A top quark mass template measurement at CDF, and How to keep the CDF Silicon detector running

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(…and a few remarks about research interests)

A little retrospective…

-First Dilepton tt cross section measurement in CDF Run II

Phys. Rev. Lett. 93, 142001 (2004).

-First observation of WW production in hadron colliders

Phys. Rev. Lett. 94, 211801 (2005).

-Simultaneous measurement of tt, WW and $Z \rightarrow \tau\tau$ cross sections in the dilepton channel at CDF

Phys. Rev. D. 78, 012003 (2008).

-First simultaneous Lepton + Jets and dilepton template

top quark mass measurement

Accepted for publication in Phys Rev D

-Moved to ATLAS research about 8 months ago

(started Jet Monitoring tasks and dijet resonance search)

-Higgs search next??

Outline

-Template measurement of the top quark mass in CDF usinng the dilepton and lepton+jets decays channels simultaneously

-Search for the Higgs?

-On keeping the CDF silicon detector running

$t\bar{t}$ production at CDF

Top quarks are primarily produced in pairs (σ~7pb), via

$q\bar{q}$(85%) and gg(15%) at Tevatron.

Top decays as free quark: $\tau_{top} \sim 4 \times 10^{-25}$ s (due to large mass)

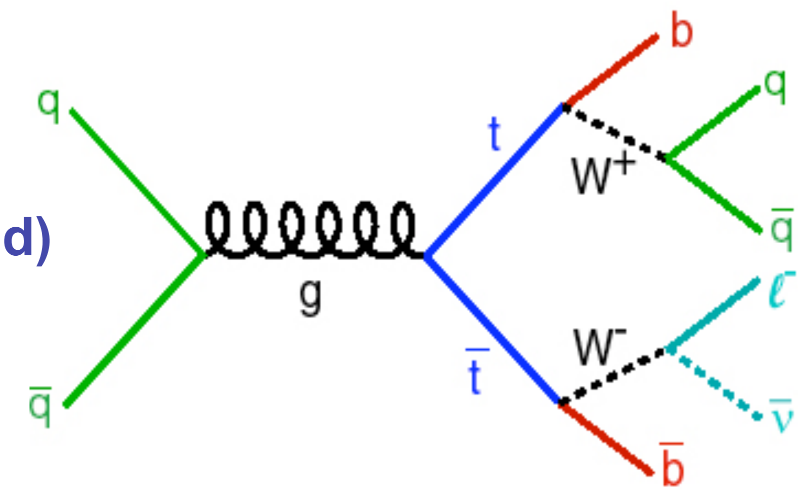
almost exclusively to a W boson and a b quark (jet)

The W decays characterize the $t\bar{t}$ decay channels:

Dilepton (5%, small background)
2 high-P_T leptons(e/μ), 2 b-jets,
large missing E_T

Lepton+Jet (30%, manageable background)
1 high-P_T lepton(e/μ), 4 jets (2 b-jets),
large missing E_T(30%)

All-hadronic (44%, large background)
6 jets (44%)



TMT - Why 2 channels?

No assumptions about correlations in systematic uncertainties between channels

No assumptions on likelihood shapes

In-situ Jet Energy Scale (JES) calibration in both channels

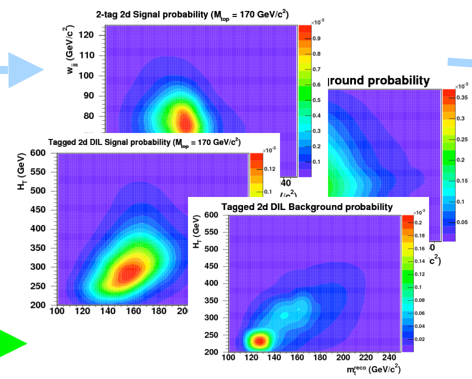
First Combined Dilepton + Lepton+Jets under the same measurement

TMT - Template Technique

MC
- ttbar: set of M_{top} and JES points
- backgrounds

DATA
Lepton+Jets

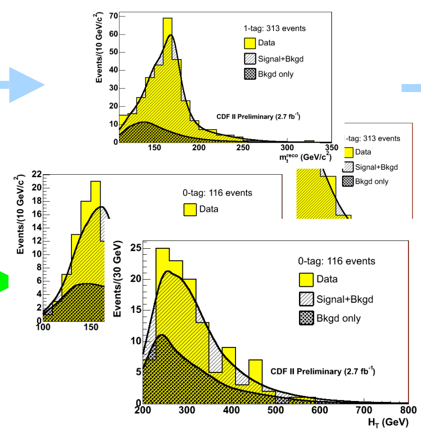
χ^2 fitter
NWA



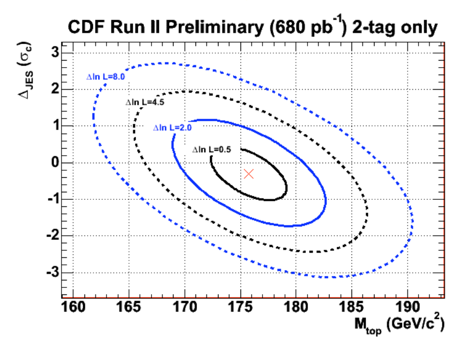
m_{top}^{reco} distribution
- Selects best jet-to-parton assigned top mass per event

Likelihood Fit:
- **Fit for signal fraction**
- **Find best M_{top} and JES**

Event Reconstruction



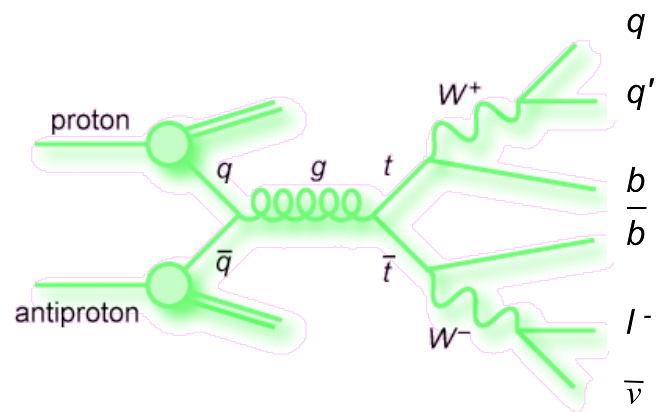
Parameterize:
- **form PDFs for each template**
- **Shapes vary as a function of true Mtop and JES**

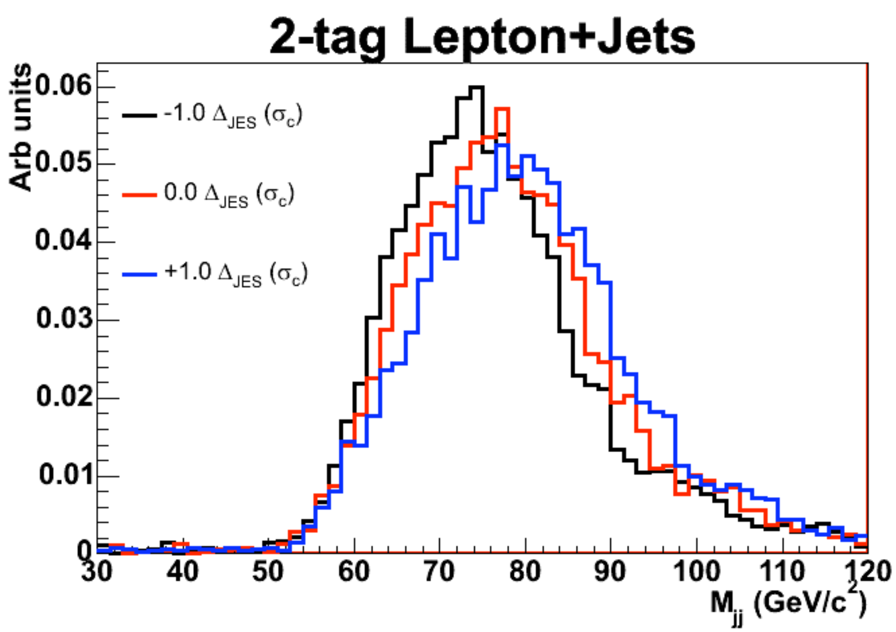


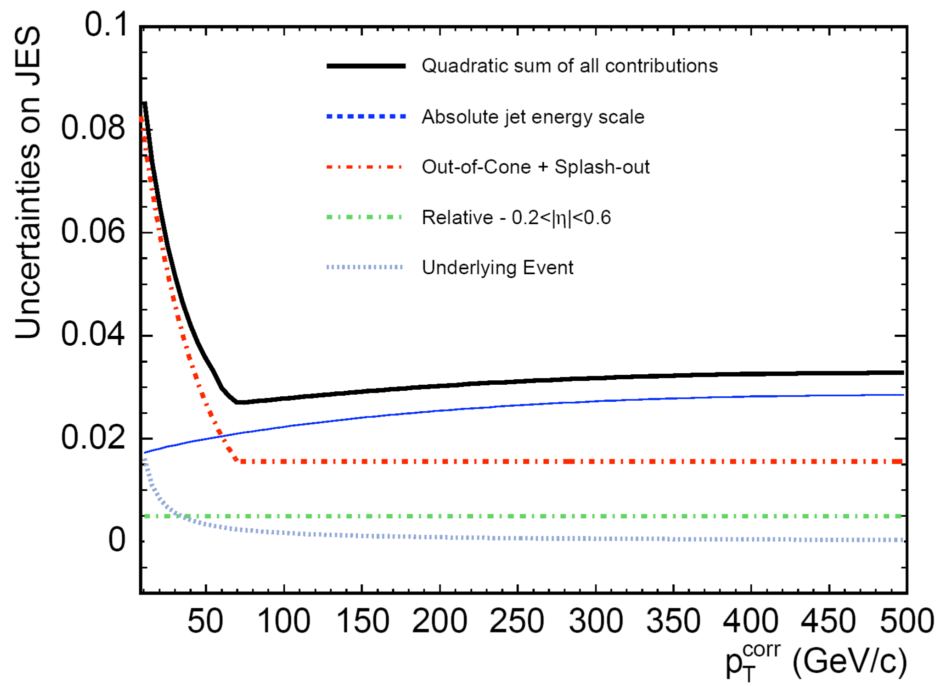
TMT - Jet Energy Scale

Use Hadronically decaying W to constrain JES

The mis-calibration is measured in units of total uncertainty







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TMT - Backgrounds

Lepton+Jets

	1-tag	2-tag
Wbb	9.1	2.1
$Wc\bar{c}$	5.0	0.4
Wc	3.3	0.1
W(mistags)	10.4	0.2
single top	2.0	0.7
diboson	2.4	0.2
QCD	10.4	0.3
Total Background	42.7±12.5	4.2±1.9
$t\bar{t}$ (6.7 pb)	156.7	76.6

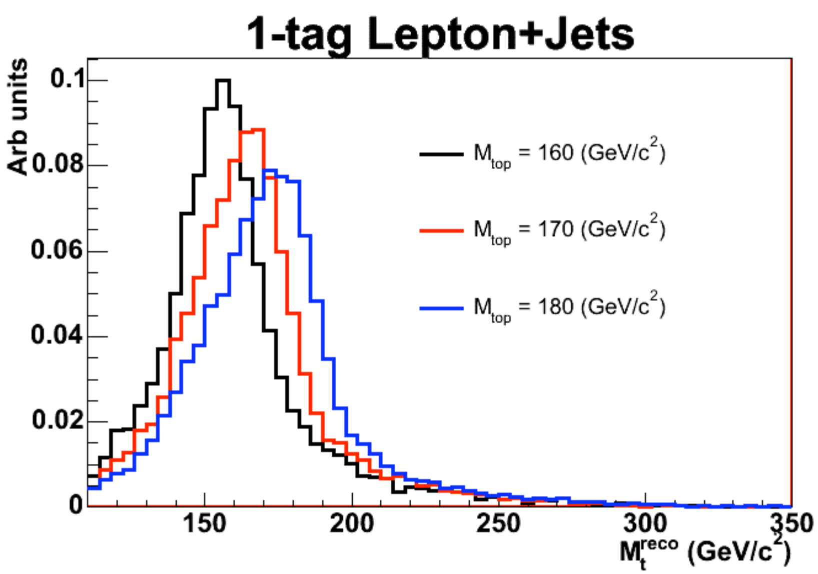
Dilepton

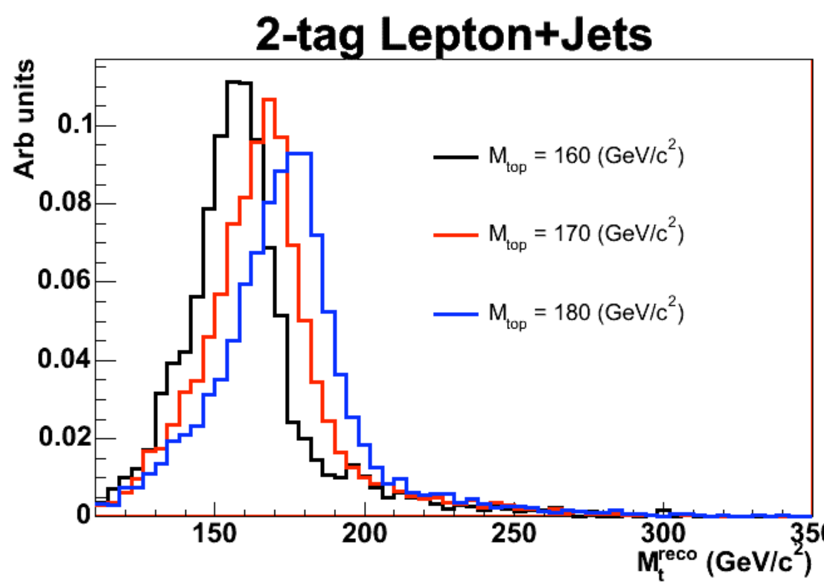
	0-tag	tagged
diboson	8.9	0.3
Drell-Yan	16.0	0.9
fakes	6.1	1.2
Total Background	31.1 ±5.6	2.4 ±0.6
$t\bar{t}$ (6.7 pb)	40.1	55.8

TMT - Lepton + Jets template

-Use standard χ^2 fit to resonctruct each single top mass per event
-Correlated with true top mass but not the same
-We use the over constrained kinematics of the tt system in the l+jets channel

$$\chi^2 = \Sigma_{i=\ell,4jets}\frac{(p_T^{i,fit}-p_T^{i,meas})^2}{\sigma_i^2}+\Sigma_{j=x,y}\frac{(U_j^{fit}-U_j^{meas})^2}{\sigma_j^2} + \frac{(M_{jj}-M_W)^2}{\Gamma_W^2}+\frac{(M_{\ell\nu}-M_W)^2}{\Gamma_W^2}+\frac{(M_{bjj}-M_t^{\rm reco})^2}{\Gamma_t^2}+\frac{(M_{b\ell\nu}-M_t^{\rm reco})^2}{\Gamma_t^2}($$





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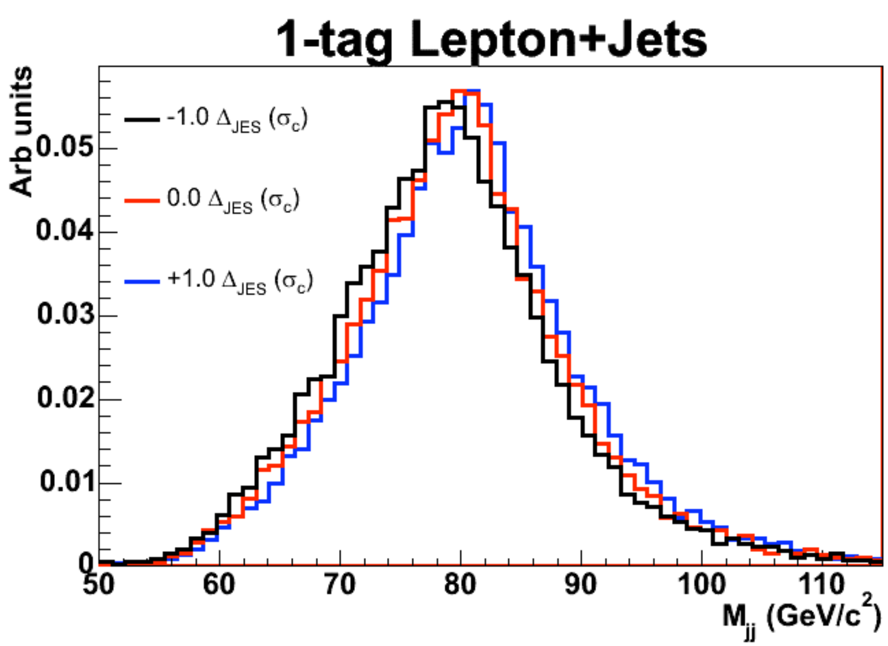
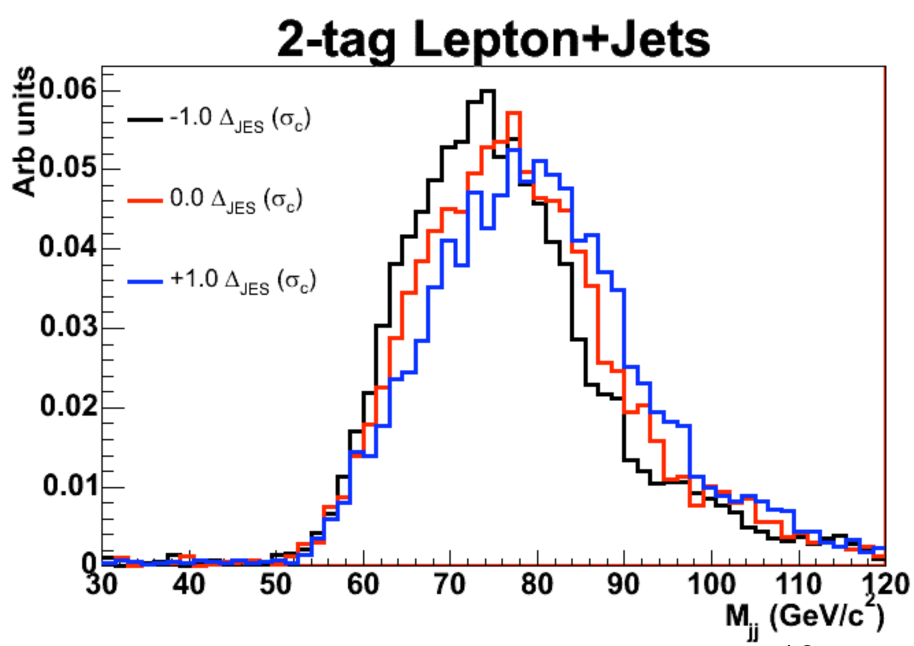
TMT - Dijet Mass Reconstruction

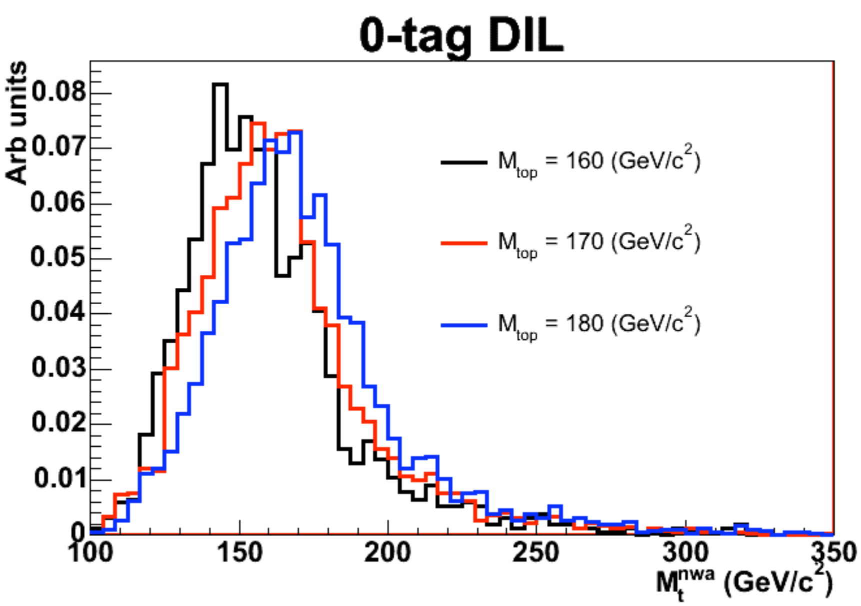
-Kinematic fitter works well but distributions are highly correlated to both top mass and JES
-Reconstruct the the dijet mass from the hadronically decaying W
-Use the dijet mass closes to the well know mass of the W from any pair of untagged jets among the leading 4 jets
-Throw away events failing χ^2 cut.

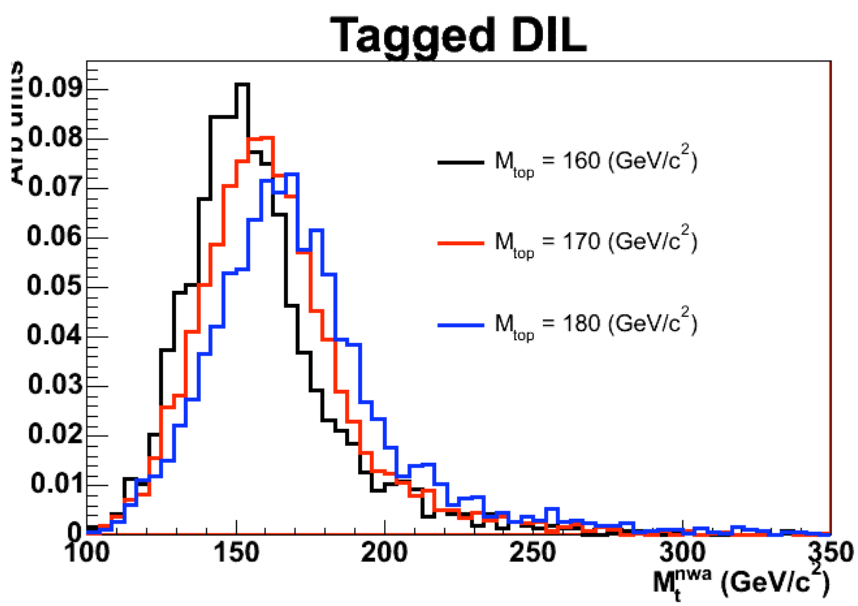




TMT - Neutrino Weighting

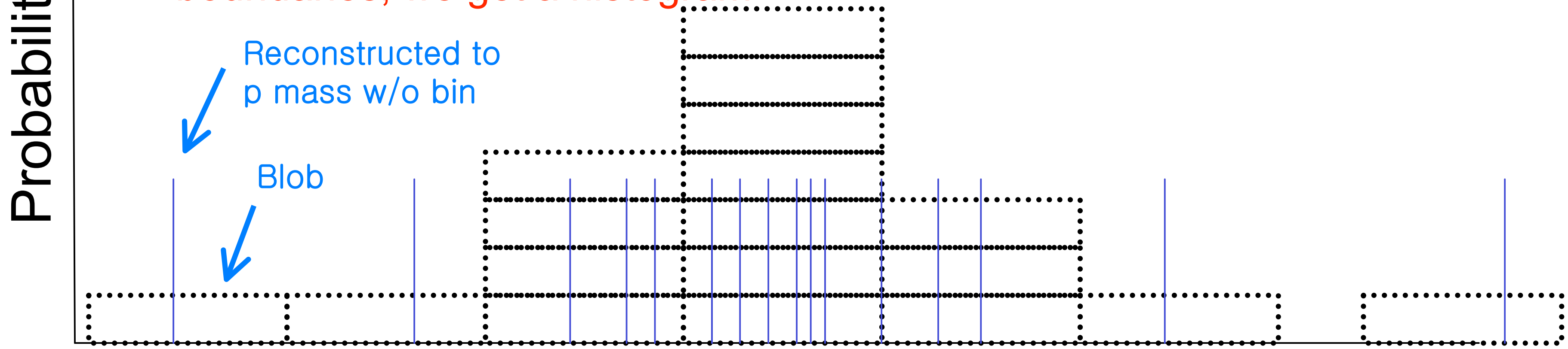
-The kinematics of the system is not fully known due to neutrinos
-Assume all possibilities of parton assignments
-Integrate over kinematical quantities of the neutrinos and calculate neutrino “statistical weight”
-Scan over a range of top masses and return that for which the “weight” is the greatest
-Find distributions for each MC sample with assumed top quark mass



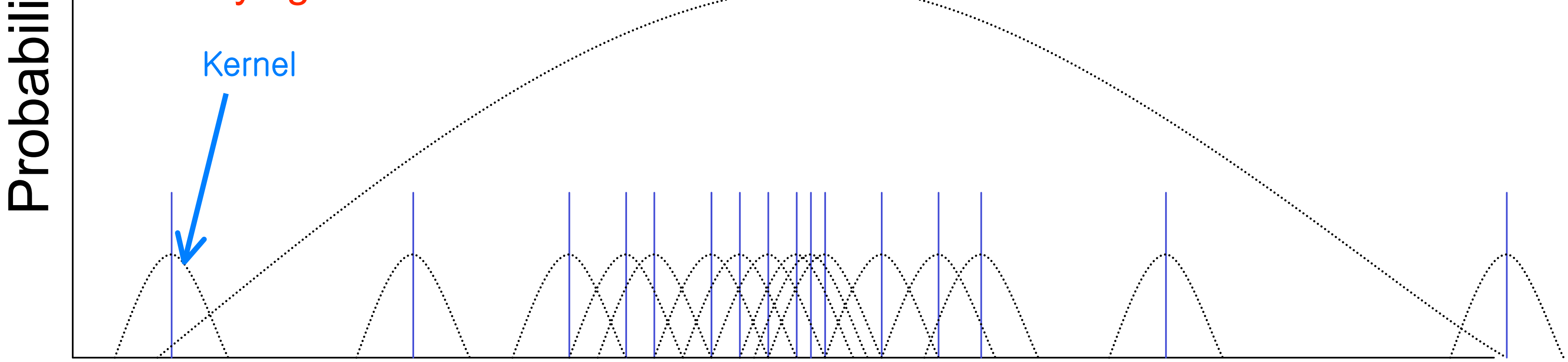


TMT - (KDE)

If the shape is a rectangular box & we force the box to straddle the bin boundaries, we get a histogram



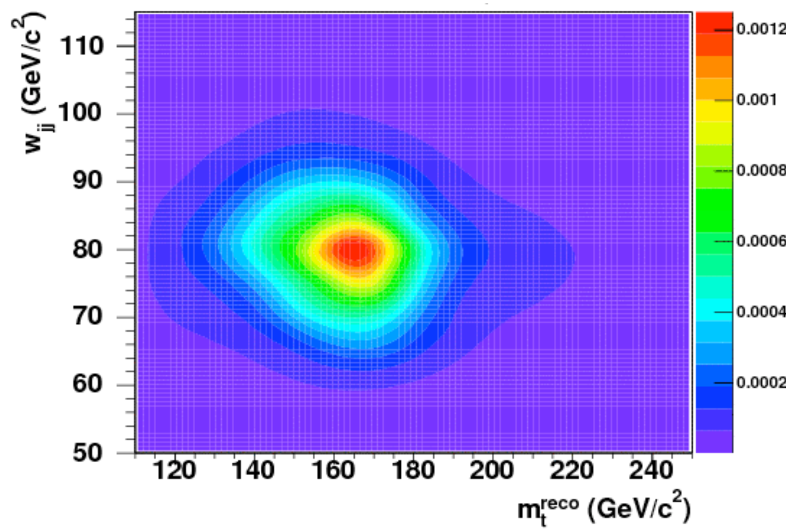
Add up all the blobs (i.e. Kernels) and you have an estimate for the true, underlying PDF



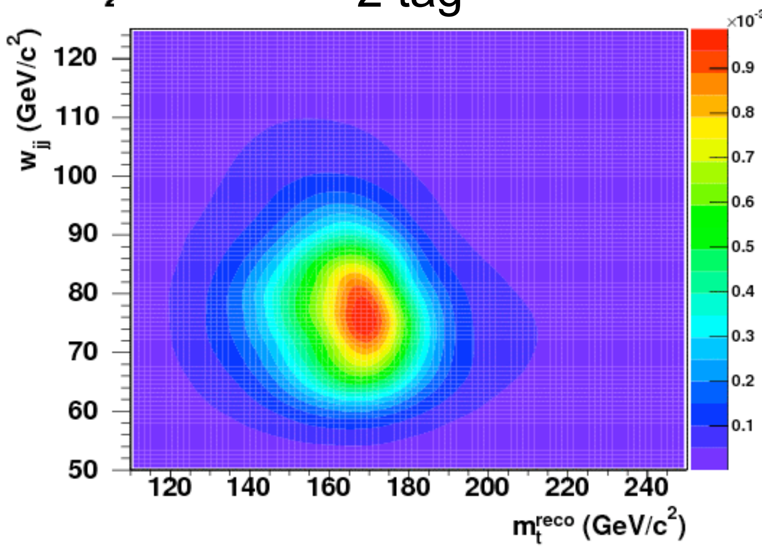
TMT - Signal PDF's

Lepton+jets

1 tag

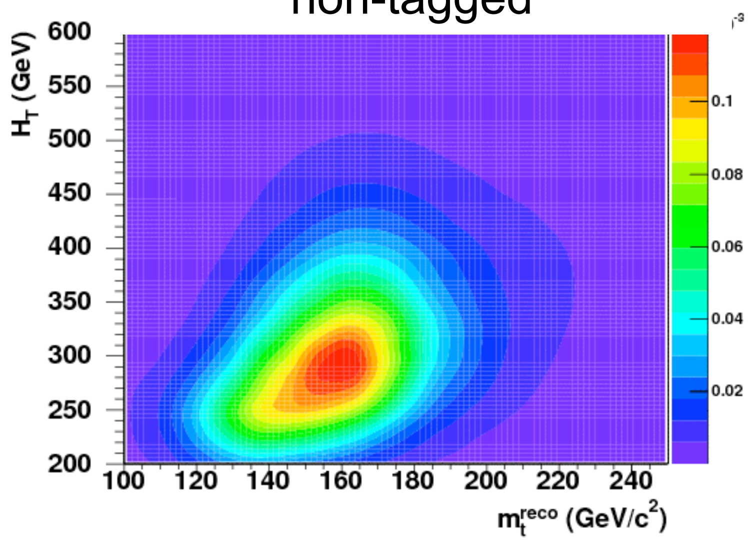


2 tag

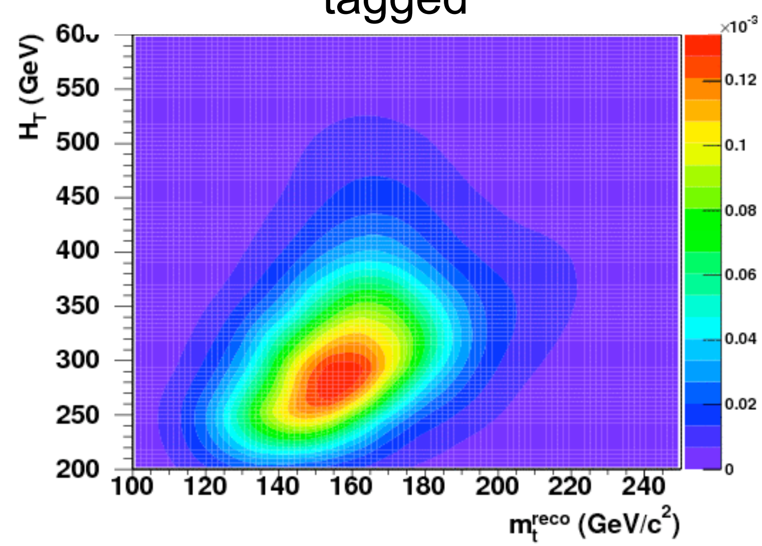


dileptons

non-tagged



tagged



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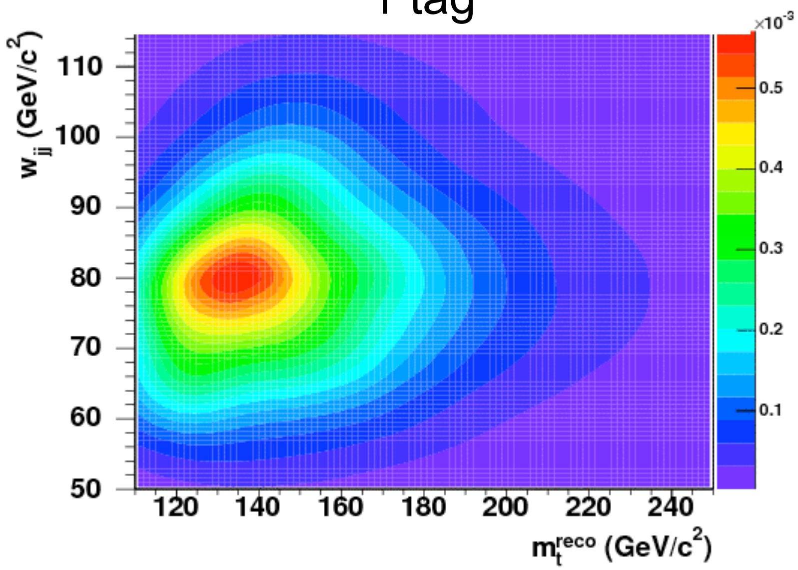
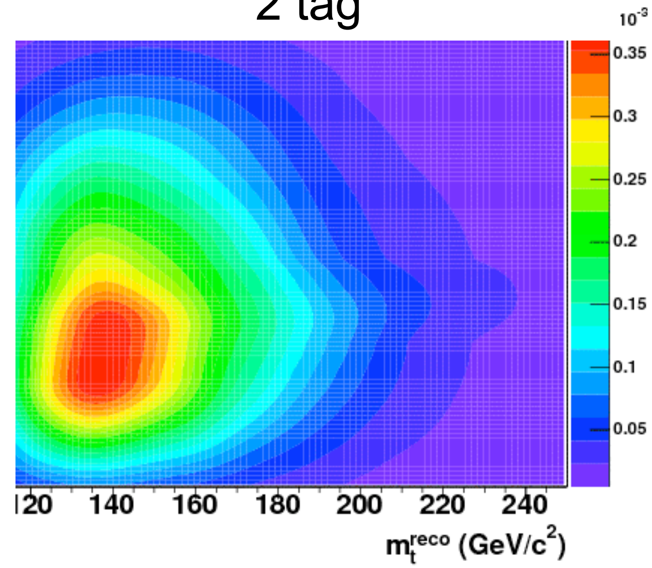
TMT - Background PDF's

lepton + jets

1 tag

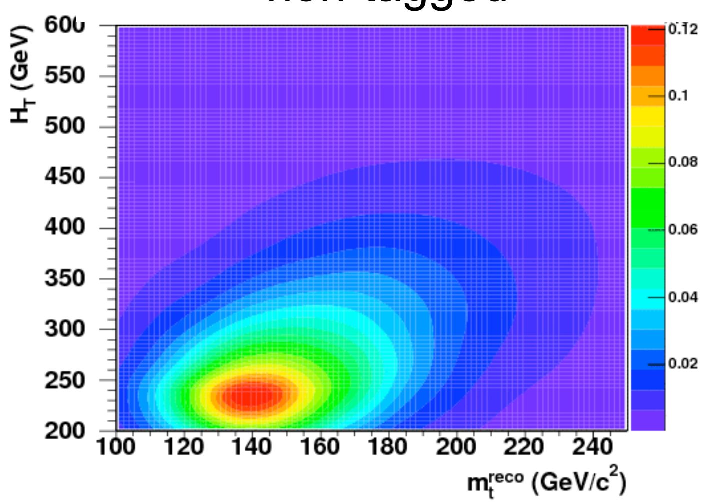


2 tag

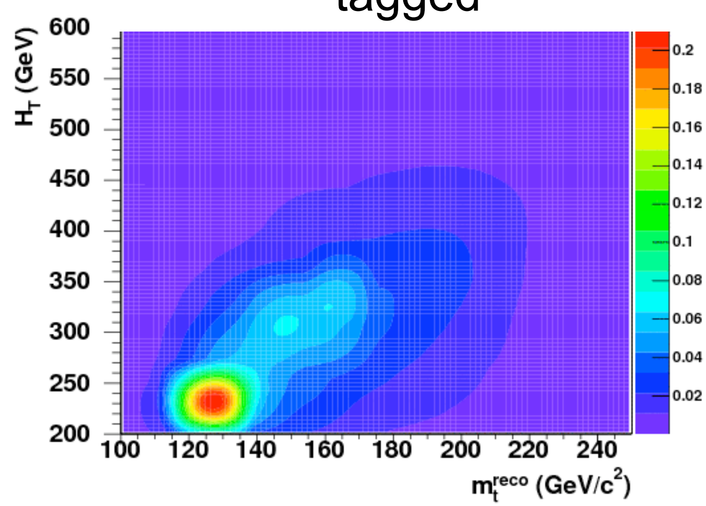


dileptons

non-tagged



tagged



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TMT - Likelihood Fit

$$\mathcal{L}_k = \exp\left(-\frac{(n_b - n_b^0)^2}{2\sigma_{n_b}^2}\right) \times \prod_{i=1}^{N} \frac{n_s P_{sig}(m_i, y_i; M_{top}, \Delta_{JES}) + n_b P_{bg}(m_i, y_i)}{n_s + n_b}$$

-Where ns and n_b are signal and background expectations

-N is the number of events in the subsample

-P_{sig} is the signal probability density function

-Pbg is the background probability density function.

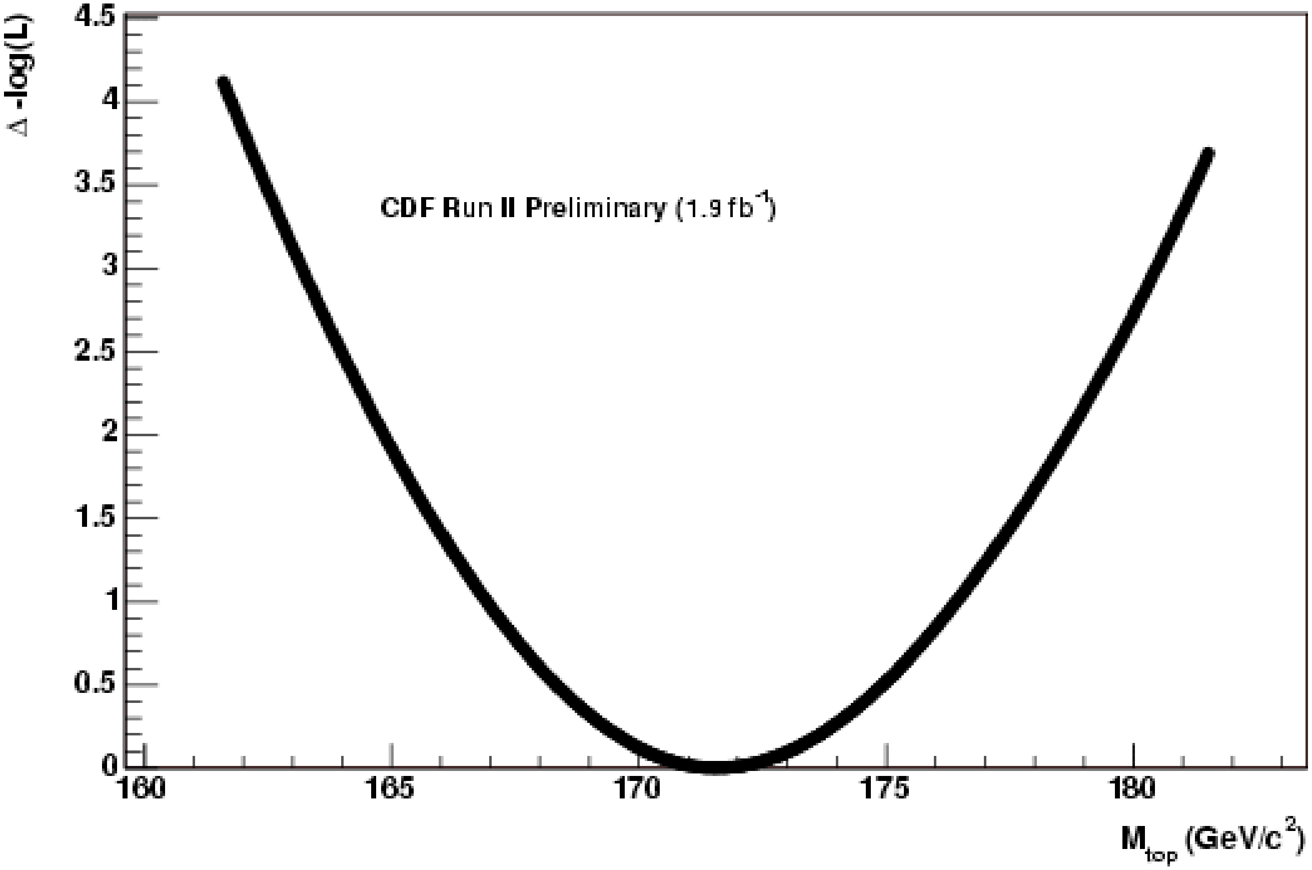
-m_i and y_i denote m_t^{reco} and m_{jj} or M_t^{NWA} and H_T depending on the sample.

-n_b^0 is the a-priori background estimate and σ_{nb} is the uncertainty on that estimate.

TMT - Systematic Uncertainties

Systematic	LJ	DIL	Combination
b-JES	0.6	0.5	0.6
Residual JES	0.5	3.5	0.5
ISR	0.3	0.4	0.4
FSR	0.2	0.5	0.2
PDFs	0.3	0.5	0.3
Generator	0.2	0.8	0.2
LJ bkgd shape	0.2	0.0	0.2
DIL bkgd shape	0.0	0.4	0.1
MC statistics	0.1	0.2	0.1
lepton energy scale	0.1	0.4	0.1
pileup	0.1	0.1	0.1
gg fraction	0.0	0.2	0.0
Combined	1.0	3.8	1.0

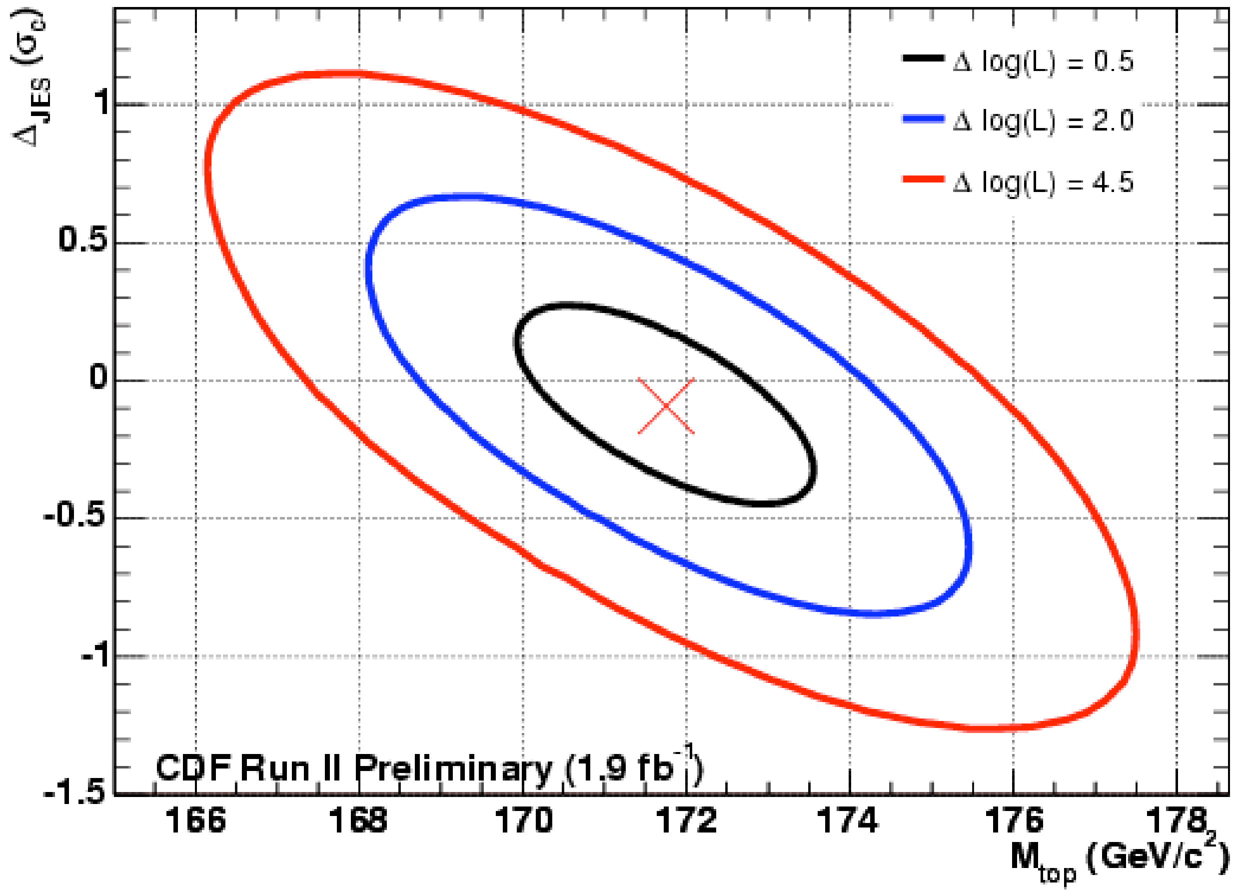
TMT - Dilepton only Fit



M_{top} = 171.6 $^{+3.4}_{-3.2}$ (stat.) +/- 3.8 (syst) GeV/c^2

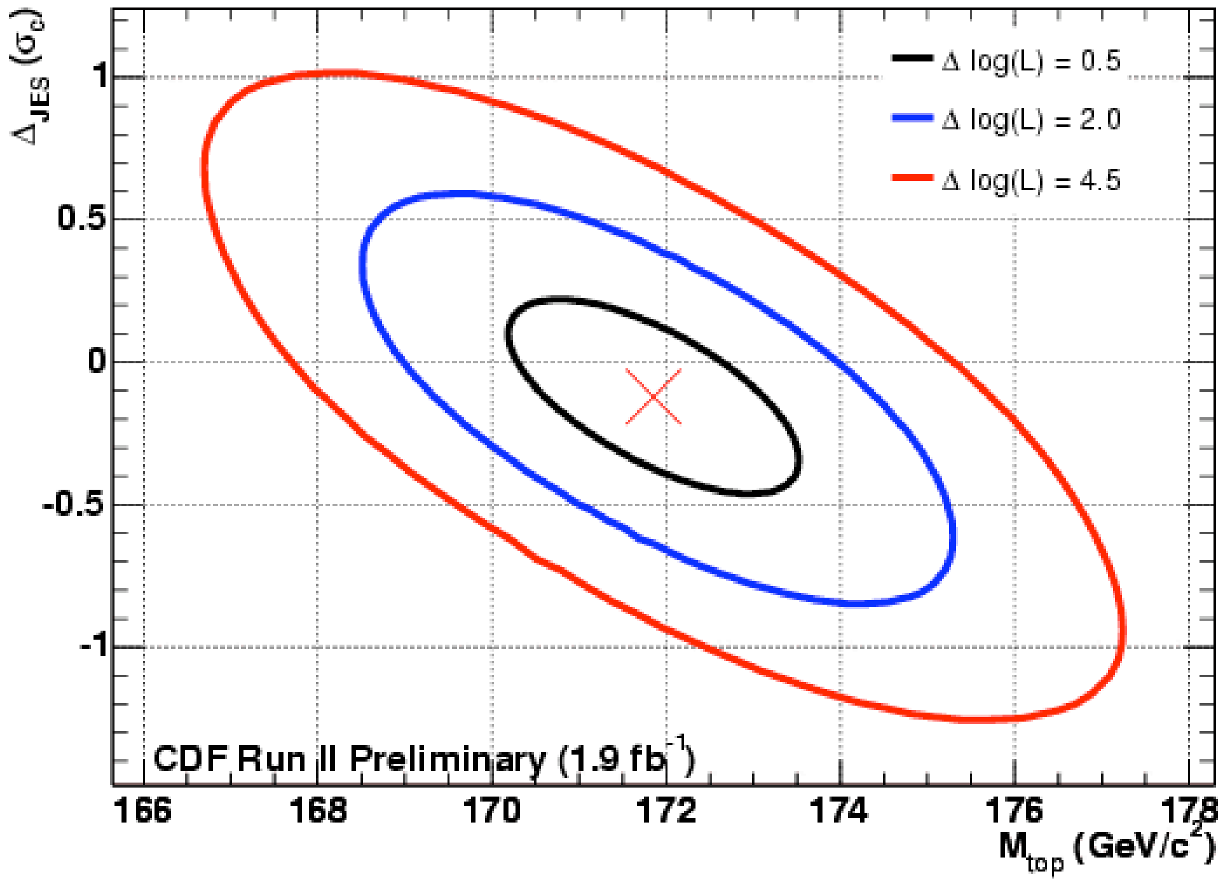
= 171.6 $^{5.1}_{-5.0}$ GeV/c^2

TMT - Lepton +Jets only Fit



M_{top} = 171.8 +/- 1.9 (stat.+JES) +/- 1.0 (syst) GeV/c^2
= 171.8 +/- 2.1 GeV/c^2

TMT - Combined Fit



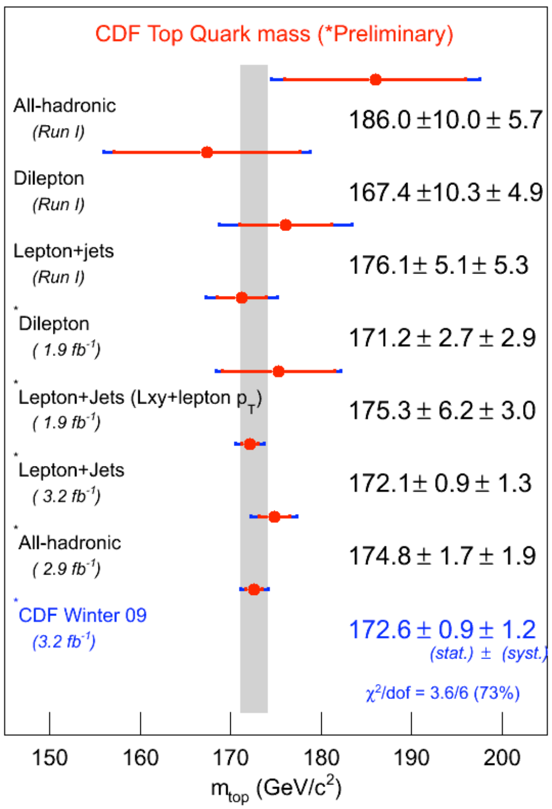
M_{top} = 171.9 +/- 1.7 (stat.+JES) +/- 1.0 (syst) GeV/c^2

= 171.9 +/- 2.0

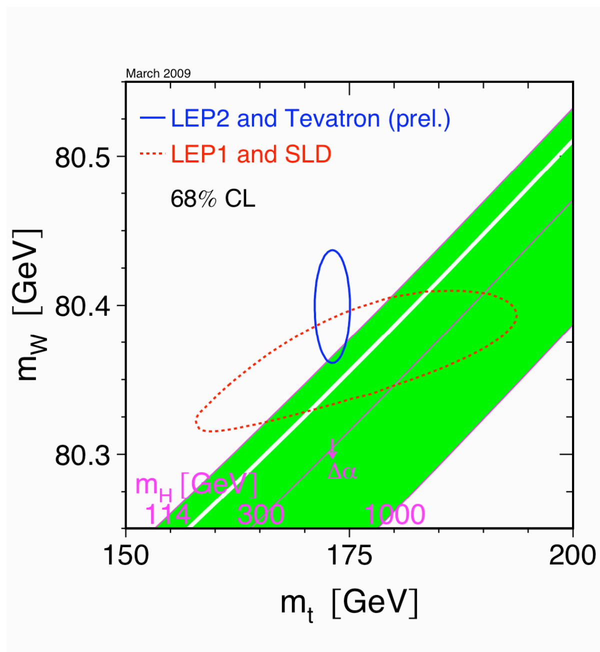
World Top Mass Results

Since then (2008) not only the TMT analysis was updated with more data (U of Chicago group) (I was gone to ATLAS), but now the top mass picture looks as follows:

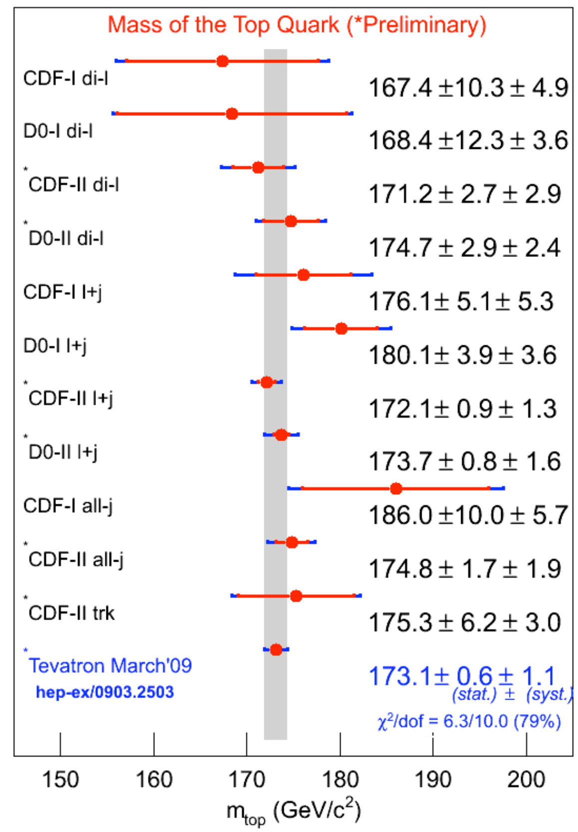
CDF



TEVATRON



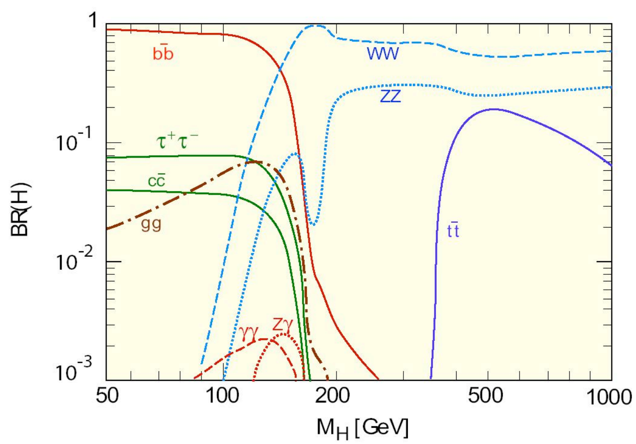
TEVATRON

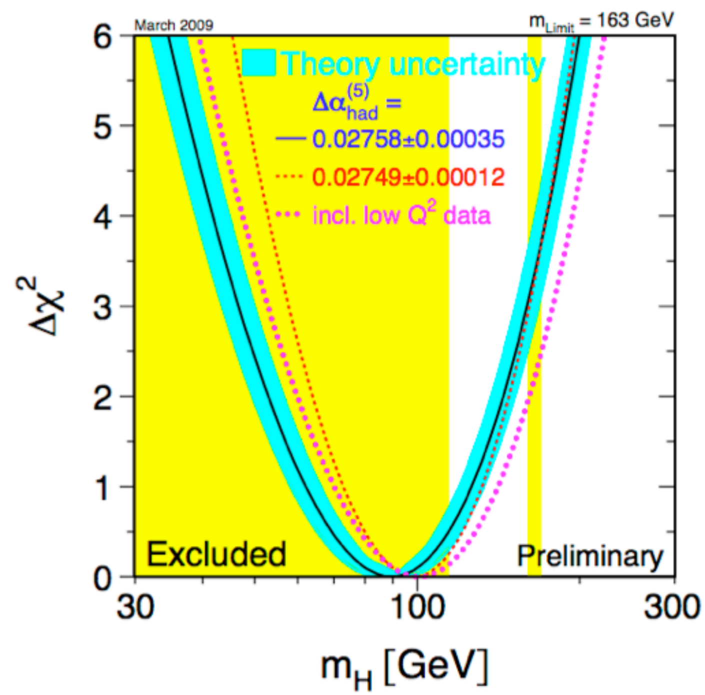


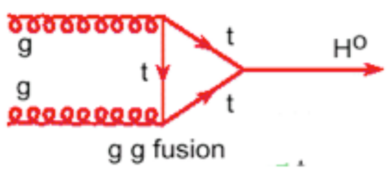
Higgs ?

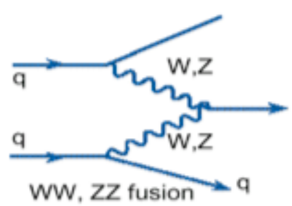
-The top mass and W mass help focus the searches for the Higgs

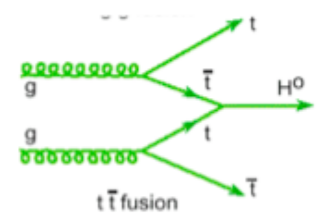
-As the LHC comes online it is expected to be a Higgs machine, However…..











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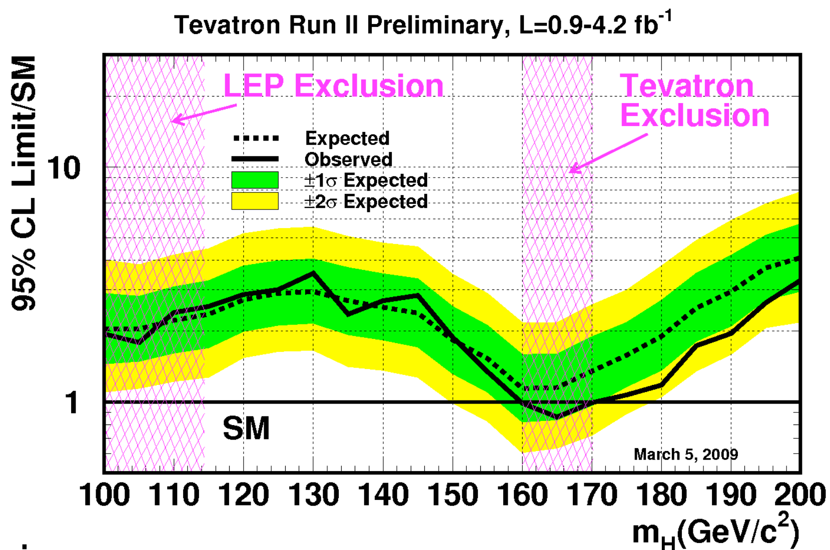
Higgs ?

The Tevatron is definitely in the race:

-Both delays at the LHC and very good Tevatron performance have improved the Tevatron chances

-Recent results have created new exclusion regions, and the tendency is for this to expand in the near future

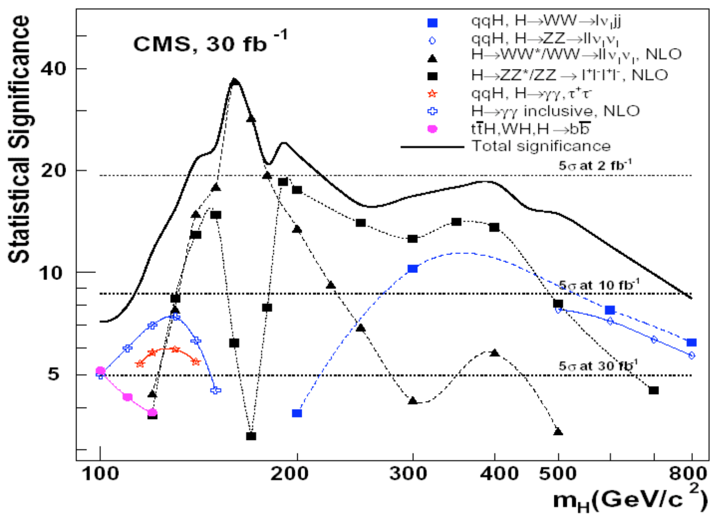
-The key is to continue taking data as efficiency as possible and avoid potential game-changers (keep the CDF silicon running for example)

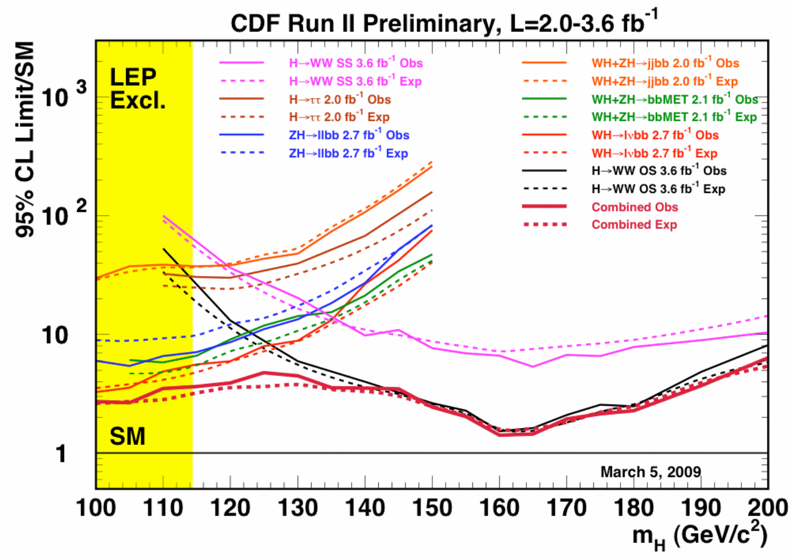


Higgs ?

-A few possible analysis to get involved in:

- -In CDF, the H->WW will be re-optimized for the 125-150 GeV range
- -In CDF, there are a multitude of WH decay channels, a few can use extra help
- -It might be beneficial to step back and explore a multi-channel fit approach
- -In CMS, it might be useful, in the very short term, to concentrate on the cleanest decay channels (H->ZZ for example) and later press on the low mass region.

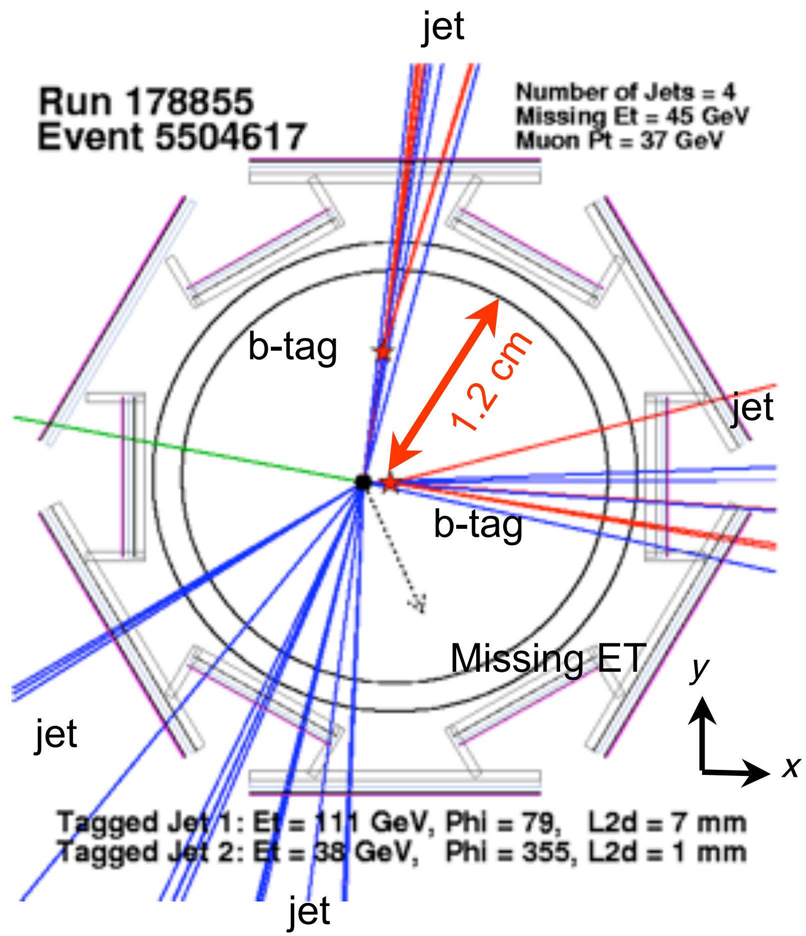




Main Purpose of Silicon Detectors

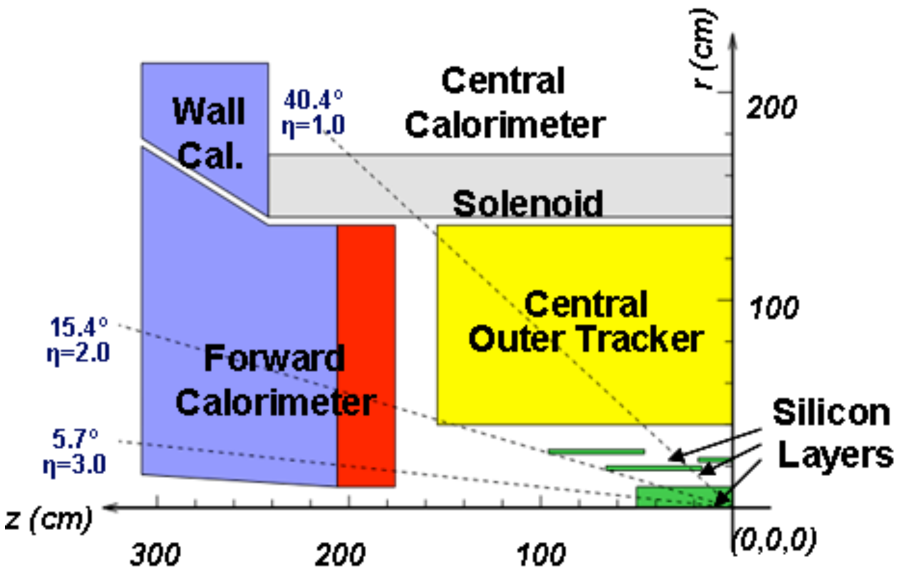
- Precision tracking
  - Momentum measurement
    - From track curvature
  - Impact parameter
    - Closest distance between track helix and z-axis:
    - Need precision tracking point close to primary interaction
- B-tagging
  - Identification of jets originating from B mesons
  - Long-lived B mesons (cτ ≈ 500 μm) lead to displaced vertices.
  - Resolution about 50 μm
- CDF triggers on displaced vertexes
  - Silicon needs to be readout at L1A (up to 35 kHz)

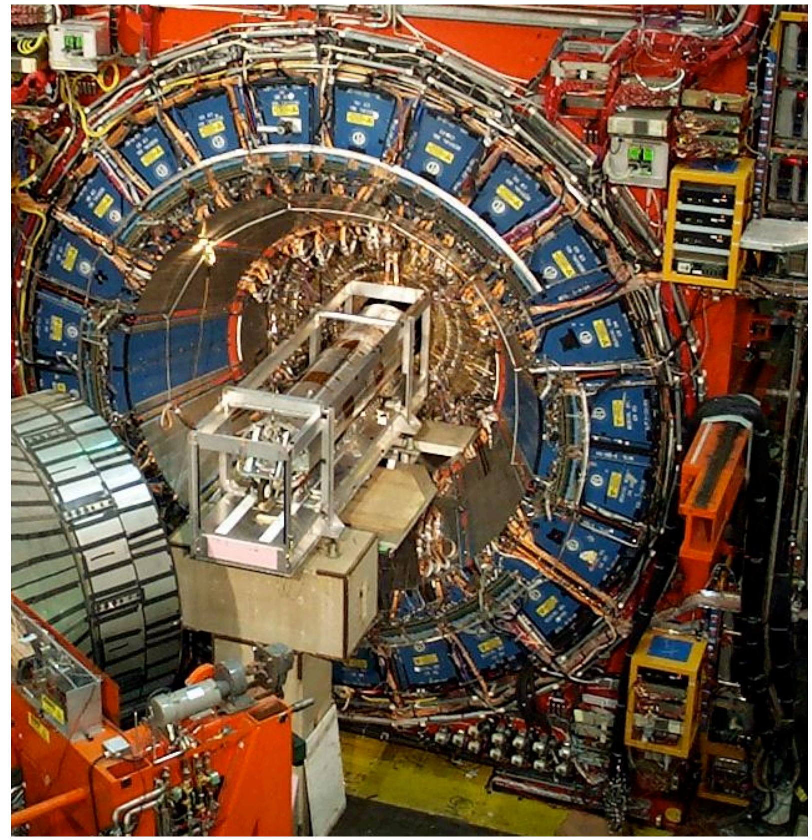
Double "tagged" event in Layer 00 of CDF silicon detector



Silicon Detectors at CDF

- At the core of the CDF detector





- Largest operating silicon detector
  - 7-8 concentric layers of silicon
  - 7 m^2 of silicon with 1.2 cm < r < 32 cm
  - 722,432 cha., 5644 chips, 704 sensors

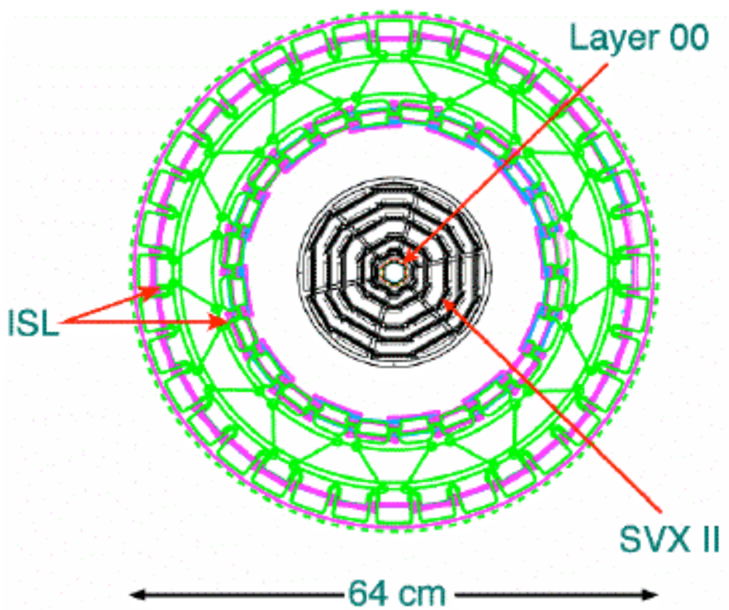
➢ **Designed only for Run IIa (~2/3fb^{-1})**

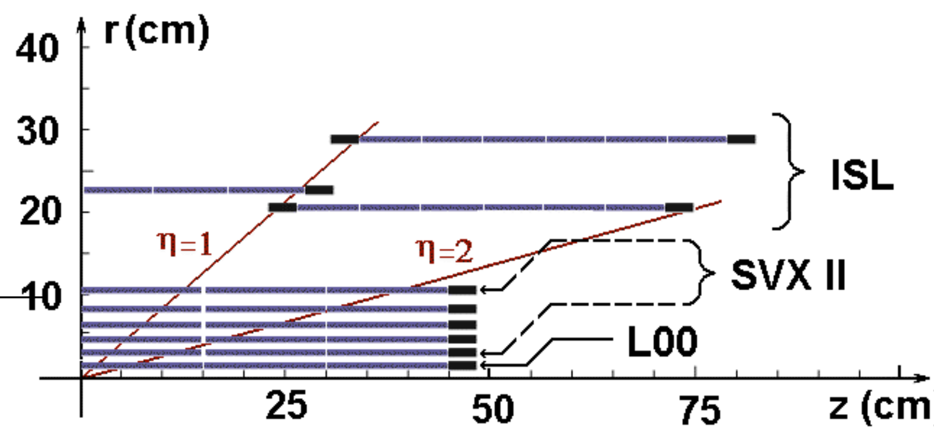
➲ **Upgrade for Run IIb was cancelled!**

Silicon will have to survive through Run IIb (10/12 fb^{-1})

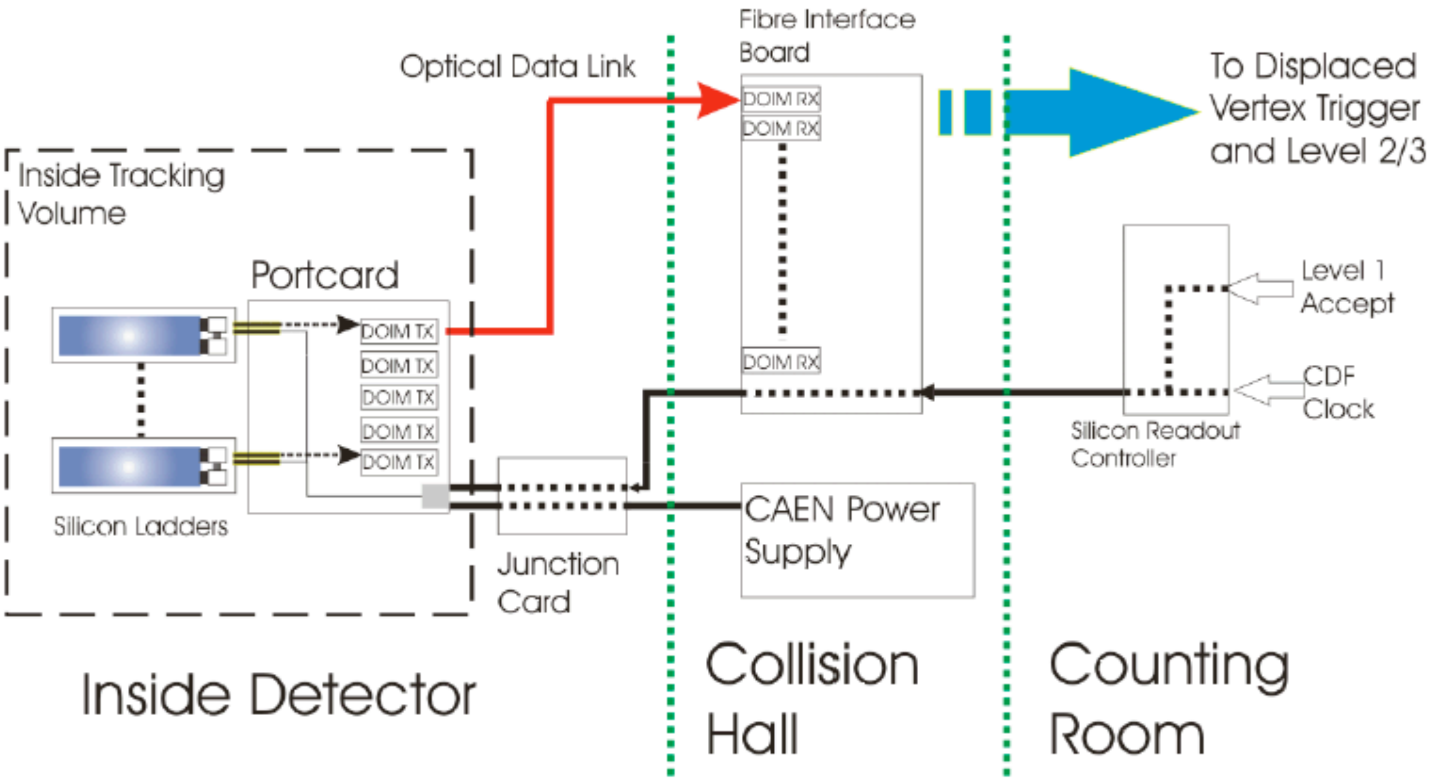
Silicon Sub-detectors

- **Three Sub-detectors**
  - SVX II: 5 double sided layers
  - Intermediate Silicon Layers (ISL): 3 double sided layers
  - Layer 00 (L00): Single sided, LHC-style sensors





Silicon Data Acquisition



A Simplified view of the DAQ, Main Components:

-Silicon Readout Controller (SRC) : “Brain” of the System
-Fiber Board Inteface (FIB): control signals and optical readout
-Portcard: Chip Command and Optical Transmitters (DOIMS)

Operational Issues

During commissioning:

-Blocked Cooling lines
(a new version of this may reappear)

-Resonances

-Beam Incidents

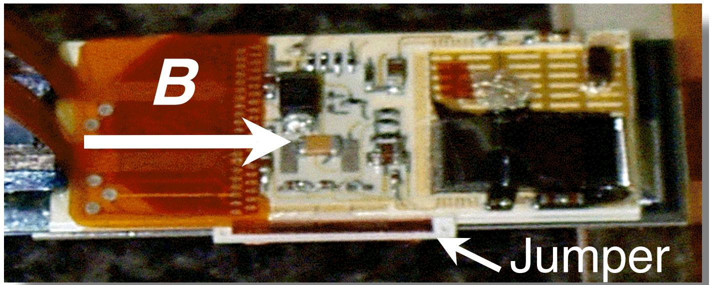
After commissioning:

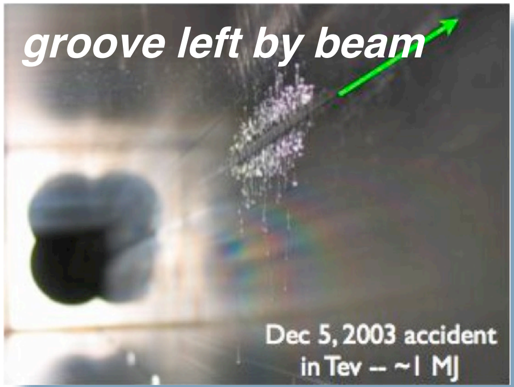
-Aging

-Loss of Know-How

-Infrastructure (Spares - Modifications necessary for increased luminosity regime)

-Dwindling Manpower

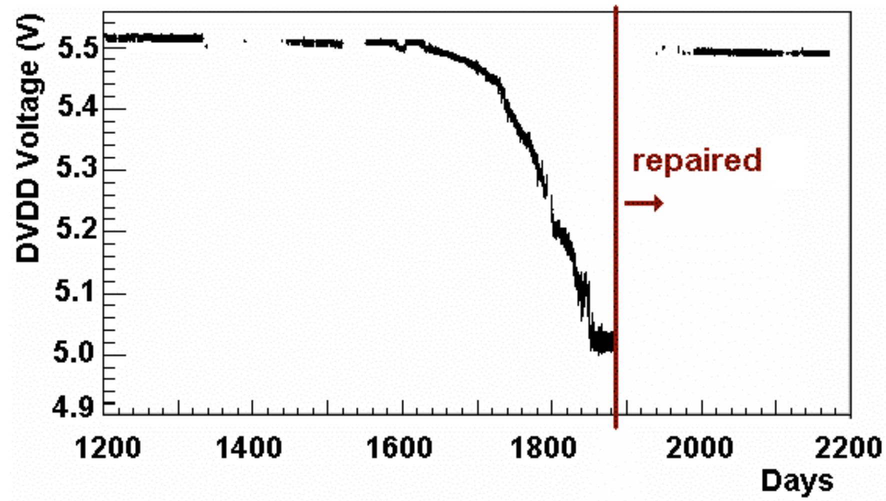




Aging: Power Supplies

- Common failure modes of CAEN SY527
  - Communication loss
  - Corrupted read back of voltages/currents
  - Spontaneous switch off

- Failure mode of power supply modules:
  - Voltages in Analog, Digital and Port-Card supply start slowly dropping.
  - Up to 47 Power showed this behaviors



- Solution:
  - In the September 2007 Shutdown we:
    - took all faulty power supplies out
    - replaced all 36 capacitors (on FNAL site)
    - put them back in and tested them on location.

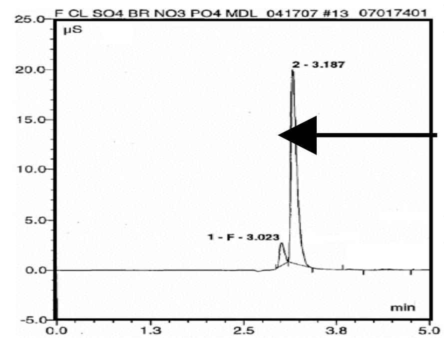
- Time intensive effort, lasted about 2 months.

- **At this point the Power Supply effort centers in keeping a healthy number of spares**

All power supplies with this failure were replaced!

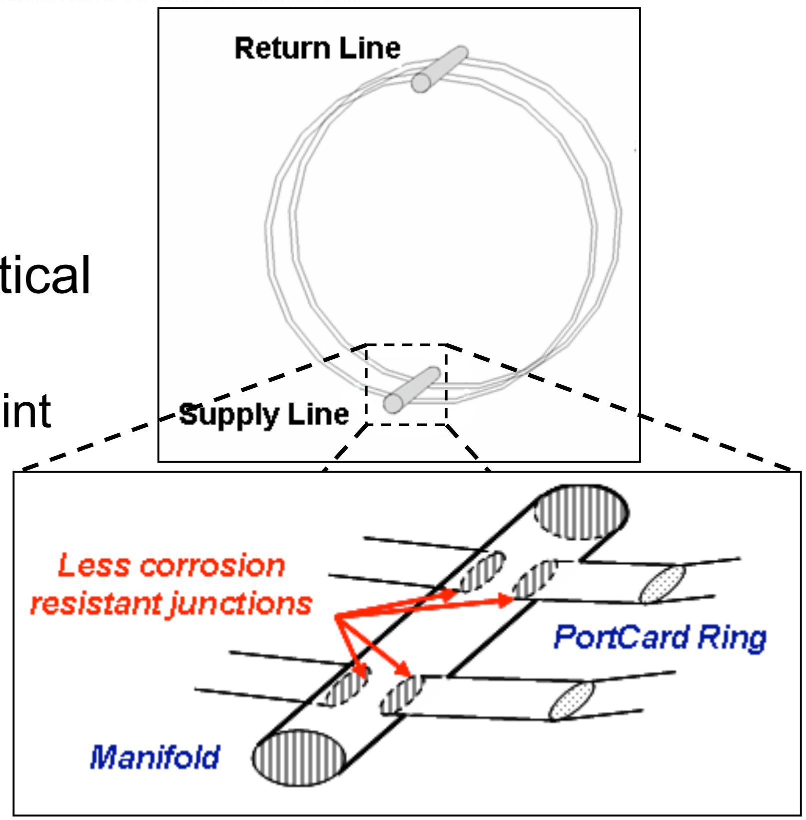
Aging: Cooling Lines

- Cooling Lines
  - Symptoms: electronic-valves start failing.
  - Problem: ISL cooling line (10% glycol in water) became ACIDIC (ph=2) during the 2006 shutdown
  - Solution: coolant neutralized by draining and larger use of de-ionizing resin bed
  - Infrastructure & Aging: Cooling Lines repaired in 2007 shutdown



- Ion chromatography analysis showed carboxylic acids, mostly formic acid.
- Likely came from the oxidation of glycol

- Welds of the aluminum rings that cool optical transmitter had already been corroded
  - One meter from the closest accessible point
  - Why there ?



- Corrosion-resistance: is alloy-dependent
  - Heat affected zone around junctions manifold most sensitive (alloy: 6061-Al).

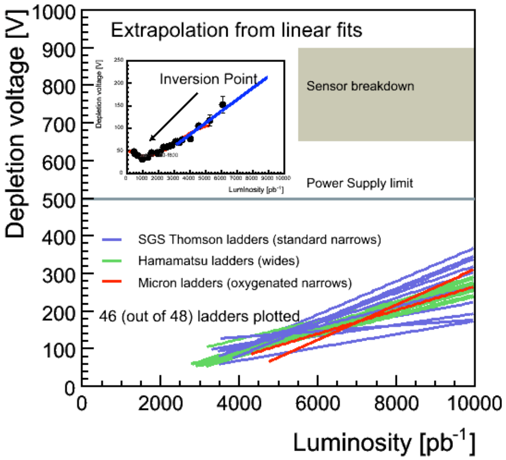
Cooling Lines - How about now?

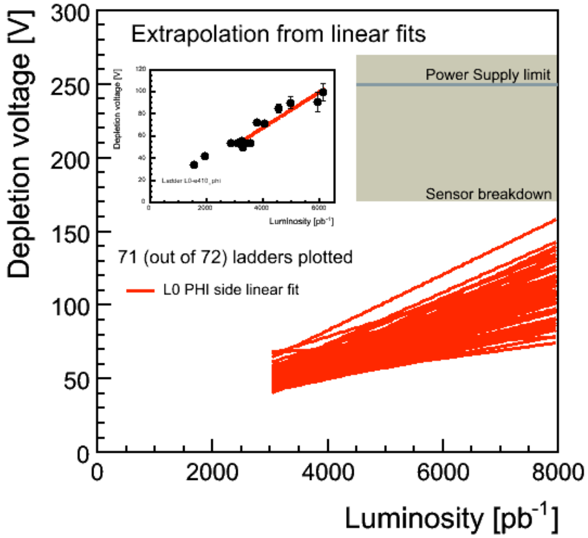
- Leaks are still present and apparently getting worse
  - The system will have leaks (thankfully it is under negative pressure)
  - A recent Rate of Rise pressure test (2 weeks ago) seems to indicate they are getting worse (not dramatically, more studies needed)
  - Careful monitoring will be necessary to follow progress
  - A major part of silicon operations in the future will center around efforts to contain and slow down the cooling system aging
- Not all of the cooling system is accessible with current tools for repairs
  - A contingency plan for currently inaccessible repairs would be useful, but the problem is technically challenging
- Amid the reduction in expert resources, this will be a major priority for future Silicon-SPL's.

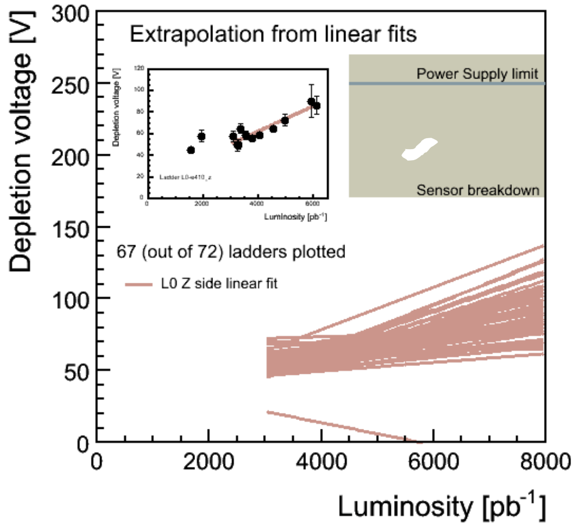
Depletion Voltage

- Prediction for L00
  - Depends on type of sensor
  - Oxygenated ladders invert much later

➢ Prediction for SVX-L0
  - Some fits are not very good!



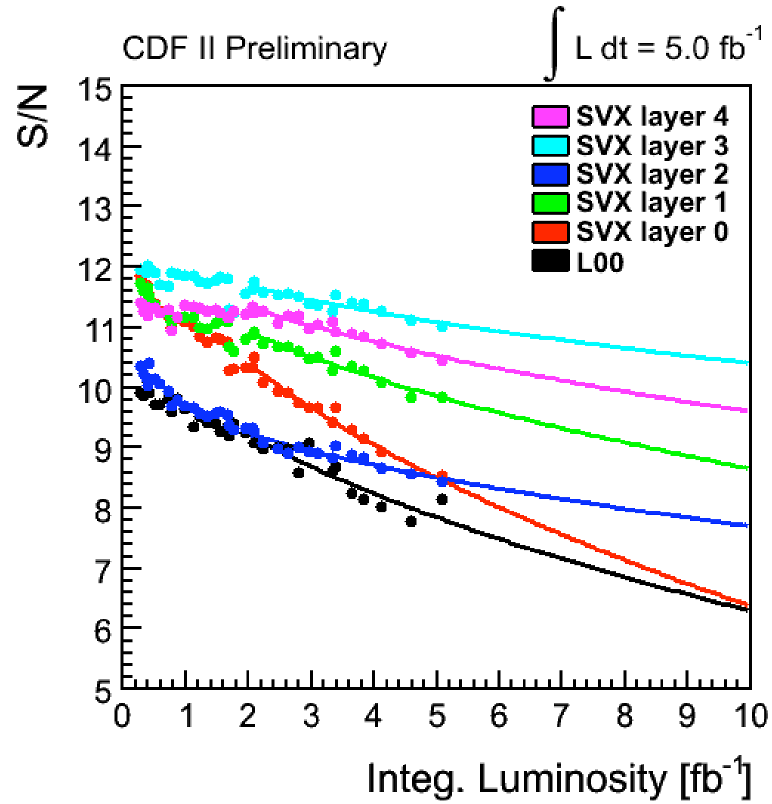




We should be able to deplete most sensors until the end of Run II

Signal to Noise Ratio

- Fit of S/N
  - Limit I: S/N=8 (SVT eff.)
    - Soft limit.
  - Limit II: S/N=3 (B tag eff.)
- Sensor-type behavior
  - Layers 2,4 (Micron)
  - Layers 0,1,3 (Hamamatsu)
- L00 and L0
  - careful monitoring to see if it is going to be useful at 8/10 fb^{-1}.



More studies needed to determine lower bound of S/N

Infrastructure: Spares

- Recent problems with electronics test stands
- SRC's
  - Out of the 7 SRC's, 2 are being used in data taking and the rest are not <u>reliable</u> spares at this moment, the issue is being pursued. (Example of loss of original experts)

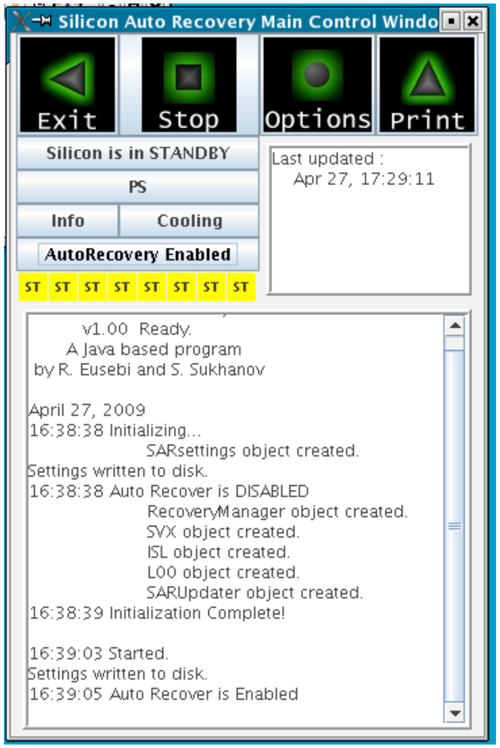
- Fibs
  - Recently there have been a slight uptake in FIB failures, cumulative radiation aging is unlikely, but studies could be made.
  - With the recent revival of the test stand (yesterday), there are now 2 tested spare FIB's, more to follow

- CAEN Power Supplies
  - We are in good shape for all layers

- Fiber links (TX/RX)
  - Recent fixes to the test stand (1 week ago) will allow to stock up on spares

Dwindling Manpower : Automation

- The silicon group operations require a lot of people: SPLs->Working Groups (Detector, DAQ
  Power Supplies, Cooling, Monitoring, Studies),
  There is an on call expert at all times, and backup
  pagers (this model might need streamlining)



- As the silicon faces a reduction in its human resources there is great interest in automating some of the operations tasks:
  - Currently automatic trip recoveries in various systems (Auto-Hockerization, SAR)
  - Might be a good idea to automate also some of the monitoring, including ladder current limits. (so called pinkie limits)

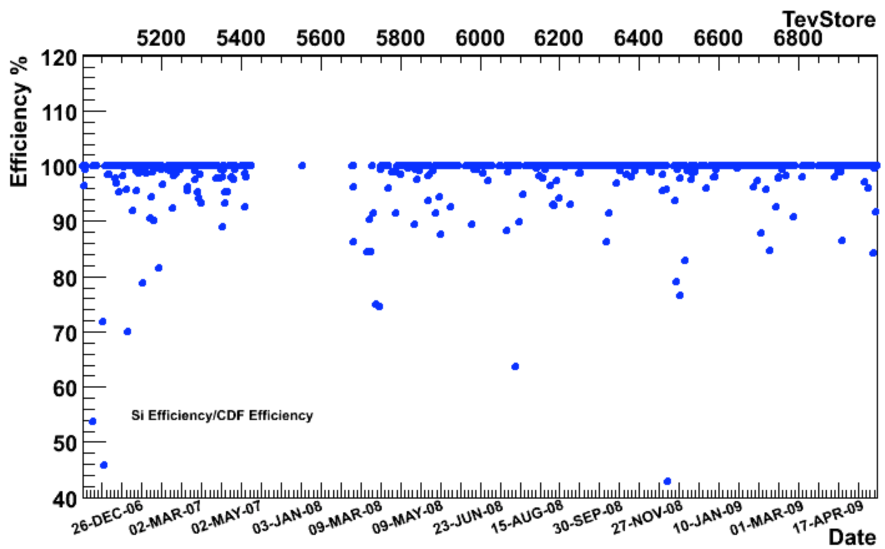
- Streamlining and automating operation processes will be key for the group to be able to attract future page carriers, and allow increased studies.

So what does it take?

- The silicon is taking data with high efficiency currently, detector is in good shape but aging fast

- Needs to survive for another 2 years perhaps.

- Need to:
  - Expect surprises (thing will break)
  - Keep expertise around if possible
  - Eliminate single points of failure
  - Monitor as much as possible
  - Streamline Operation procedures
  - Spares, Spares, Spares…



If all goes well, who knows, maybe CDF can, among other things continue making major contributions to Higgs searches