Muon PRS Report

Tasks & Manpower Needs
DC04 Preparations
High Momentum Muon Reconstruction
$H \rightarrow 4\mu$ Studies

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PRS Task List and Manpower

As part of the CPT Annual Review and the LHCC review, we were asked to provide a task list for the next couple years and the estimated manpower required

Tasks:

- Simulation
- Reconstruction
- Calibration & Alignment
- Data Handling & Monitoring
- L1 Trigger Simulation
- HLT
- Testbeam Software

Annual Review Recommendations

Recommendations (in Order of Priority):

1. **A renewed effort is needed in detector calibration. This includes all the PRS detector groups as well as calibration infrastructure from CCS. Since an exercise of calibration was already planned for DC04 as input to the computing TDR, this is clearly an urgent problem.**
2. **The detector groups should supply manpower to perform time critical activities such as calibration.**
3. **PRS should participate in the specification of a minimal (Distributed) Analysis Model which can be implemented in time for the Physics TDR. In fact, it would be good if we could have an implementation to study in time for the Computing TDR.**
4. **PRS should rapidly move to produce persistent physics objects in the new framework.**

PRS Tasks & Estimated Manpower Needs

Muons (FTE)	2003 (now)	2003 (need)	2004	2005	2006	2007
Simulation	1.5	2.5	2.5	2.5	2.5	2.5
(Geometry, simHits, digitization, Validation, CommonDet and Tracker domains, fast simulation)	8					
Reconstruction	2	2.5	4	4	3	4
(pulse reconstruction; maintenance and development of clustering algorithms)	5					
Calibration	0.5	2	4	4	4	4
(Simulation studies, application of constants)	2					
Data handling & Monitoring	0.3	0.5	2	3	2	3
(Any off-line and quasi-online software needed to cope with real data, Tracker and DAQ Proto.)	0					
Level-1 Trigger simulation	2	2	1.5	1	1	2
HLT	1	1.5	4	4	3	5
muon object reconstruction, and full analysis like for Physics TDR	10					
Test-beam software and analysis	4	4	4	4	4	4
(Normally included in Data handling and Monitoring)	12					
TOTAL	11.3	15	22	22.5	19.5	24.5

Effort needs to double in the next year

Simulation Tasks

√ **Final adjustments & tuning to OSCAR (Geant-4 detector simulation)**

√ **Refinement of simulation based on testbeam results**

Implementation of muon performance parameterizations into FAMOS (fast detector simulation)

Development of a long-term supportable XML geometry description for DDD (and short term maintenance/update of existing XML)

√ **Support for the production of necessary MC samples for muon analyses**

(√ = task started, partially covered)

Reconstruction Tasks

- √ Further improve/optimize local reconstruction (DT, CSC, RPC)
  - ➔ In presence of backgrounds
  - ➔ From results of testbeam studies
  - ➔ Develop tools for MC/testbeam comparison
- √ Optimize global reconstruction for efficiency, speed, rate reduction:
  - ➔ Define/implement “reconstruction geometry” (different level of details than “simulation geom.”; same DDD source)
  - ➔ Develop improved navigation & extrapolation tools
  - ➔ Develop improved B-field tools (data retrieval, interpolation)

Calibration & Alignment Tasks

For DT, CSC, RPC separately:

- ➔ Establish calibration procedures, frequency, and data volume
- ➔ Define format of constants stored in DB
- ➔ Possibly transfer exisiting data from chamber/electronics production DB to CMS-wide DB (once latter is defined)
- ➔ Define interface between DB and HLT/reconstruction code
- ➔ Develop software to apply DB constants to HLT/reconstruction

Same for alignment ($\Rightarrow$ constants from alignment hardware)

Additionally:

- √ ➔ Interface "misalignment tools" to "reconstruction geometry" (from DDD) in ORCA
- ➔ Develop calibration strategies & software (e.g. vs magnetic field knowledge)
- √ ➔ Develop alignment strategies with tracks & software ("internal" barrel/endcap, overlap region, muon-Tracker)

Data Handling & Monitoring Tasks

- Define monitored quantities and possible alarms for DCS
- Define monitored quantities and tolerance criteria for online farm
  - ➔ Probably a lot of experience at FAST sites…
- Develop software to produce histograms and alarms from online data, HLT monitoring (once CMS-wide framework developed)
- Define muon data sets (streams) and data volume
  - √ ➔ Single muon and di-muon streams
  - ➔ Other physics streams?
  - ➔ Prescaled loose triggers (e.g. HLT pass-through triggers)
- Define data handling procedure for reconstruction (application of calibration and alignment corrections)
- √ Introduce realistic data formats in HLT processing in ORCA
  - ➔ Started in "slice test" software development

L1 Trigger Simulation Tasks

Update L1 simulation to exactly match electronics algorithms:

√ ➔ RPC trigger with 4/6 logic and HO added

√ ➔ DT BTI+TRACO+TSS updates

➔ RPC $\rightarrow$ CSC interface (TMB)

Refine L1 algorithms to further improve efficiency, rate reduction and functionality:

√ ➔ CSC single μ trigger for $|\eta|>1.6$ without RPC and ME4/2

√ ➔ CSC di-muon trigger with increased η coverage

(See Alexei's talk)

➔ Cosmic ray trigger

- We'll need a cosmic trigger for slice tests on the surface

➔ Accelerator muon trigger

- Needed for beam running (alignment studies)

HLT and Full Analyses

- √ Minimize HLT execution time
- Adapt HLT code to any specific online filter farm requirements
- √ Refine HLT algorithms to further improve efficiency, rate reduction and functionality (especially based on analyses)
- Muon reconstruction at very high p_T
  - ➔ Study/optimize performance
- √ Muon identification
  - ➔ Isolated & inside jets ($\Rightarrow$ b-physics)
- √ Perform full analysis of $H \rightarrow 4\mu$
  - ➔ No U.S. group?
- √ Perform full analysis of $H \rightarrow 2\mu$
- √ Perform full analysis of $Z' \rightarrow 2\mu$

} For Physics TDR

Test Beam Software & Analysis

- √ Integrate testbeam DAQ software into ORCA framework
  - ➔ Log data into native ORCA data format
    - Work of R.Wilkinson for EMU, with P.Kreuzer (UCLA) joining
  - ➔ Develop testbeam geometries (prototype exists for Barrel with simple "one-station" setup)
    - M.Case (UCD) assists for EMU (?)
- √ Perform analysis of local reconstruction quantities (e.g. residuals) for comparison and tuning of detector simulation
  - ➔ Could benefit from an analysis of the latest CSC beam test data with production electronics
- Perform dedicated mini-experiments (e.g. scattering in iron) to check HLT and validate Geant4 physics simulation
  - ➔ Develop software for 2 stations setup (geometry, L1 TrackFinder LUTs, reconstruction...)
- √ Evolve testbeam software into system software for slice tests of many chambers and for CMS commissioning
  - ➔ Starting for CSCs

DC04 Status

The 2004 Data Challenge is a 50M event production

- ➔ In fact 70M Pythia events were requested by the PRS groups
- ➔ 35M events have already been pushed through CMSIM

OSCAR (G4) is ready for detector simulation

- ➔ Will be used for all PRS/μ samples except W/Z (i.e. we've been waiting…)

ORCA is about ready for digitization

- ➔ First 4M events will be ready within a month
  - ◻ 0.7M requested by PRS/μ: single muons, high-mass DY, t-tbar events
- ➔ Remaining 46M available after Feb'04 challenge

Data will be available at CERN or FNAL

- ➔ But perhaps not at both

High Momentum Muon Reconstruction

Improvement to muon reconstruction algorithm driven by physics study of Z' search

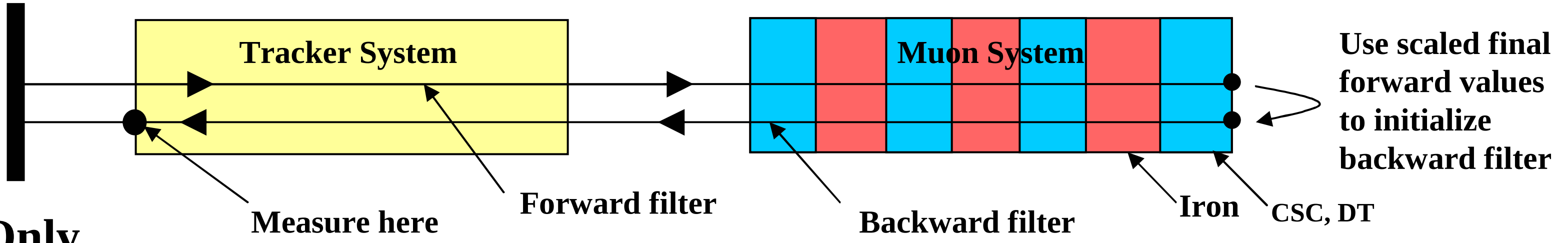
- ➔ **Work of R. Cousins and J. Mumford (UCLA)**
- ➔ **Significant tails in mass resolution of high-mass di-muon pairs are a major source of background for the Z´ signal**
- ➔ **Would like to reduce tails while maintaining or improving Z´ FWHM**

Detailed report given at Muon PRS Meeting during Sept'03 CMS Week

Some Possible Track Fitting Methods

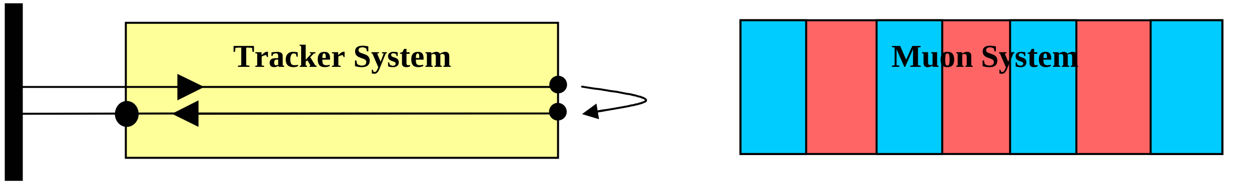
GMR

- 5 Parameter measurement at inner surface of tracker from backward part of Kalman filter fit to tracker and muon hits (default L3 fitting method).
- http://agenda.cern.ch/askArchive.php?base=agenda&categ=a03423&id=a03423s1t0/transparencies for more information.



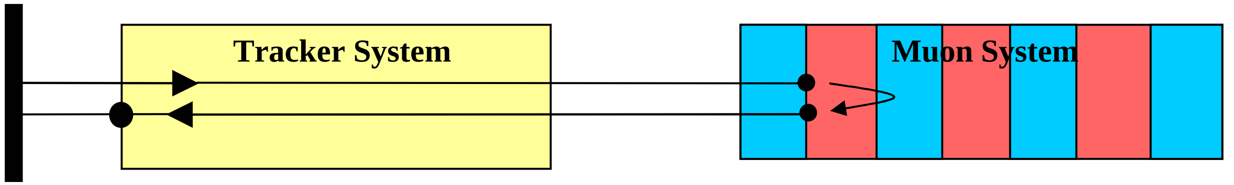
Tracker Only

- Use only tracker hits for Kalman filter. Take measurement from innermost tracker surface.
- Available as reconstruction option in ORCA 6.3.0 (implementation by Norbert Neumeister).

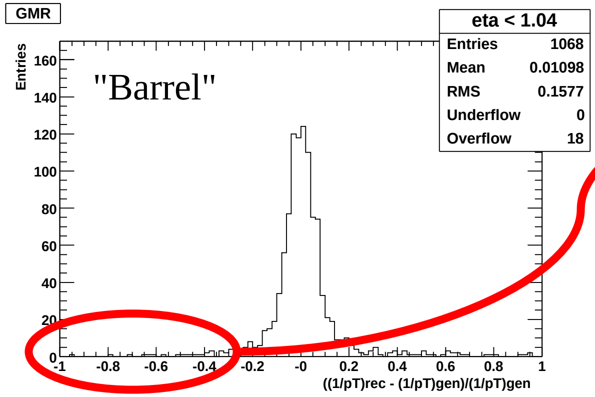


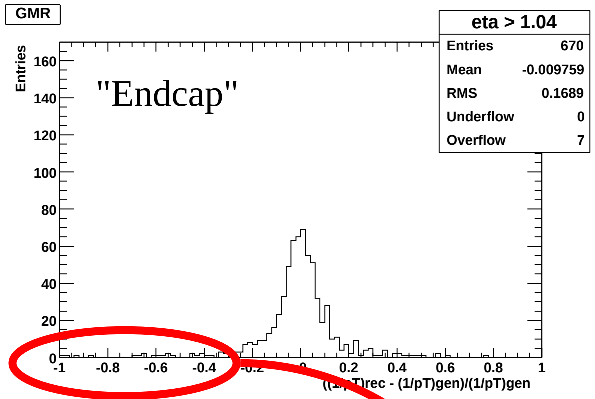
Tracker + 1 Muon-Station

- Use tracker and hits from first muon station which contains hits.

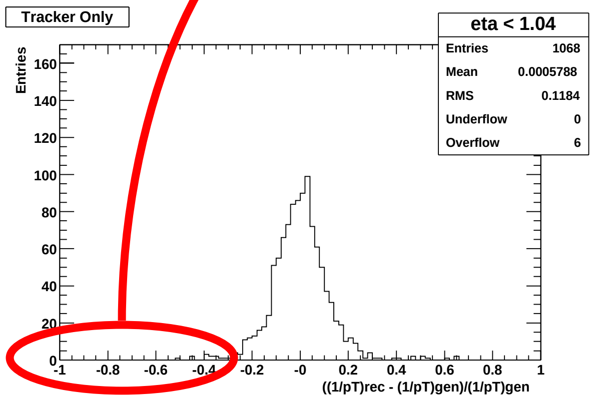


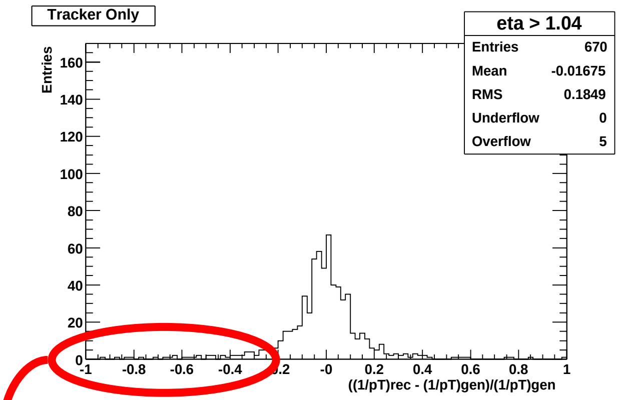
1/pT Resolution : Fit Comparison I

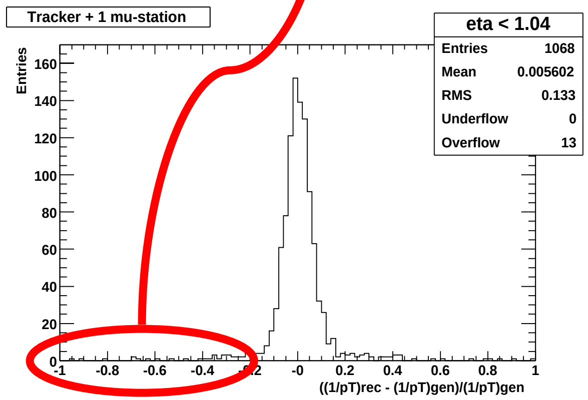


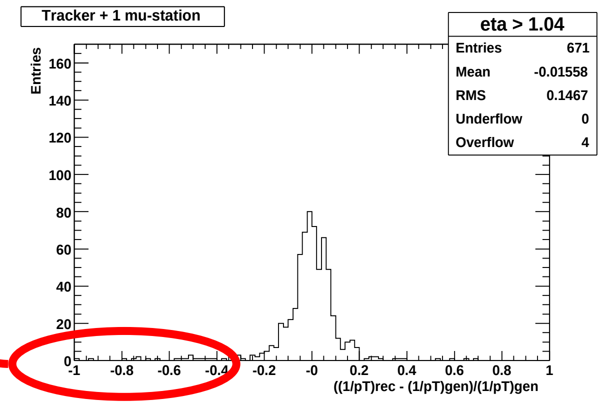


In barrel, tracker-only has smaller tails, (truncated) RMS







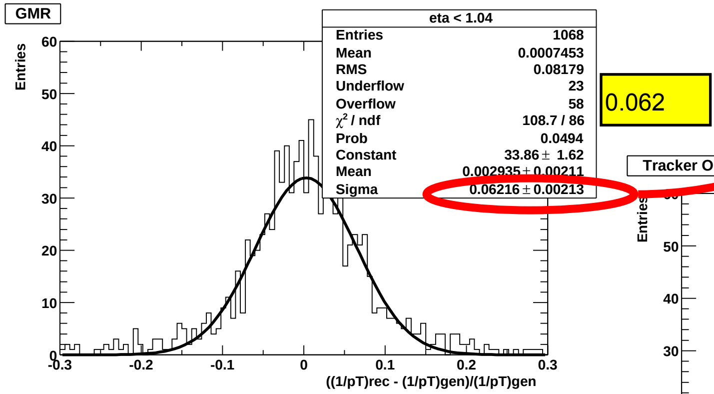


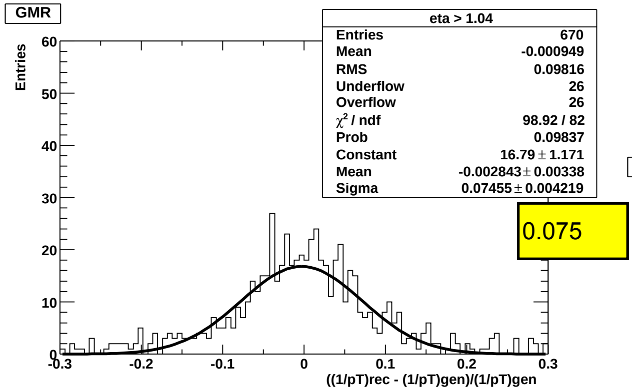
Differences between fits in endcap less clear

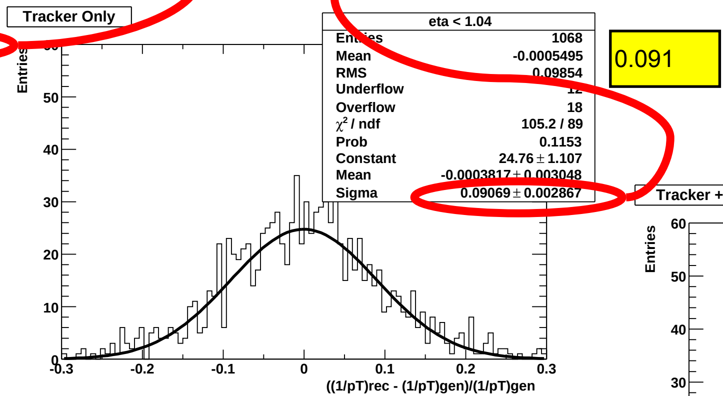
ORCA 6.3.0 Digis
ORCA 6.3.0 MuonAnalysis package
Drell Yan Mass > 1.5 TeV Sample
pT > 100 GeV

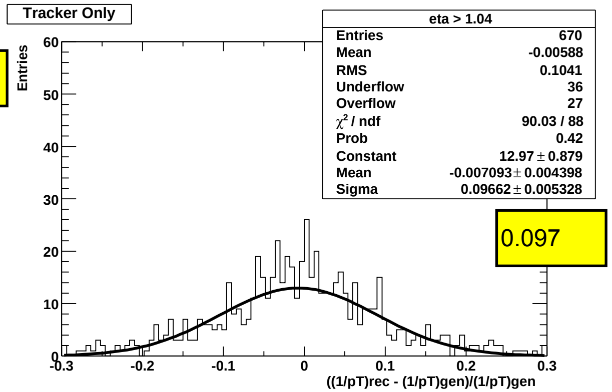
1/pT Resolution : Fit Comparison II

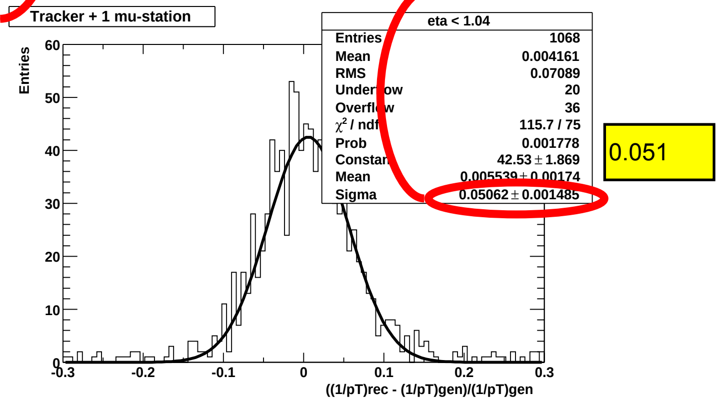
In barrel and endcap, tracker + 1 mu-station has best fitted-sigma

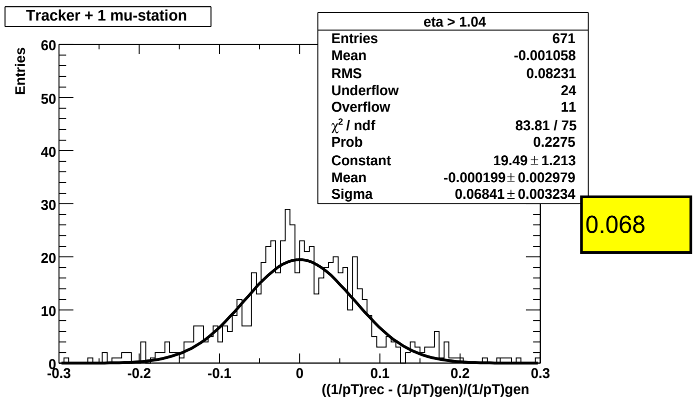








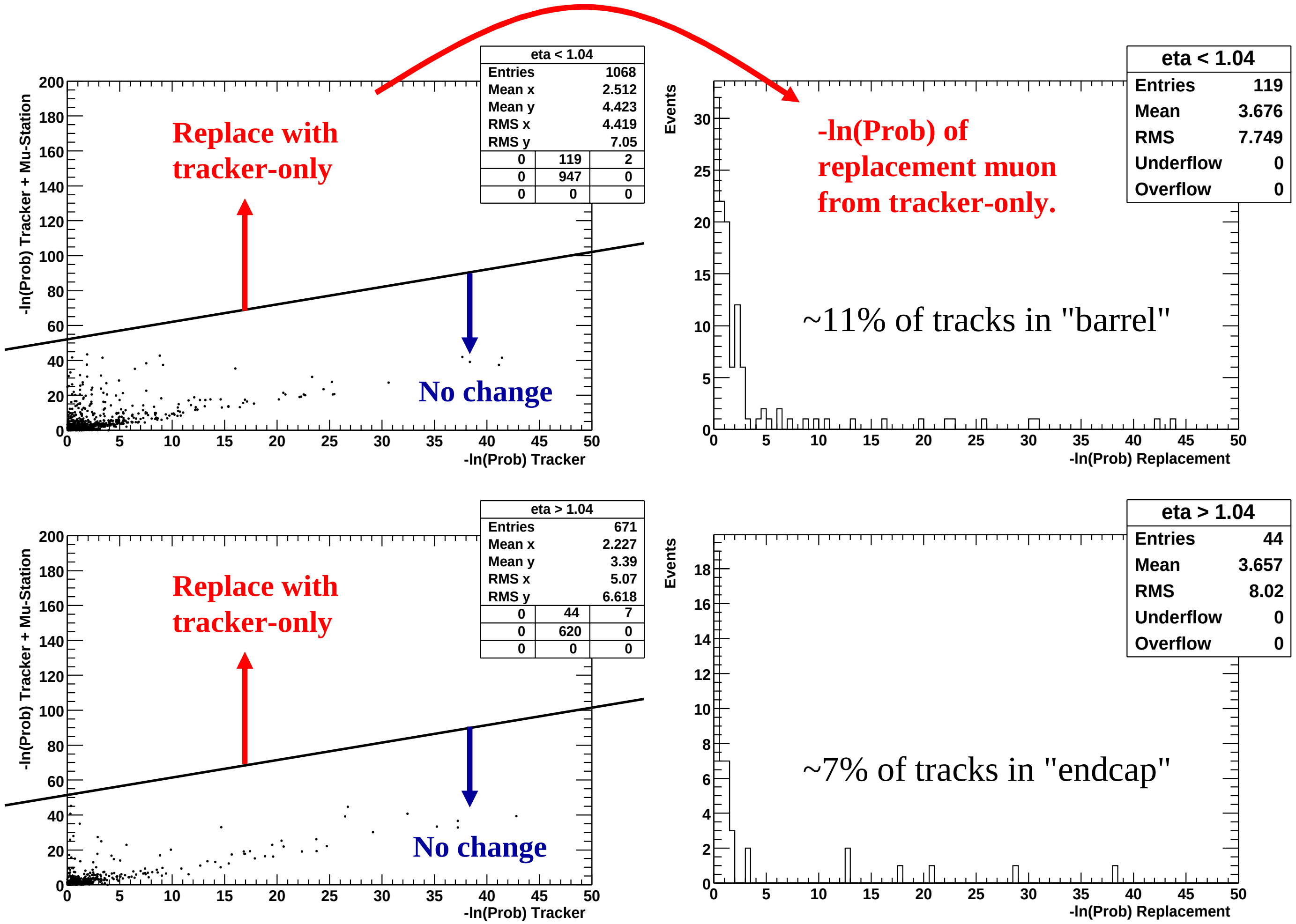




ORCA 6.3.0 Digis
ORCA 6.3.0 MuonAnalysis package
Drell Yan Mass > 1.5 TeV Sample
pT > 100 GeV

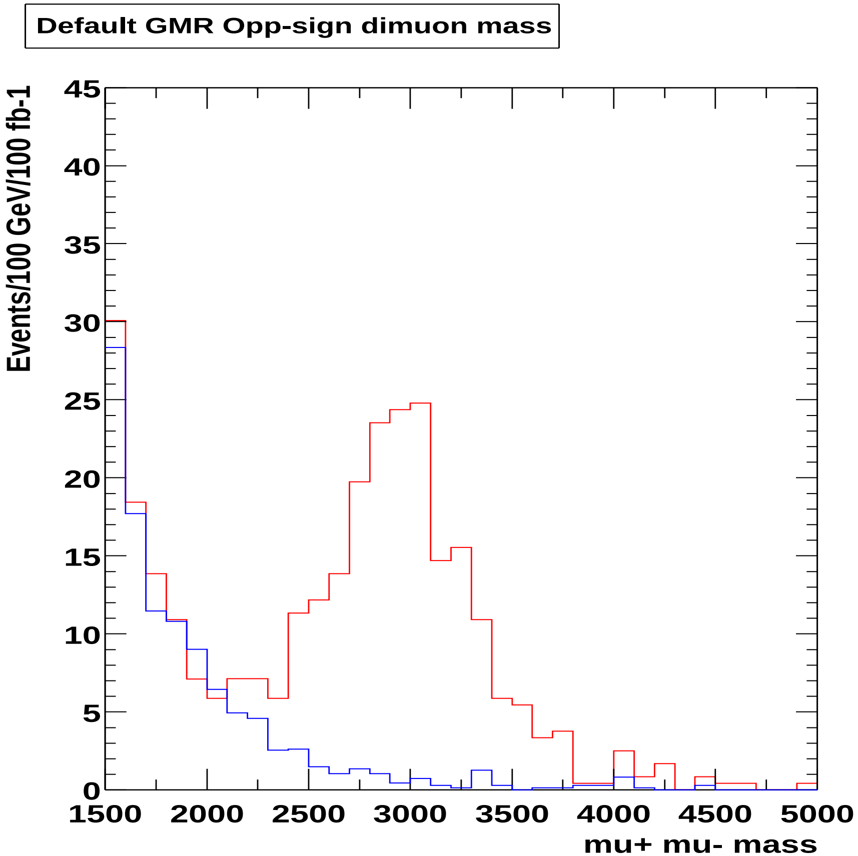
A Prototype Selection Criterion Using “Prob” in Tail of χ^2 Distribution > Observed χ^2

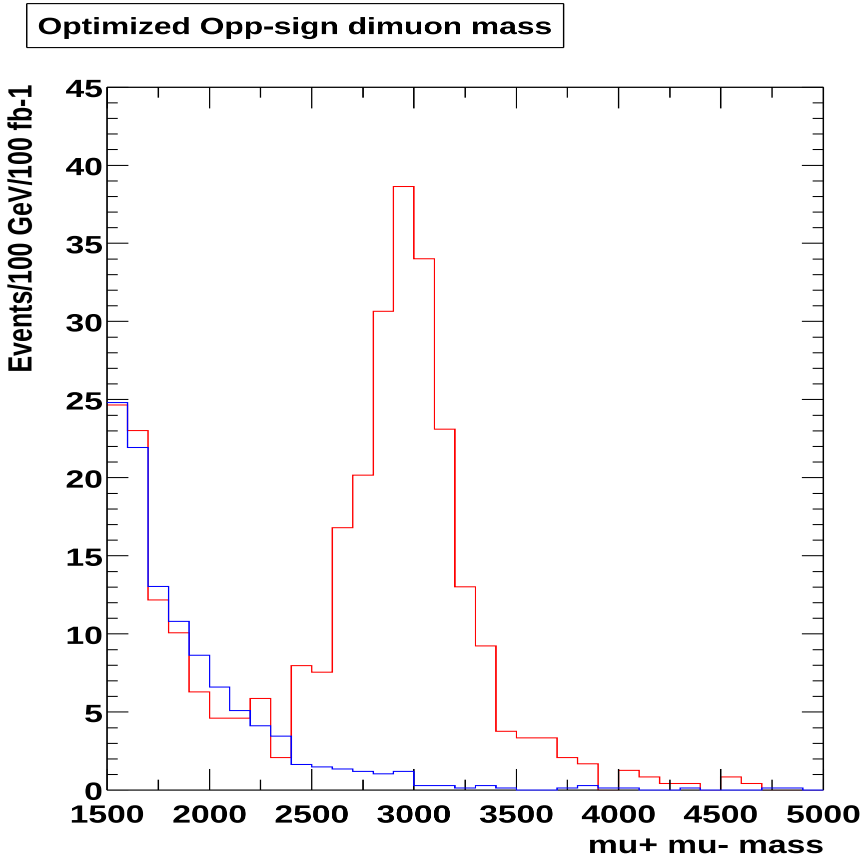
1. Start with tracker + 1 mu-station fit.
2. Check difference in -ln(Prob) between tracker + 1 mu-station and tracker-only fits
3. If difference is greater than 50 (optimized value), replace with tracker-only fit.
4. Track is now referred to as “optimized”.



ORCA 6.3.0 Digis
ORCA 6.3.0 MuonAnalysis package
Drell Yan Mass > 1.5 TeV Sample
Muon pT > 100 GeV

Zssm (3 TeV) vs Drell-Yan background





ORCA 6.3.0 Digis
MuonAnalysis package
Note: Optimization algorithm was tuned on different sample.

Optimized has narrower signal, perhaps reduced background tails.

H→4μ Full Analyses

Two groups have started investigations using CMSIM & ORCA

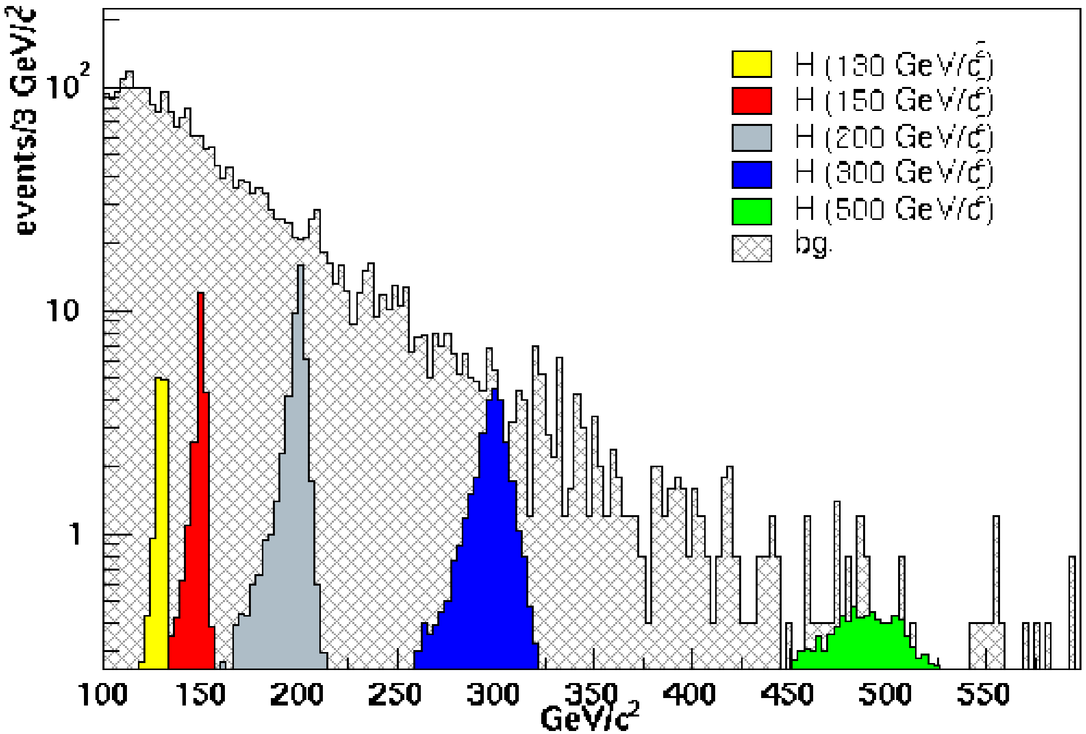
- ➔ **Karlsruhe**
  - **Concentrating on low mass region $M_H < 2M_Z$ mostly**
- ➔ **INFN Firenze**
  - **Concentrating on high mass region $M_H > 2M_Z$ mostly**
  - **CMS-IN 2003-046**

Work is under review by PRS Higgs and Muon groups

- ➔ **Only results approved during a PRS plenary meeting can be released publicly for conferences (Nov. CPT Week in this case)**

Preselection

Signal and background after preselection ($L = 20\ fb^{-1}$):



Selection optimized for $M_H > 2M_Z$ and $M_H < 2M_Z$.

Selection ($M_H > 2M_Z$)

- ✓ di-muon mass: both muon pairs with an invariant mass

$$\left| m_{\mu^+\mu^-} - M_Z \right| < 8.0\ \mathrm{GeV/c^2}$$

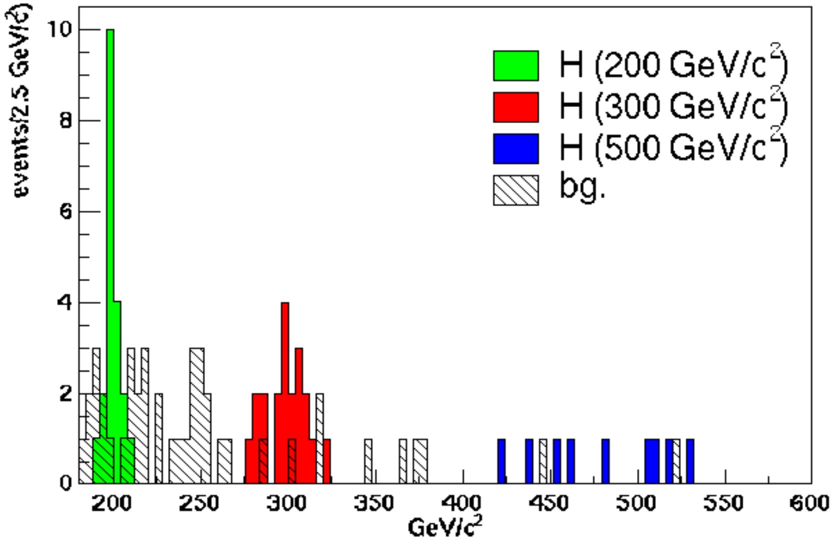
- ✓ transverse momenta
  - – thresholds at 20, 15, 15, 10 GeV/c
- ✓ p_T of the Higgs candidate

Efficiencies ($M_H > 2M_Z$)

	reco	Z mass + p_T	$p_T^{4\mu}$
$t\bar{t}$	42.4 %	0.05 %	0.05 %
$Zb\bar{b}$	40.2 %	0.3 %	0.3 %
ZZ	68.6 %	35.8 %	15.2 %
H (200 GeV/c^2)	71.4 %	49.4 %	37.4 %
H (300 GeV/c^2)	76.7 %	51.5 %	42.1 %
H (500 GeV/c^2)	76.6 %	50.6 %	43.8 %

Signal and background after the selection described before

($L = 20\ fb^{-1}$)



Results ($L = 20\ fb^{-1}$)

($M_H < 2M_Z$)

- ✓ $|m_{\mu\mu} - M_Z| < 6$ GeV/c²
- ✓ p_T thres. (20, 15, 10 , 7 GeV/c)
- ✓ iso.: ΔR=0.2, p_T^{max} = 4.0 GeV/c
- ✓ $-0.9 < \cos\theta_D < 0.8$

($M_H > 2M_Z$)

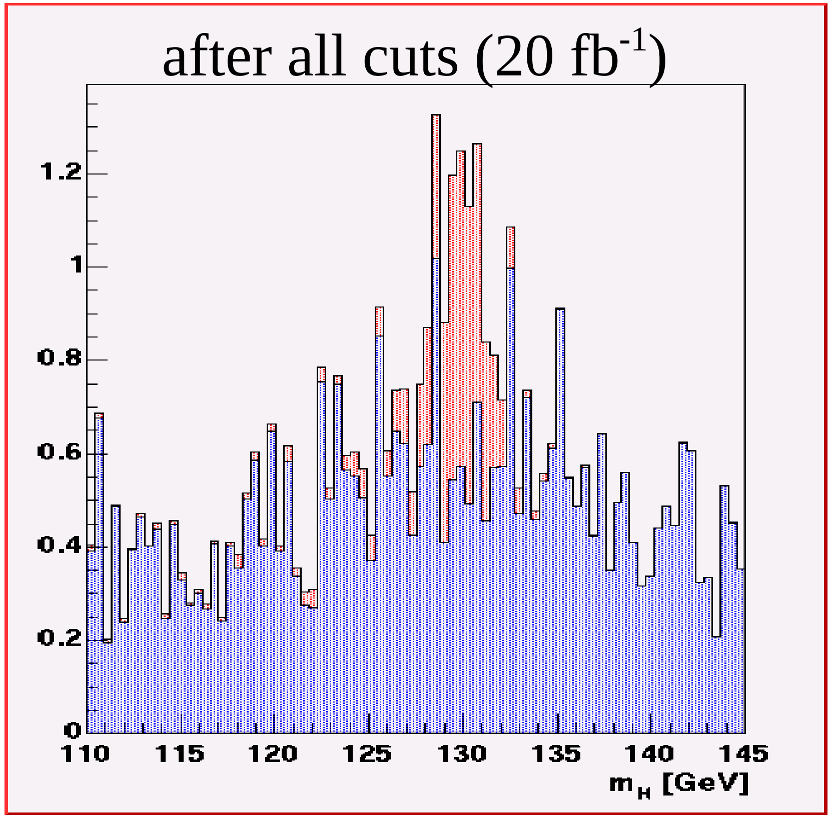
- ✓ $|m_{\mu\mu} - M_Z| < 8$ GeV/c²
- ✓ p_T thres. (20, 15, 15, 10 GeV/c)
- ✓ four μ system $p_T > 15$ GeV/c

M_H (GeV/c²)	Higgs	$ZZ^{(*)}$	$t\bar{t}$	$Zb\bar{b}$
130	5.0	0.65	< 0.5	1.2
150	10.9	0.71	< 0.5	< 1.7
200	19.4	2.5	0.35	< 1.7
300	13.9	2.0	< 0.5	< 1.7
500	7.0	1.5	< 0.5	< 1.7

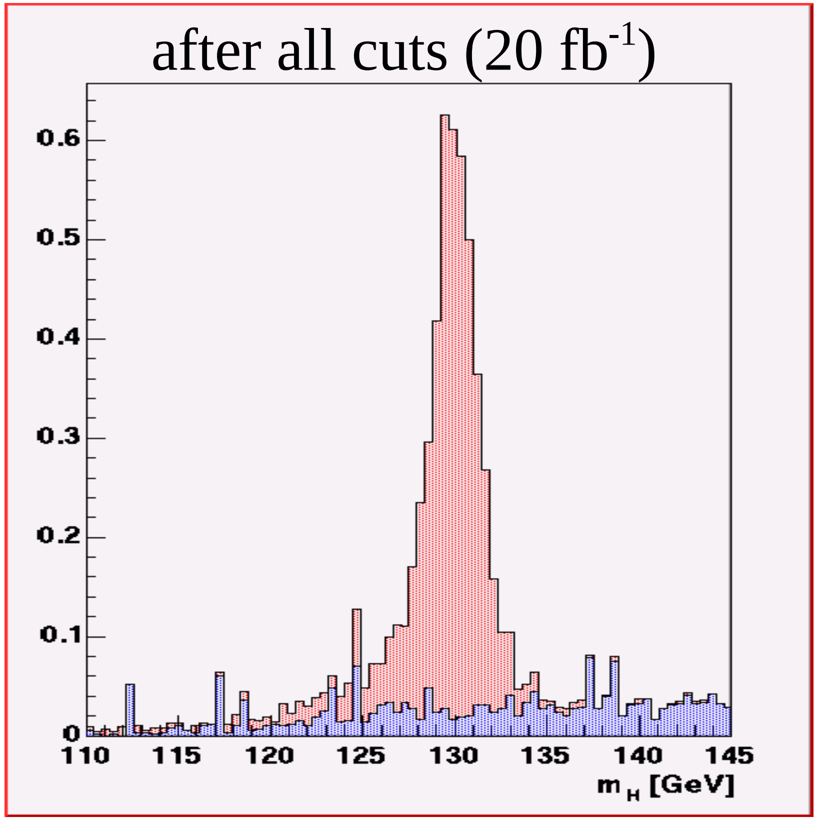
Events falling inside $\pm 2\sigma_H$

When no events are found the upper limit at 68 % C.L. is given

Isolation criterion:



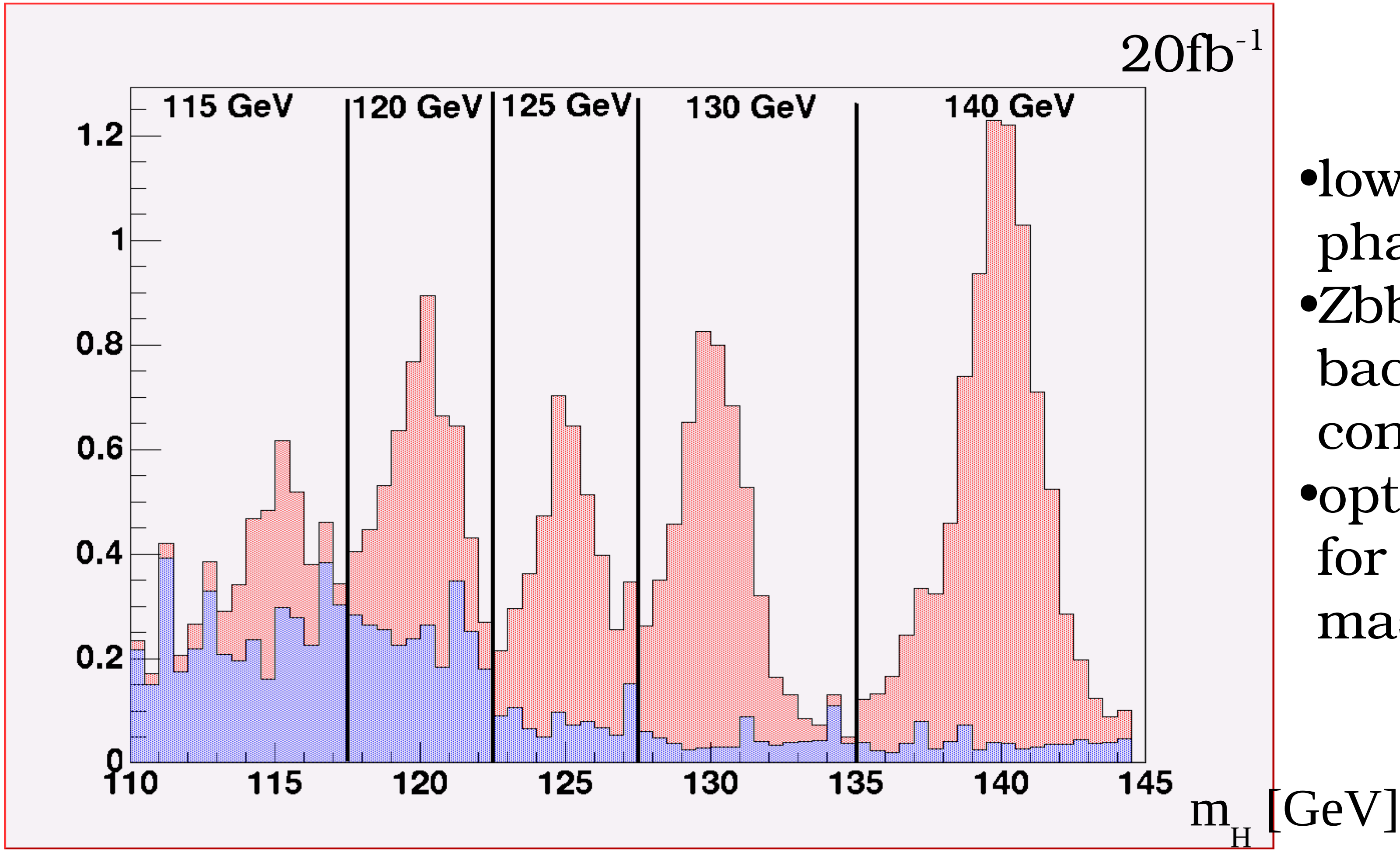
after isolation cut with default value



after optimized isolation cut

isolation cut improves signal visibility significantly

H->ZZ*->4μ: fully simulated Signal and Backgrounds after all cuts (20fb^{-1})



- low luminosity phase
- Zbb + tt + ZZ backgrounds considered
- optimised cuts for each Higgs mass

Conclusions

- **With CSC production nearly over, FAST sites nearly finished, and installation well in hand:**
  - ➔ **Need to transfer experience to PRS groups!**
    - **Especially in the areas of local reconstruction, test beam analysis, calibration & alignment schemes, data handling & monitoring**

- **Physics studies are starting to drive reconstruction improvements**
  - ➔ **Muon reconstruction in Z' search**
  - ➔ **Isolation techniques for $H \rightarrow 4\mu$ studies**

Recent Agenda

Tuesday 16 September 2003

14:00	**News** (15') (more information transparencies)	U.Gasparini
14:15	**Magnetic field implementation and validation** (15') (transparencies)	V. Andreev
14:30	**Magnetic field interpolation** (10') (transparencies)	V. Drollinger
14:40	**DT digitization** (15') (transparencies)	G.Bevilacqua
14:55	**Improvement id Di-Muon trigger** (15') (transparencies)	A. Drozdetski
15:10	**Progress in fitting muons in ORCA** (15') (transparencies)	J. Mumford
15:25	**H -> 4 mu study using FAMOS** (15') (transparencies)	S. Bolognesi

Tuesday 30 September 2003

17:00	**OSCAR validation status report for muons** (30') (more information transparencies)	P. Arce

Tuesday 14 October 2003

16:30	**DT Digitization & RecHits in ORCA 7_5** (20') (transparencies)	N. Amapane
16:50	**DT L1 trigger emulator revised: comparison with testbeam data** (20') (transparencies)	S. Vanini
17:10	**New framework for muon reconstruction in DT** (20') (transparencies)	S.Lacaprara
17:30	**H => 4mu full analysis with ORCA 6** (25') (transparencies)	M. Sani