Search for Light Higgs Boson in the $h \to \gamma\gamma$ Channel

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Alex Melnitchouk
(Brown University)
on behalf of the DØ Collaboration

OUTLINE

- Theoretical Outlook.
  Higgs production and $\gamma\gamma$ decay
- Search strategies. Backgrounds
- Previous results
- Sensitivity estimates for Tevatron
- Selection of candidate events
- Mass distribution from recent data
- Event displays
- Conclusions

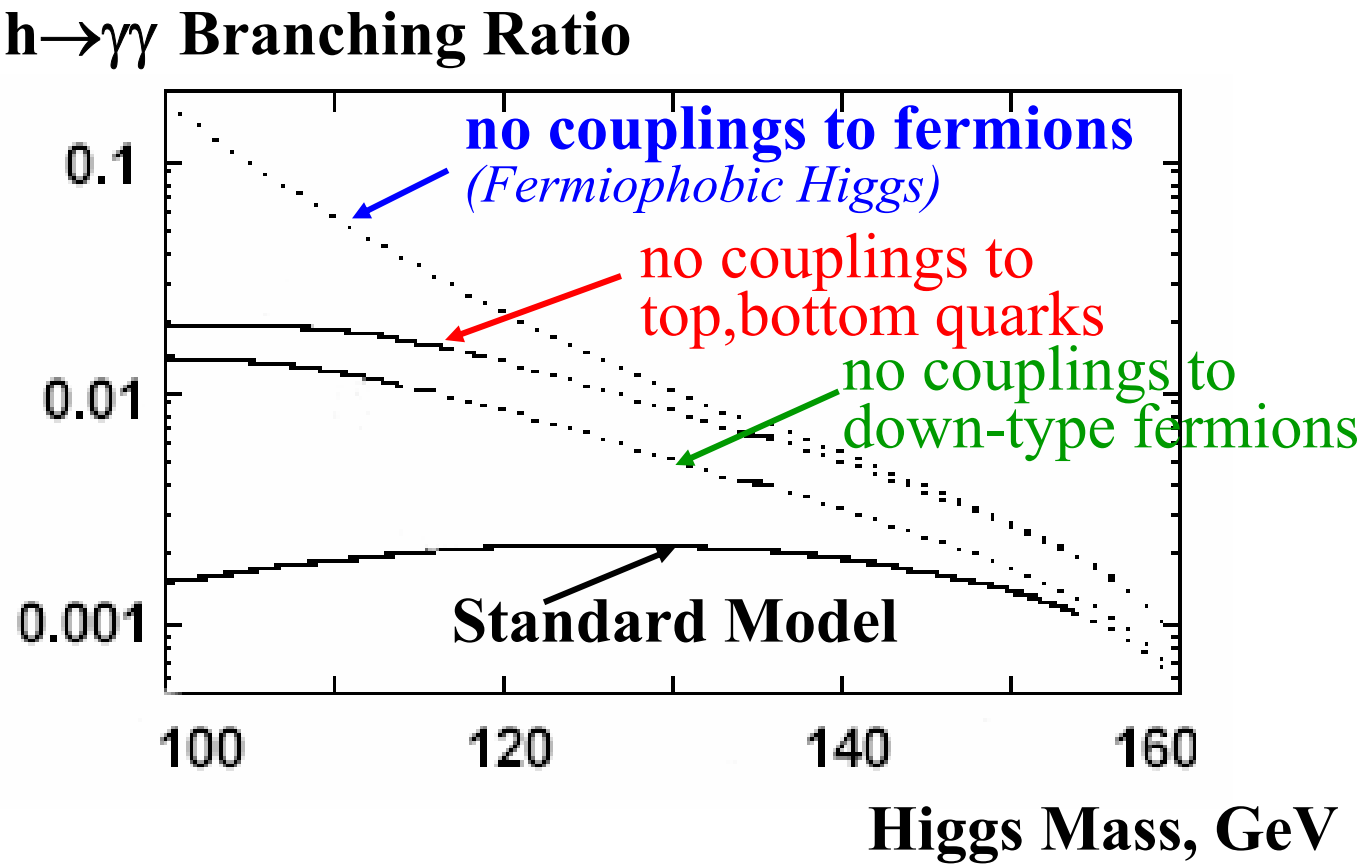
$h \rightarrow \gamma\gamma$ channel

Theoretical Outlook

- In Standard Model $H \rightarrow \gamma\gamma$ Branching Ratio is small: $\sim 10^{-3}$ - 10^{-4}
- However many extensions of the SM predict enhanced $\gamma\gamma$ decay rate of the Higgs due to **suppressed couplings** to
  - all fermions *(Fermiophobic Higgs)*
    H.E.Haber et al, Nucl. Phys. ***B161****, 493 (1979)*
  - all fermions but top quark *(Topcolor Higgs)*
    B.Dobrescu, Phys. Rev. ***D63,*** *015004 (2001)*
  - top and bottom quark
    J.D. Wells, Phys. Rev. ***D56****, 1504 (1997)*
  - down-type fermions,
    H. Baer, J.D. Wells, Phys. Rev. ***D57****, 446 (1998)*

Enhanced $\gamma\gamma$ rate is also predicted by some models that employ Large Extra Dimensions
L. Hall, C.Kolda, Phys. Lett. ***B459****, 213 (1999)*

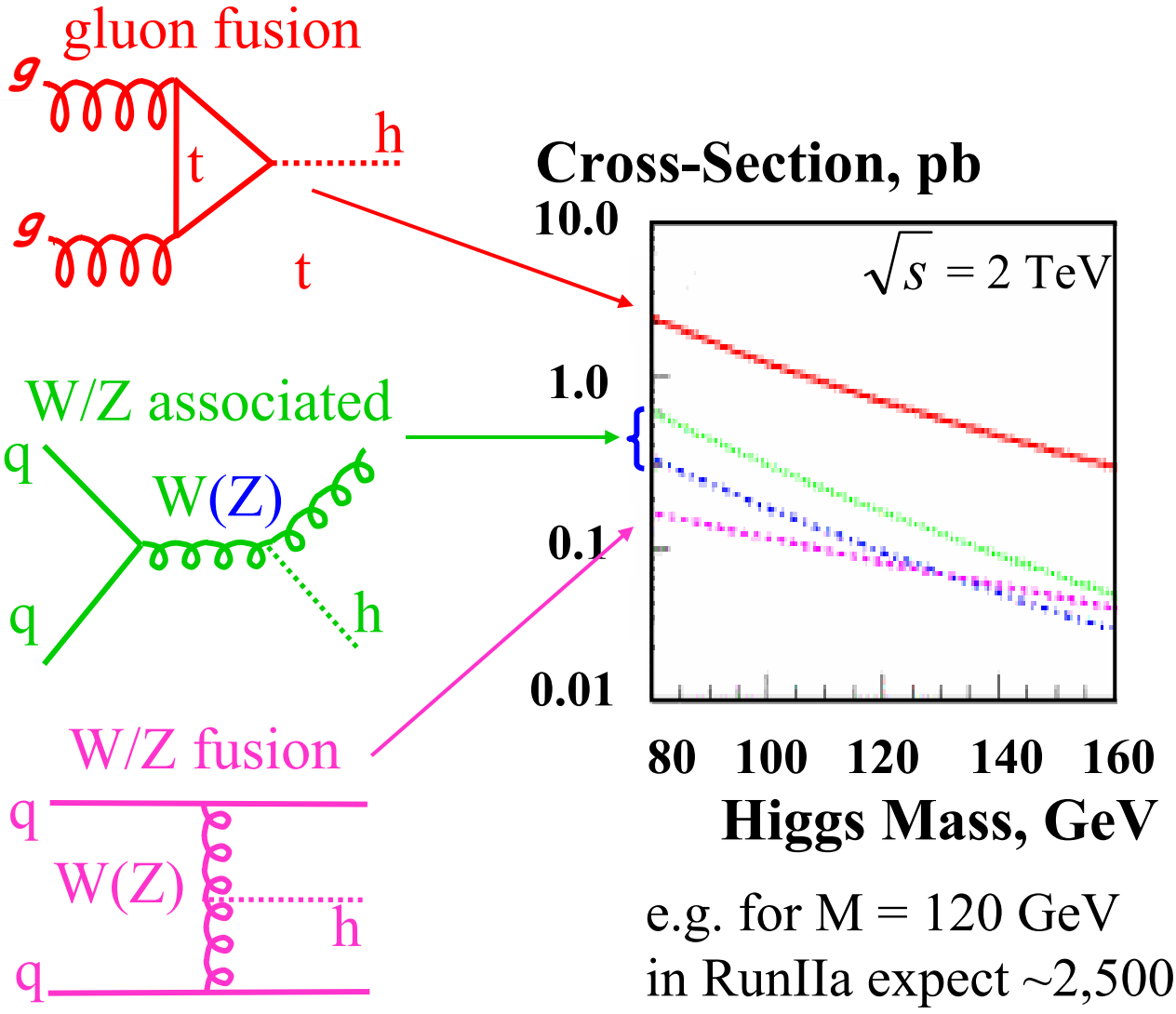
Examples of Enhancement of h→γγ decays



S.Mrenna, J.Wells, Phys. Rev. ***D63****, 015006 (2001)*

in general we should be prepared for any h→γγ branching ratio (up to 1.0) due to new physics

Leading Higgs Production Processes at Tevatron



e.g. for M = 120 GeV
in RunIIa expect ~2,500
produced Higgs events

$h \to \gamma\gamma$ Search Strategy

Focus on 2 Extreme Scenarios

1. ***Fermiophobic Higgs****(does not couple to fermions)*

can be produced in association with W/Z and by W/Z fusion (no gluon fusion)

1. ***Topcolor Higgs****(of all fermions couples only to top)*

can be produced via all three leading processes

Remaining scenarios as far as production rates and signatures can be approximated by one of these two

e.g. since u,d,c,s contribute negligibly to gluon fusion

- **no top,bottom couplings ≅ *Fermiophobic***
  with Br($h \to \gamma\gamma$) reduced due to $h \to \tau\tau$, $h \to cc$ decays
- **no down-type fermionic couplings ≅ *Topcolor***
  with Br($h \to \gamma\gamma$) reduced due to $h \to cc$ decays

for Topcolor Higgs search Tevatron has a big advantage in comparison with LEP : gluon fusion !

Backgrounds

Major Backgrounds are:

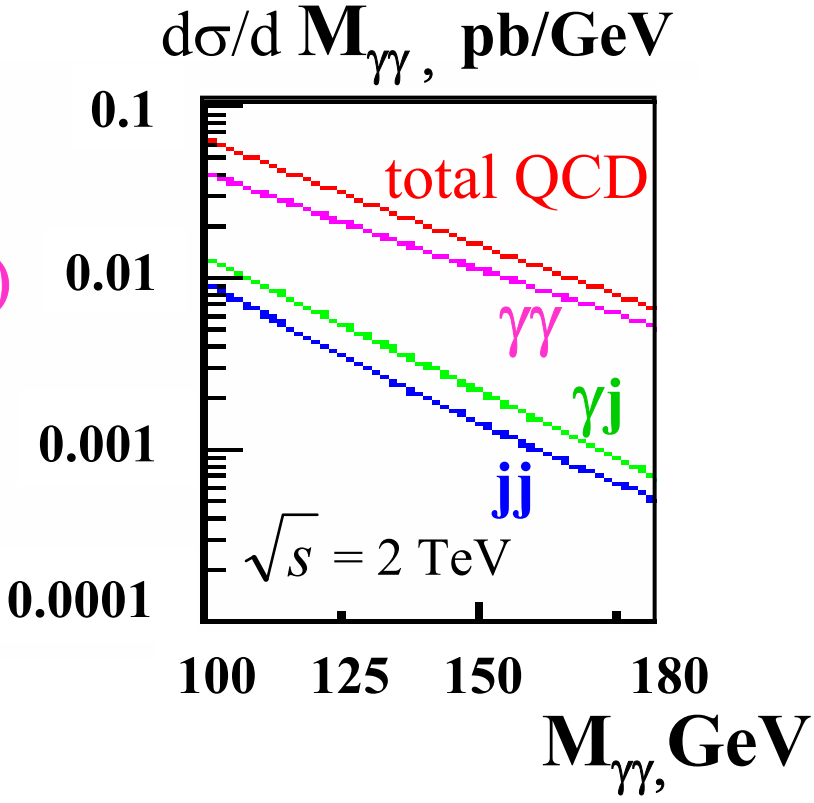
1. **$Z/\gamma^* \rightarrow ee$** with lost tracks

2. **QCD processes** that in the final state contain :

   - two photons ($\gamma\gamma$)

   - a photon and a hadronic jet misidentified as photon (γj)

   - two hadronic jets misidentified as photons (jj)



1999 FNAL Higgs Workshop results based on RunI estimates of photon misidentification

Previous Results

Fermiophobic Higgs Scenario

Tevatron RunI (0.1 fb^{-1}) 1992-1996

D0 : $\gamma\gamma$+2 jets analysis

found 4 events (expected background = 6.0 +/-2.1)
set mass limit of 78.5 GeV at 95% C.L.
B.Abbot et al. Phys. Rev. Lett. ***82****, 2244 (1999)*

CDF : $\gamma\gamma$+2 jets; $\gamma\gamma$+e, μ, MissingEt analysis

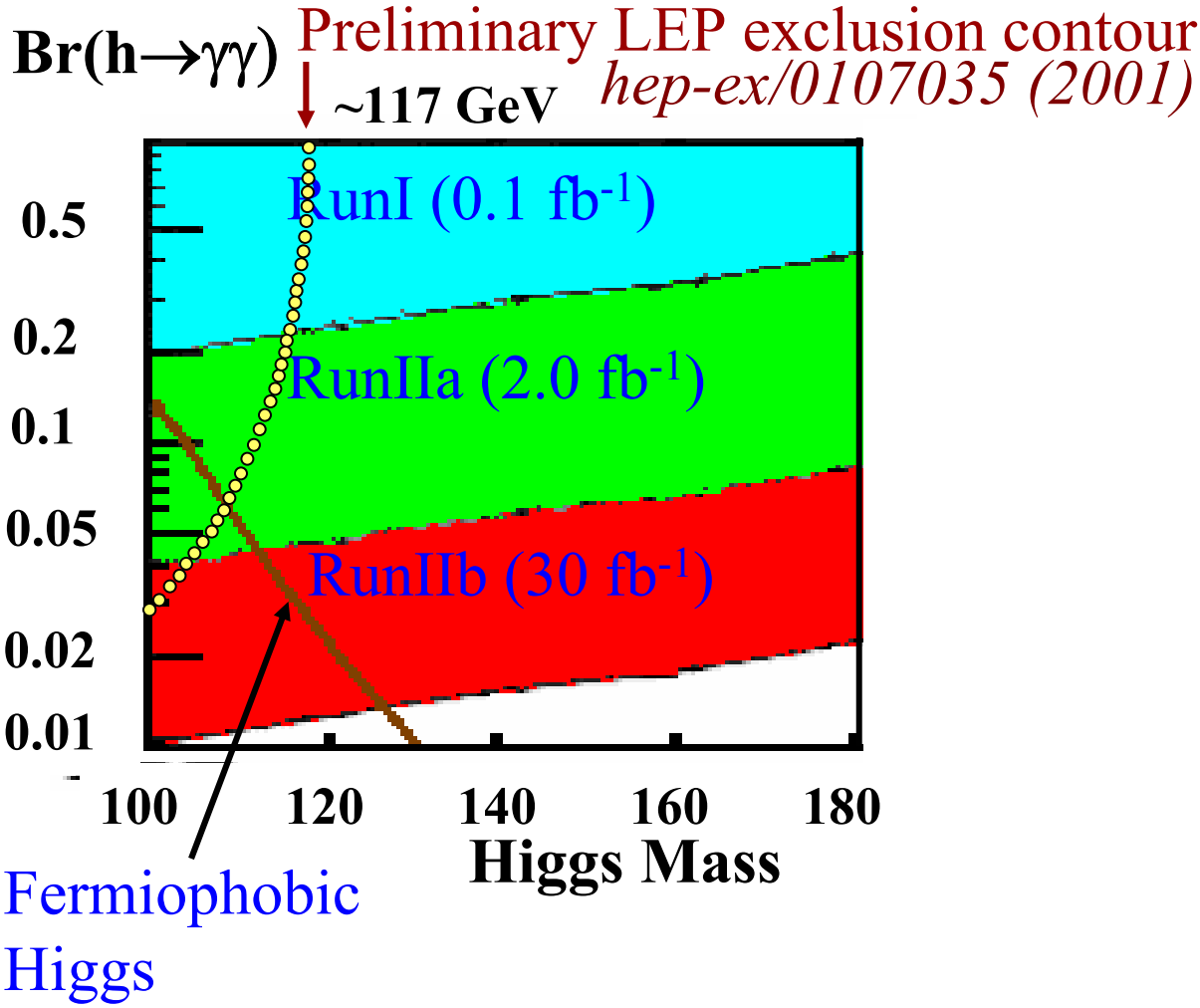
found 6 events (expected background = 6.2 +/-2.1)
set mass limit of 82 GeV at 95% C.L.
F.Abe et al. Phys. Rev. ***D59****, 092002 (1999)*

LEP limit : 108.2 GeV at 95% CL
hep-ex/0107035 (2001)

Tevatron RunII Sensitivities

Fermiophobic Higgs Scenario

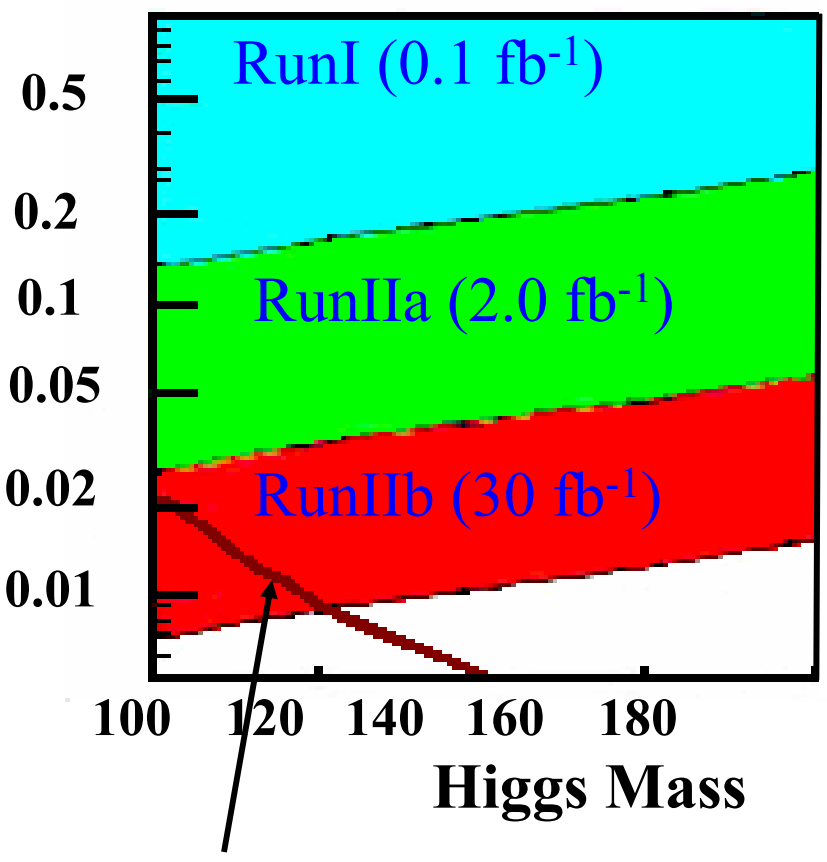
G.Landsberg , K.Matchev
Phys. Rev. ***D62****, 035004 (2000)*
estimated limits on h→γγ Branching Ratio as a function of Higgs Mass with 95% CL



Tevatron RunII Sensitivities

Topcolor Higgs Scenario

h→γγ Branching Ratio



Model in which Higgs does not couple to down-type fermions

Selection of $\gamma\gamma$ Candidate Events

- ***Trigger:***
  di-EM or Single EM high Pt triggers

- ***Offline:*** *(on both objects)*

  Kinematic cuts: Pt >20GeV

  Acceptance cuts: Central or End Cap Calorimeter up to $|\eta|$=2.4

  Photon ID: - shower shape consistent with EM shape (EMfraction, Isolation, H-matrix χ2)

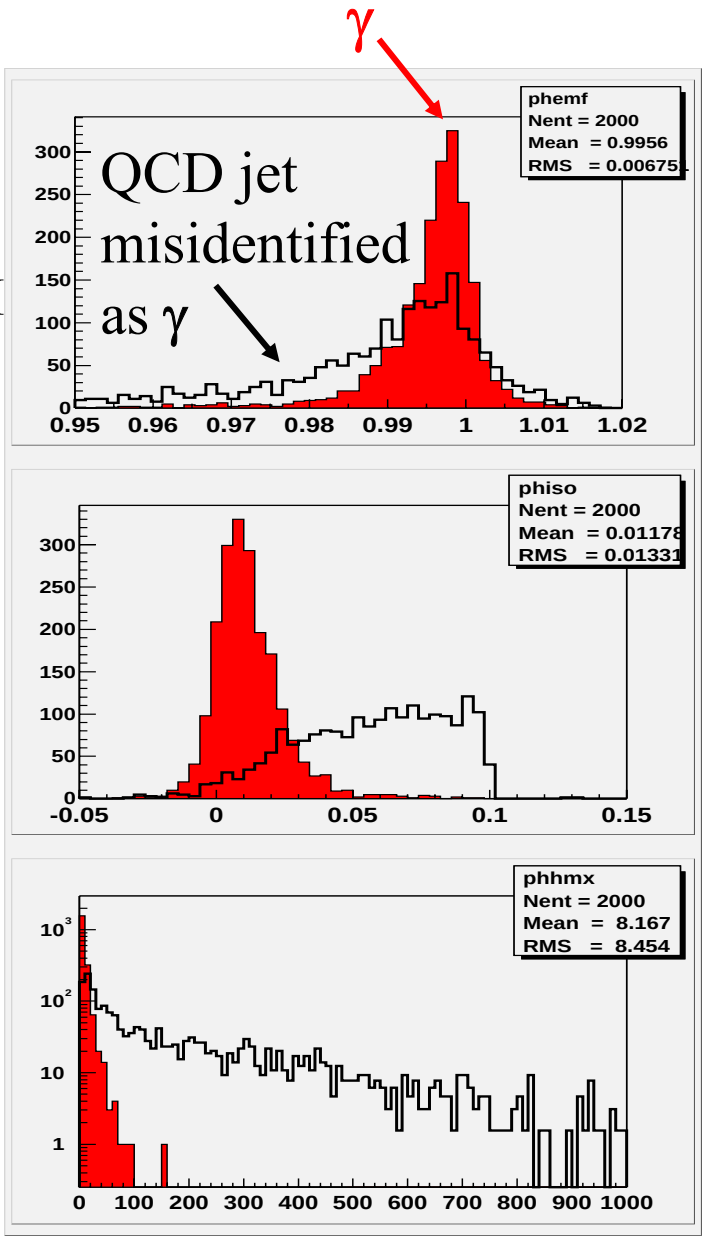
  - track veto

Photon ID Tools
(Monte Carlo Distributions)

EM fraction
ratio of EM cluster energy deposited in EM calorimeter and total energy

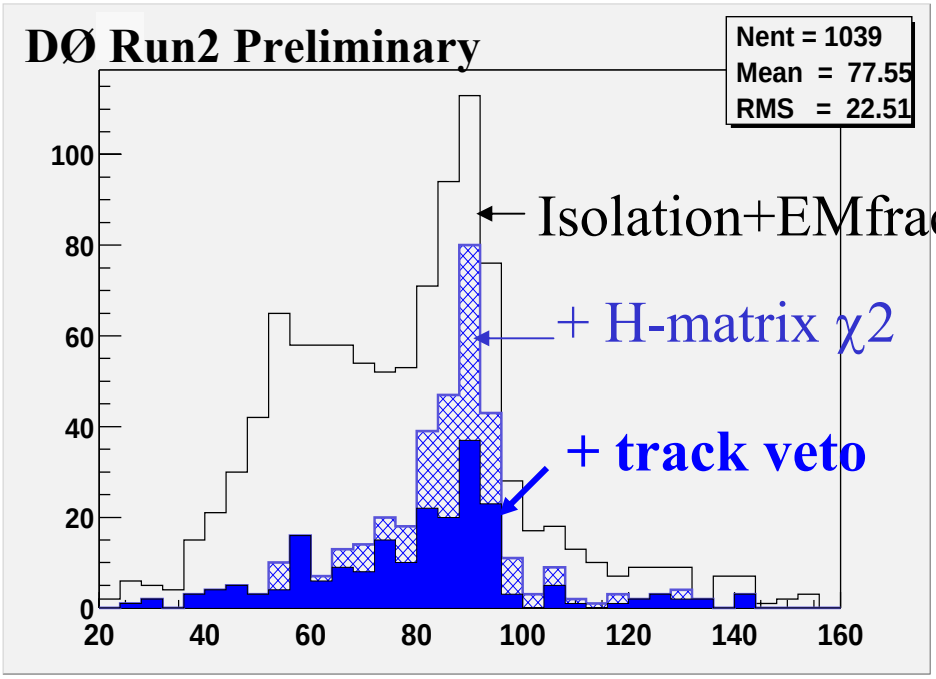
Isolation
measure of cluster narrowness

H-matrix χ2
multi-variable tool describing shower shape



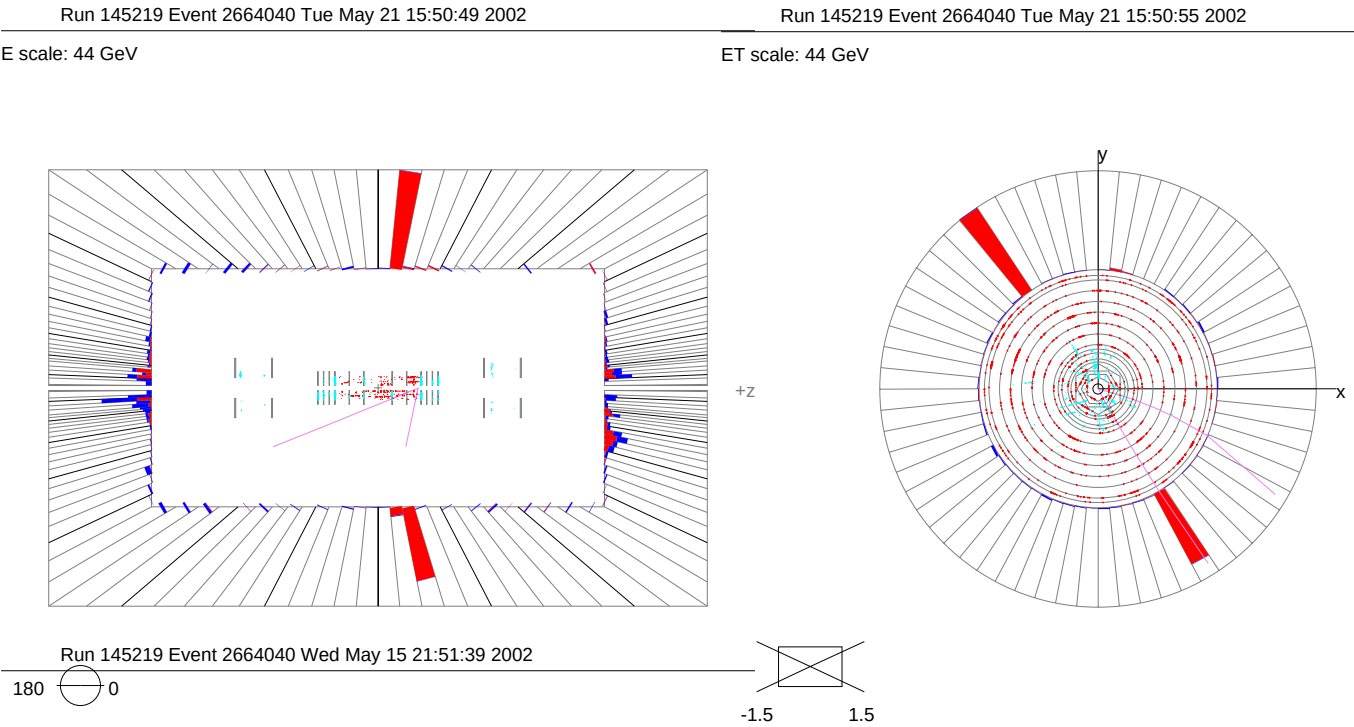
di-EM Mass Distribution from 11/01-04/02 D0 data

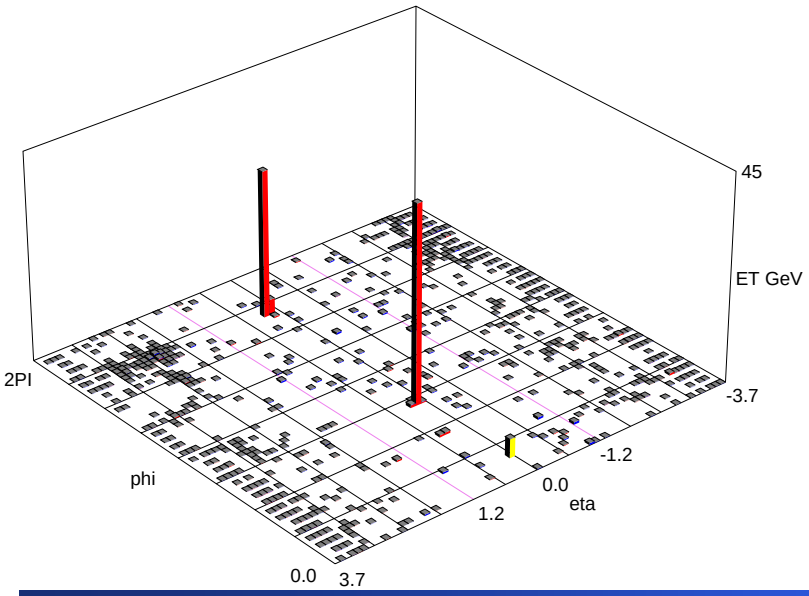
first look at selected $\gamma\gamma$ candidate events in a small data set with only partial calibration:



currently work is in progress on understanding backgrounds and reducing photon misidentification rate

Event Displays of γγ Candidate Event



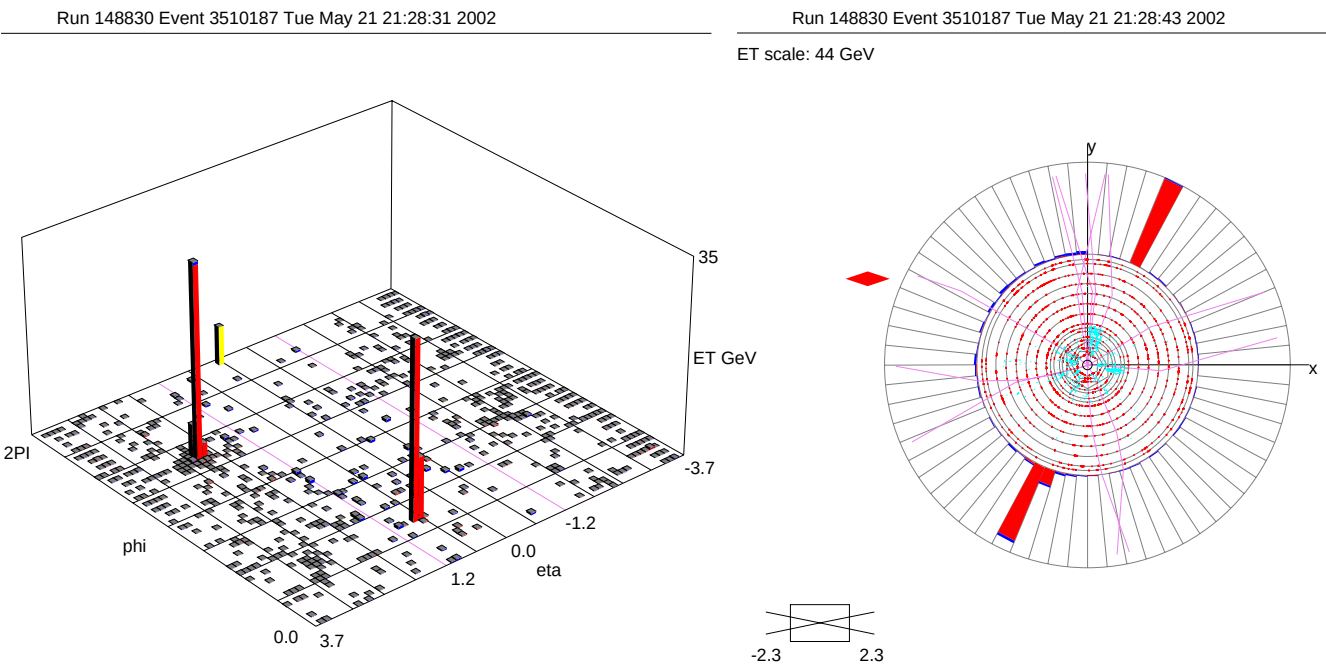


Mass = 84.9 GeV

loose track match
for one of the objects

very likely
Z→ee event

Another γγ Candidate



Mass = 125.8 GeV

h→γγ event
may be expected
to look like this

Conclusions

- At Tevatron Standard Model Higgs Boson can not be probed using $\gamma\gamma$ decay mode beyond LEP findings
- non-SM Higgs Boson may be probed soon (e.g. the reach for Fermiophobic Higgs at 95% CL in RunIIa is ~115 GeV)
- RunIIa data is being accumulated and we are beginning to understand it
- It is enjoyable experience
- Stay tuned