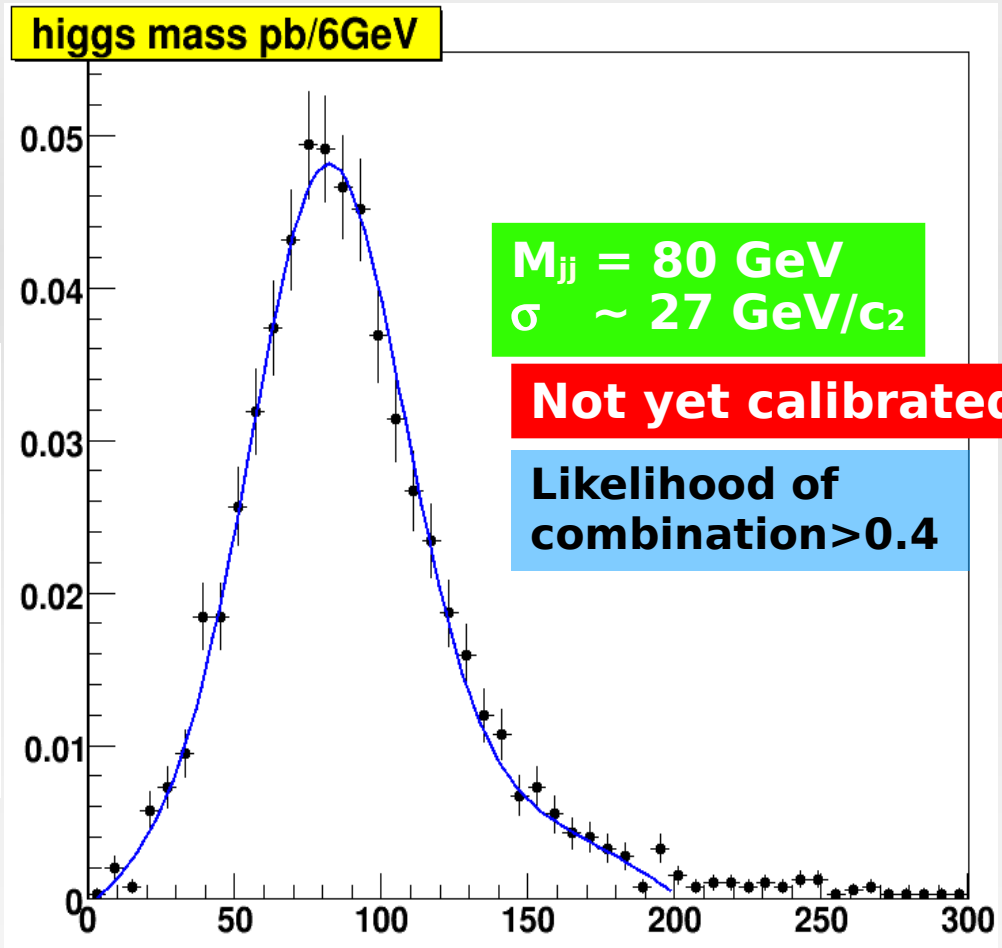
p_t

Sources of background [pb]		**weapon to fight it:**
reducible background		
$b\bar{b}$	$500 \cdot 10^6$	associated production
$t\bar{t}$	570	extra jet activity
γ *,Z+jets	10^4	b jet identification
W + jets	10^5	
irreducible background		
ZW	6.3	di-jet mass resolution
ZZ	2.5	

Level 0 trigger 88% efficient to select HW e HZ events

Jets construction





Energy of Jets need to be calibrated. One can initially study it with MC and then use Z→bb events

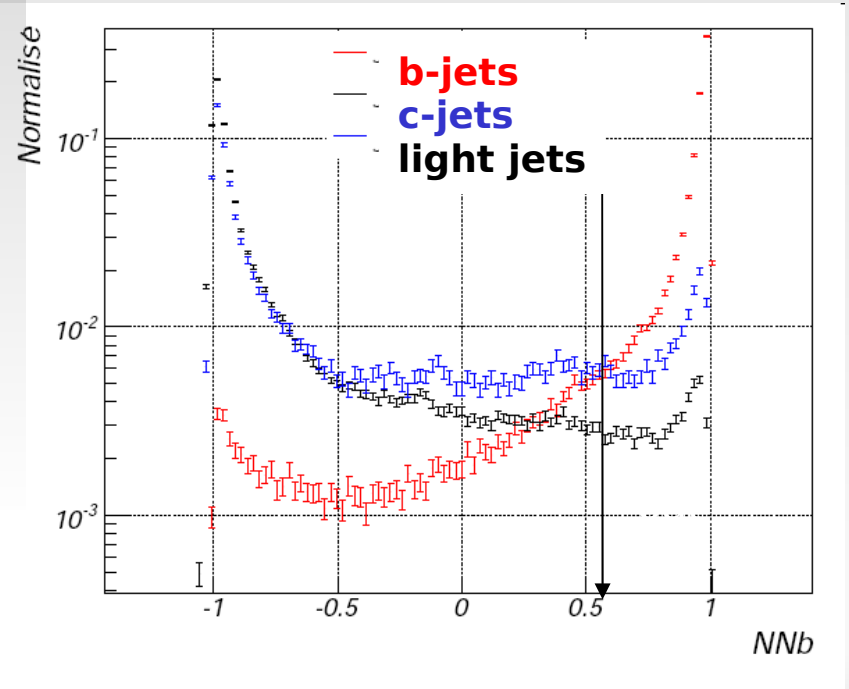
Detailed background studies in this approach are under way

Kt algorithm

- Standard algorithm used by many experiments
- In LHCb Kt algorithm is used to make jets in the event with $\Delta R=0.75$
- Need to identify the b-jet

A jet then is defined as a b-jet if it has
at least 7 particles
at least 2 tracks with impact parameter significance>2
at least 1 tracks with impact parameter significance>5
energy of charged particles > 3% of the total energy
energy in a cone of R=0.4 around the jet axis>70%
Ejet

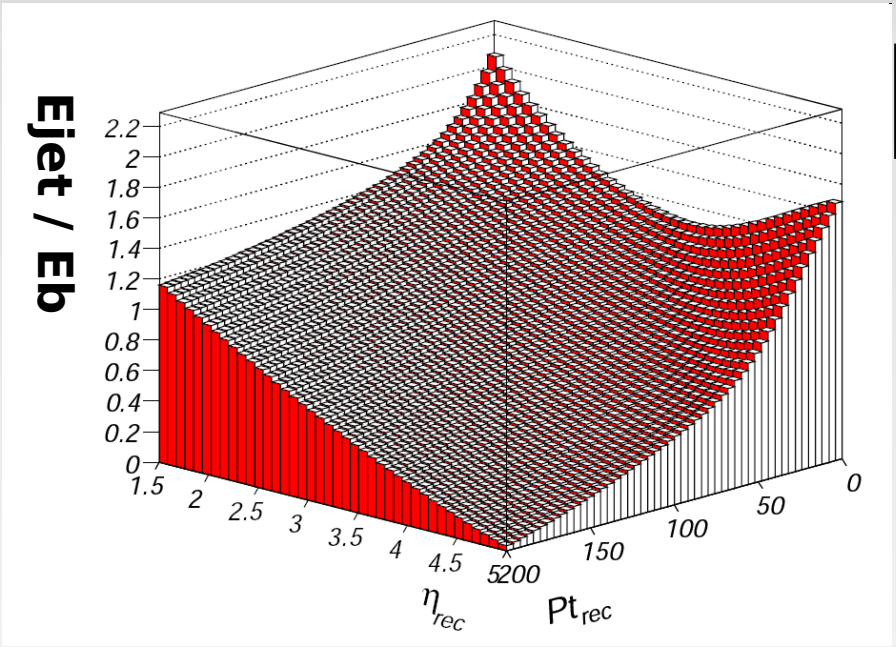
A neural net also trained to discriminate against
c-jets and light jets is also applied using kin. variables

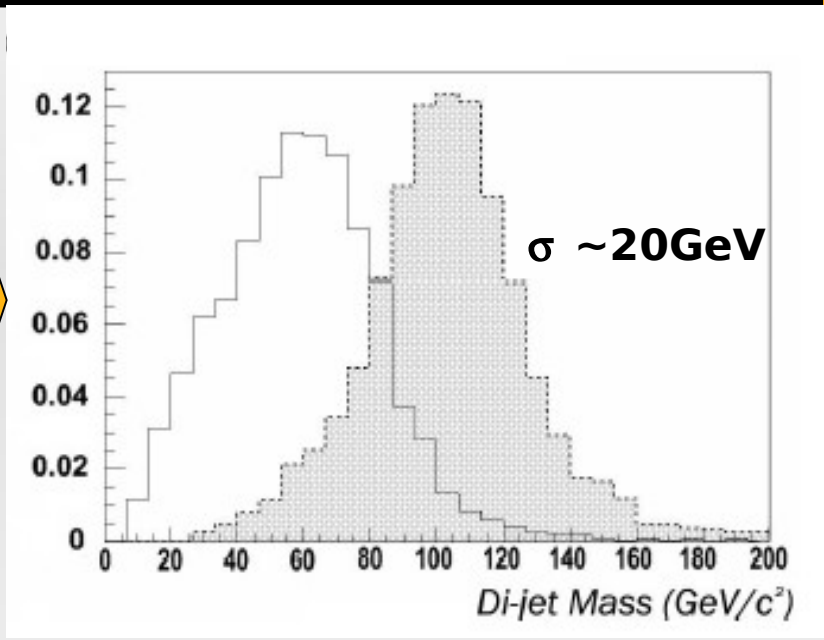


Selection efficiency for b-jets 80%
with very good non-b jet rejection of 99.7%

Kt algorithm, jet calibration

If energy correction is used which takes into account the dependence of the rapidity and Pt of jet





Mass peak not centered on true mass (120 GeV) due to neutral hadrons and neutrino losses. Improvements are possible by adding HCAL information,

Dependence on the proportions of charged and neutral particles is to be looked at.

A better mass resolution is very important for improving the B/S ratio

- **Search for a SM Higgs**

Higgs of 120 GeV, associated production HW HZ,
Taking into account background sources like $t\bar{t}$, ZW, $Wb\bar{b}$, etc,
The expectation is about 15-20 reconstructed signal events
in one year of data taking (2/fb) with $S/\sqrt{B} = 0.34$

Need to suppress large $t\bar{t}$ contribution, work in progress.

- Development of jet algorithms is also useful for other searches involving exotic or heavy objects decaying into $b\bar{b}$ with finite lifetime
  (e.g. Π_v in Hidden Valley models, χ_0 neutralinos in SUSY models).
  Interesting prospects for observation of New Physics, depending on the values of the model parameters.

Conclusions

- A dedicated approach based on displaced vertices for jet seeding has been developed. Jet calibration is mandatory to discriminate various sources of backgrounds.
- In LHCb it is a very challenging attempt to reconstruct a SM Higgs in the mass region up to ~135 GeV. At the moment the largely dominant background is $t\bar{t}$. Work is focused in trying to optimize background rejection.
- The high performance of LHCb in detecting secondary vertices and identify b-jets can be applied to any exotic particle decaying into 2 b quarks giving rise to high momentum jets in the high rapidity region.