

Propects for Discovery of Neutral Higgs Bosons in RunII Data

Aaron Dominguez
LBNL

University of Toronto, April 2004

- Motivation
- SM Higgs: Mission Improbable
- MSSM Higgs: Mission Quite Possible
- Silicon detector is key
- B-Tagging
- Re-measuring the top gives us confidence
- Trigger and the SVT
- Analysis: 4b search
- Outlook

Have We Really Unified Weak Force & EM?

- SM of particle physics has a “problem” with massive fermions and vector bosons
 - Gravity and EM long ranged: vectors massless
 - Why is weak force short ranged? ($< 10^{-16}$ cm)
 - Why are masses of fermions added to theory *ad hoc*?
- Experimentally, one piece is missing from Electroweak Unification...

Our Asymmetric World

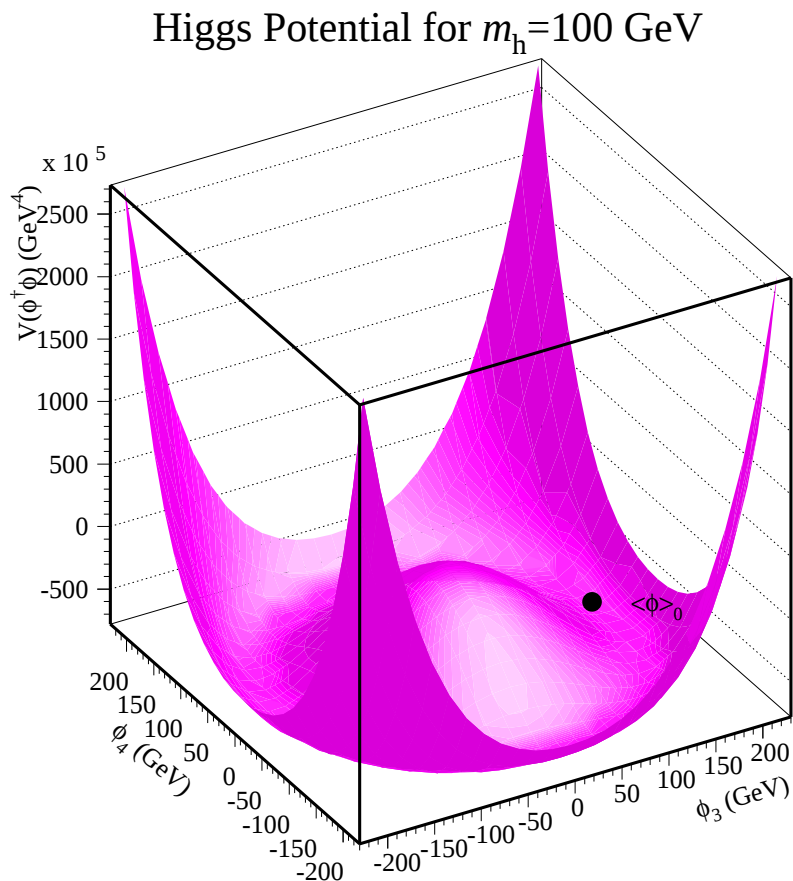
Reverse engineer it: **Want a theory with particles below**

Charge (e) & Mass (MeV) of Matter (Fermions)				Force Carriers (Bosons)	
	I	II	III		
Quarks	$\frac{+2/3}{1.5-4.5}$ u	$\frac{+2/3}{\sim 1200}$ c	$\frac{+2/3}{174300}$ t	Electro-magnetic	$\frac{0}{0}$ γ
	$\frac{-1/3}{5-8.5}$ d	$\frac{-1/3}{80-155}$ s	$\frac{-1/3}{\sim 4250}$ b		$\frac{0}{0}$ g
	$\frac{-1}{0.511}$ e	$\frac{-1}{105.7}$ μ	$\frac{-1}{1777}$ τ	Weak	$\frac{0}{91188}$ Z
Leptons	$\frac{0}{\sim 0}$ ν_e	$\frac{0}{< 0.19}$ ν_μ	$\frac{0}{< 18.2}$ ν_τ		$\frac{\pm 1}{80425}$ W

and allows for mass

Add Potential Term from Neutral Spin 0 Massive Particle

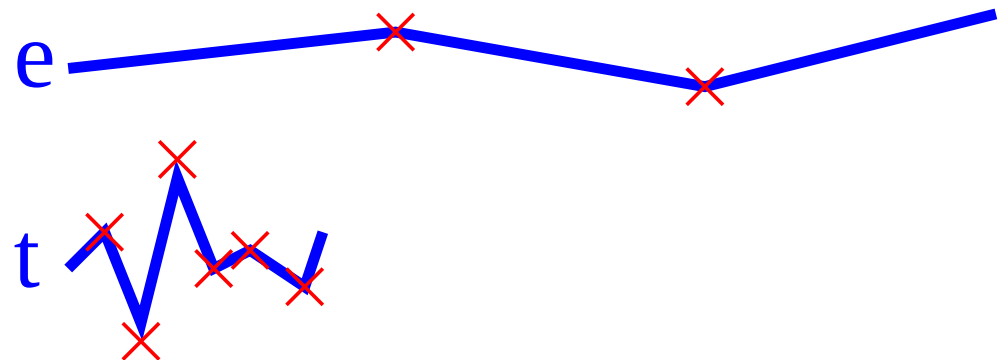
$$V = \mu^2(\phi^\dagger\phi) + \lambda(\phi^\dagger\phi)^2$$



- **Massless** particles
 $\Rightarrow$ **vev at zero**
- Quartic potential: zero is unstable
- **Non-zero** gnd state
 $\Rightarrow$ **massive** particles
(Higgs mechanism)
- *Don't have to add masses ad hoc anymore!*
- It happens dynamically now

Higgs: Missing Piece of Electroweak Unification

- Not only do weak vector bosons get mass, but so do fermions, like the electron!
- One new free parameter to SM: m_h
- *Strange:* physical vacuum filled with Higgs particles (condensate), but doesn't disturb gravity or EM
- Higgs coupling to particle proportional to its mass



And Now for the Bad News...

- Remember our nice quartic scalar potential?
- 1st order m_h (tree-level) related to coefficients of potential
- Higher order corrections to m_h are “unstable” or divergent
- Requires subtracting huge numbers ($\sim 10^{30} \text{ GeV}^2$) to get $m_h \sim 100 \text{ GeV}$
- Basic problem is poor co-existence of fundamental (Planck) scale and electroweak scale ($\sim \text{TeV}$) in SM
- We've traded one problem for a new one...

Supersymmetry

- The **symmetry** of supersymmetry is a direct **relationship between fermions and bosons**
- For every fermion, there is bosonic partner, vice versa
- **Doubles # of particles in theory!**
- (Reminescent of electron crisis solved with antimatter)
- **Consequence** that new partners **exactly cancel divergent** terms in m_h
- **Now have mass generation and natural TeV scale**

Searching for the Higgs Boson

- LEP was best chance to find SM Higgs (until LHC)
- SM Higgs search is notoriously difficult at Tevatron
- SM needs some kind of help to stabilize Higgs mass (hierarchy/naturalness problem)
- MSSM one candidate that has held up well to experimental scrutiny that solves some of these problems
- Introduces 5 physical Higgses
- But production cross sections at Tev can be quite large

And Now for the Fun Part!

- Have chance of extending LEP's SM Higgs limit
- And good chance of discovering MSSM Higgs at the Tevatron

Chicago

The High Energy Frontier ↓

- 980 GeV protons colliding with 980 GeV antiprotons
- Initial luminosities of $5\text{-}6 \times 10^{31} \text{ cm}^{-2} \text{ s}^{-1}$
- Beam crossings every 396 ns

Booster

CDF

DØ

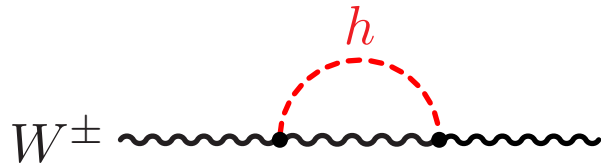
Tevatron

$\bar{p}$ source

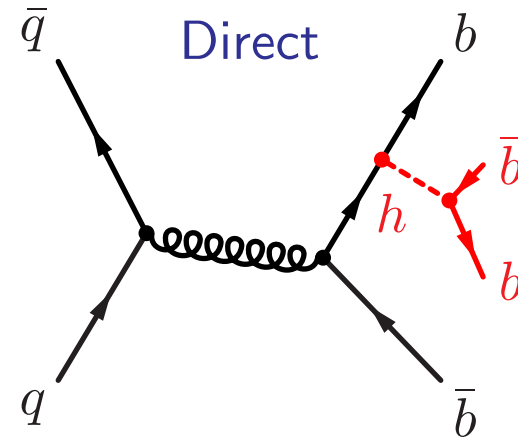
**Main Injector
(new)**

Direct and Indirect Searches

Indirect: Quantum Corrections

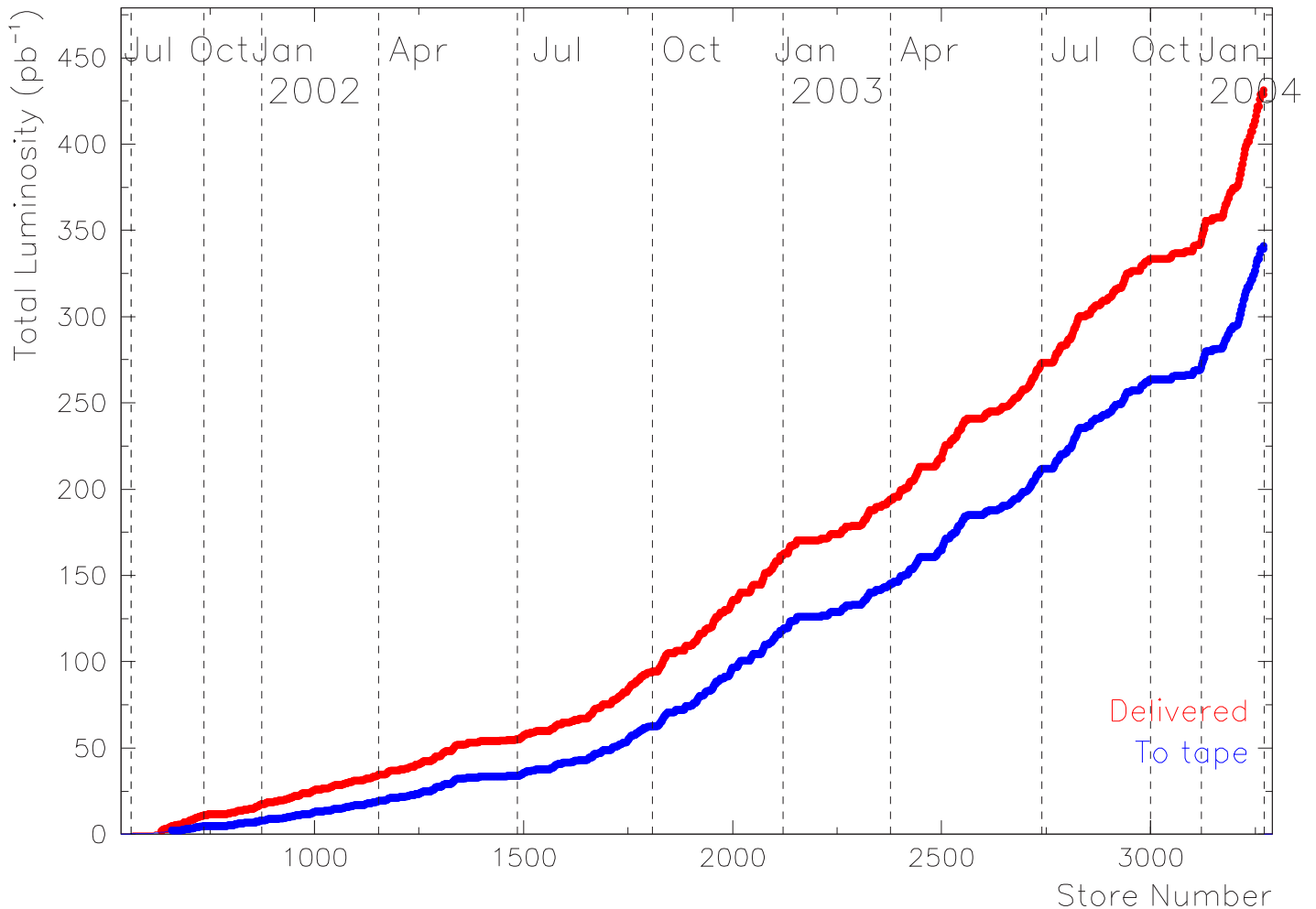


- Higher order corrections to EW observables usually depend on $\ln(m_h)$
- Precision measurements can give some indirect sensitivity to m_h
- Best indirect limits on m_h come from global fits to many (~ 15) EW parameters, but difficult to handle inconsistent measurements



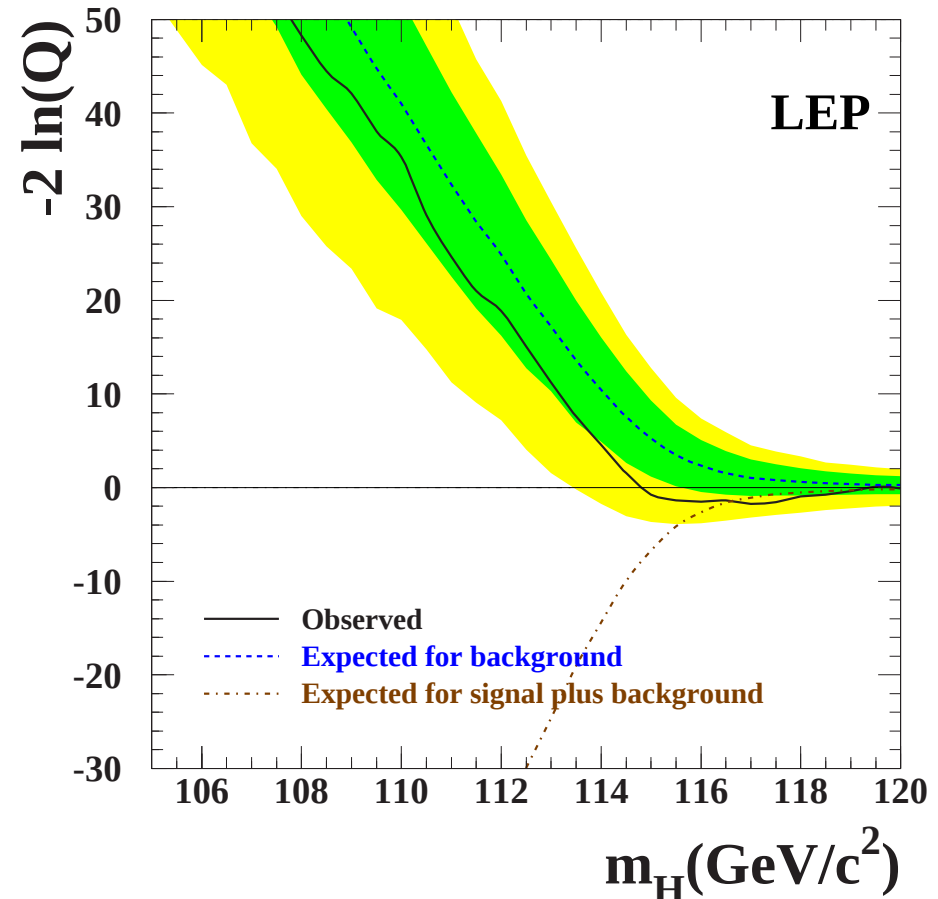
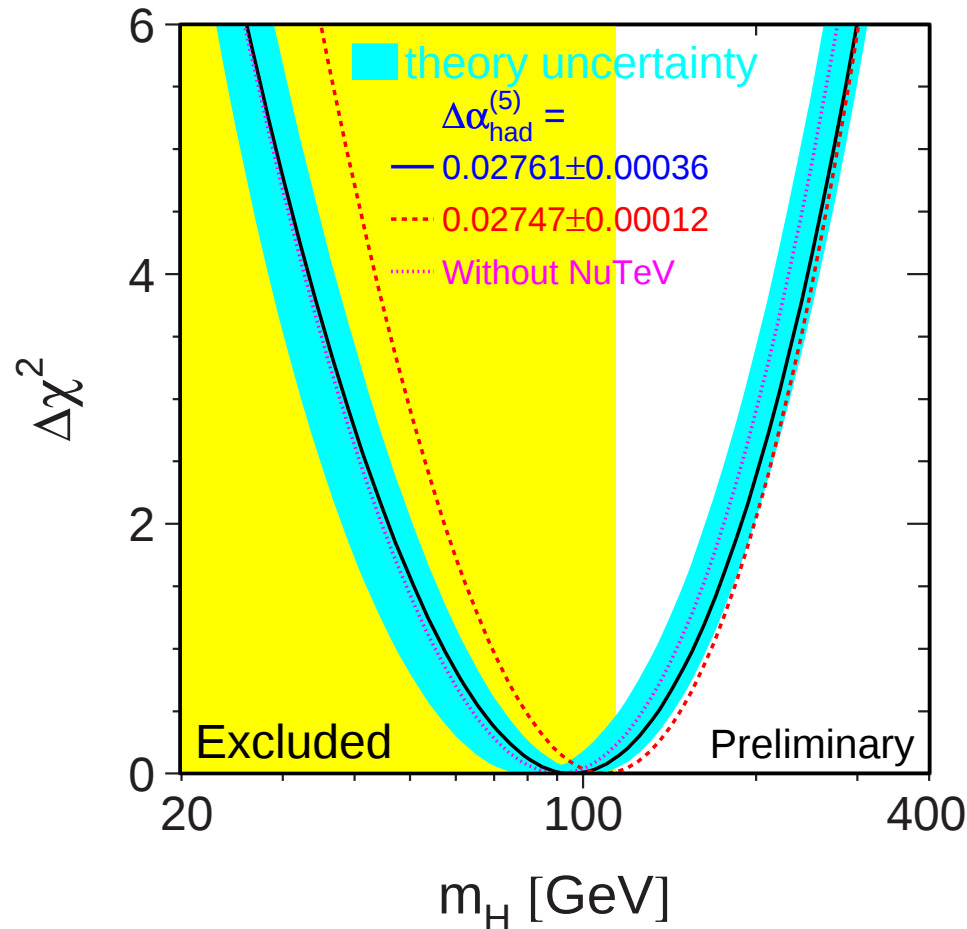
- At LEP and now the Tevatron, we could in principle make Higgs bosons directly
- Higgs will decay into **heaviest kinematically accessible particle**
- Will consider mass range where $\text{Br}(h \rightarrow b\bar{b}) \sim 90\%$

RunII Well Under Way!



- Now have **more data than RunI**
- Can do **precision measurements** and **searches**
- What can we do to understand **neutral Higgs Sector** with our **new data and new CDF detector?**

SM Higgs: Current State of Affairs

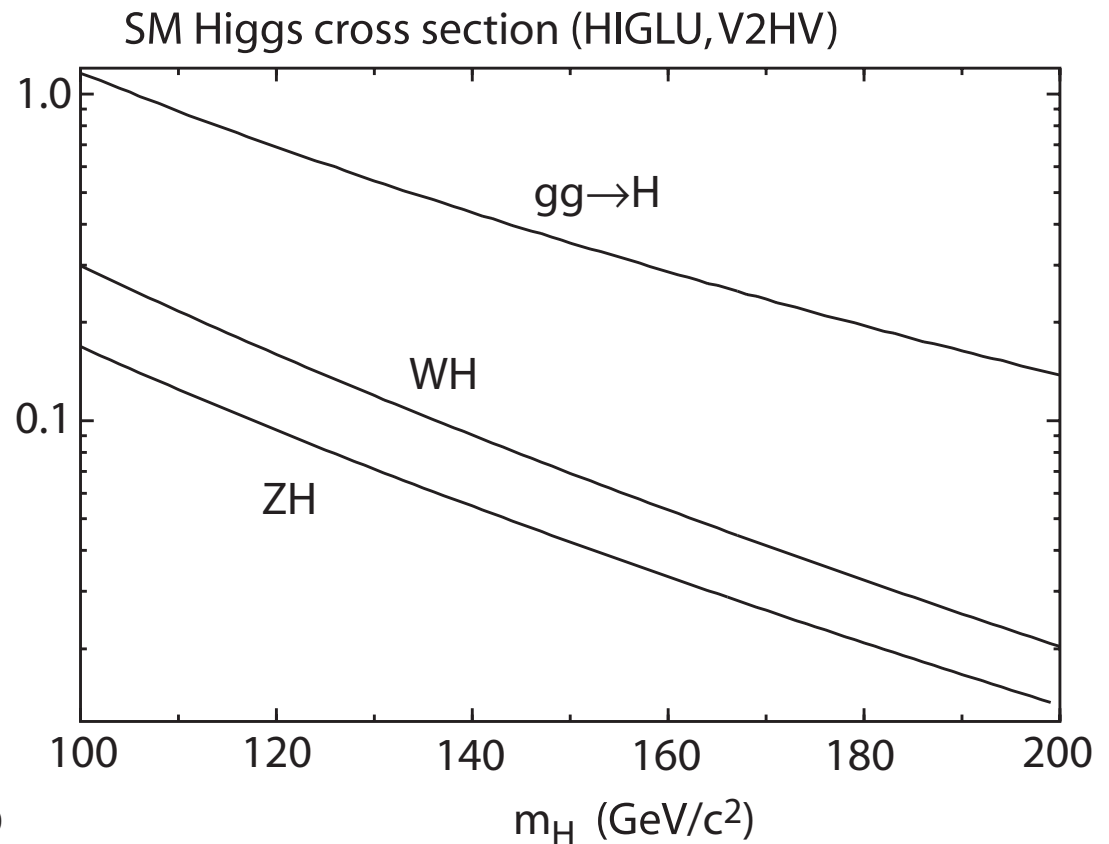
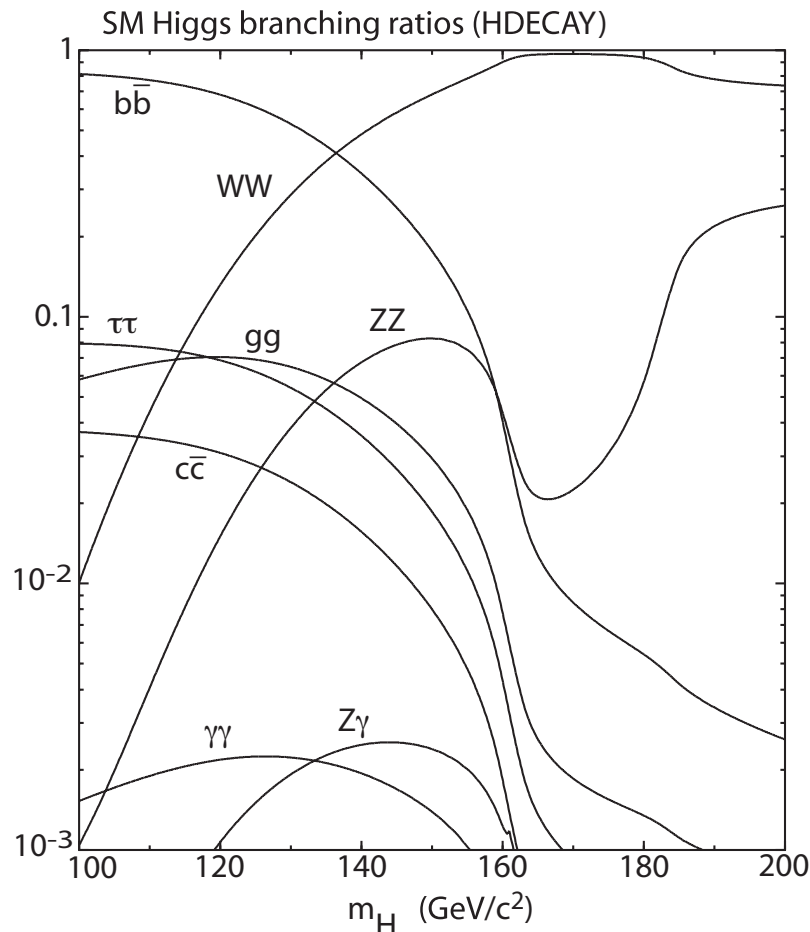


- EW Precision fits “predict” light Higgs
 $m_H < 219 \text{ GeV}$, 95%CL
- One set of measurements (A_{FB}^b) differ by 3σ and pull m_h fit high. But removing them leaves

us with $m_h \approx 50 \text{ GeV}$ and $m_h \lesssim 110 \text{ GeV}$ 95%CL (Chanowitz)

- LEP Combined search limits
 $m_H > 114 \text{ GeV}$, 95%CL

SM Higgs: Mission Improbable



- Most promising SM discovery modes:
 - Associated production with Z/W
 - Followed by $W \rightarrow \ell \nu$ or $Z \rightarrow \nu \bar{\nu}$, with $H \rightarrow b\bar{b}$
- Cross sections mostly $\lesssim 0.3$ pb! at Tevatron, and that's before branching ratio

SM Higgs: Reevaluated Sensitivity

- **Last summer**, CDF & D0 reconsidered work of **RunII Higgs Workshop** (hep-ph/0010338) taking into account knowledge of new detector
- Dominant backgrounds from SM physics that look just like signal!
 - **W+jets**: $p\bar{p} \rightarrow W + gg, g \rightarrow b\bar{b}/c\bar{c}$.
 ~ 10 's pb
 - **$t\bar{t}$** : $p\bar{p} \rightarrow t\bar{t} \rightarrow W^+bW^-\bar{b}$. ~ 7 pb
 - **Single top**: $p\bar{p} \rightarrow t\bar{b} \rightarrow W^+b\bar{b}$. ~ 2 pb
 - **WZ**: $p\bar{p} \rightarrow WZ \rightarrow \ell\nu b\bar{b}$. ~ 3 pb.

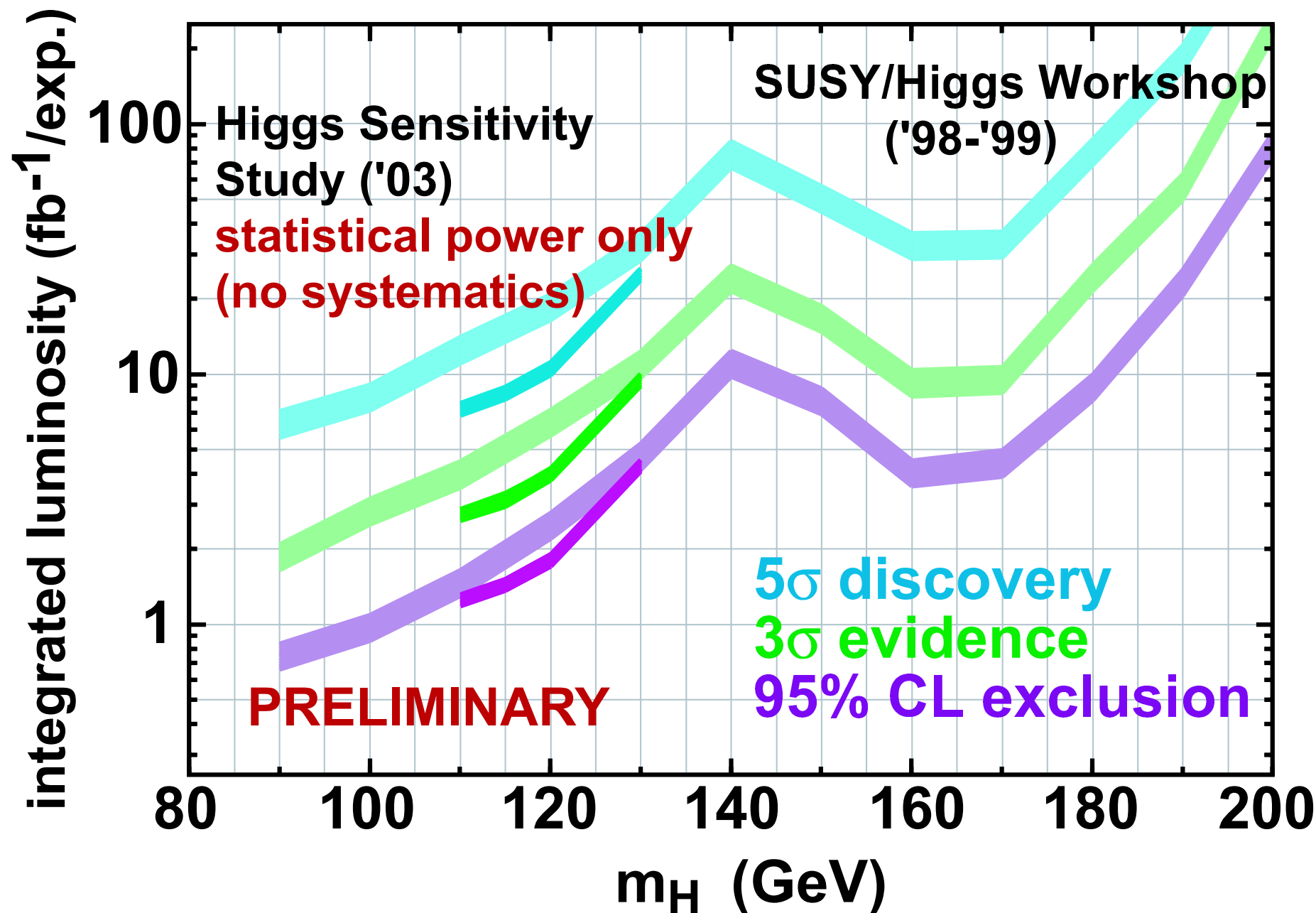
HSC vs SHW at 115 GeV

	WH (lnbb)		ZH (nnbb)	
	HSC	SHW	HSC	SHW
signal	3.7	4.6	3.5	5.5
tt	12.3	7.8	1.9	3.0
tqb/tb	6.9	5.3	1.0	5.0
Wbb/Zbb	20.9	7.7	2.9	13.8
WZ/ZZ	1.6	1.4	2.6	3.3
QCD	-	-	8.1	25.1
bkgd	42	22	16.5	50
S/B	0.57	0.98	0.86	0.78

mass window: 100-130 GeV

- “HSC” is new estimate with current algorithms for 1 fb^{-1} per Experiment
- Will be *very challenging*

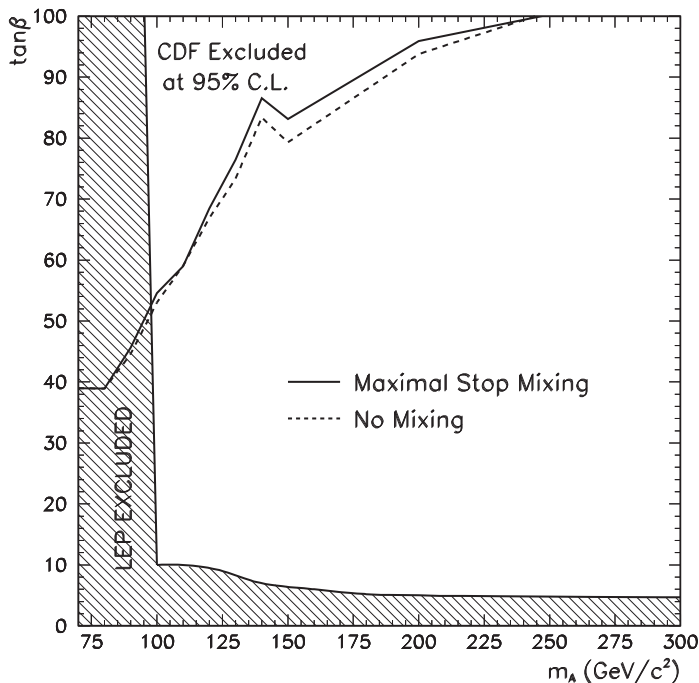
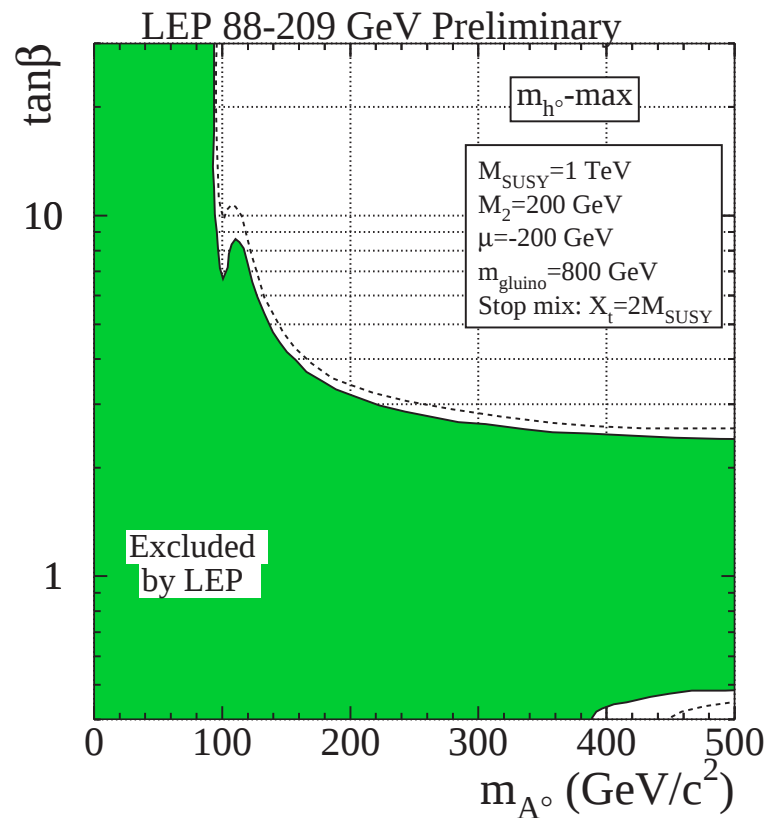
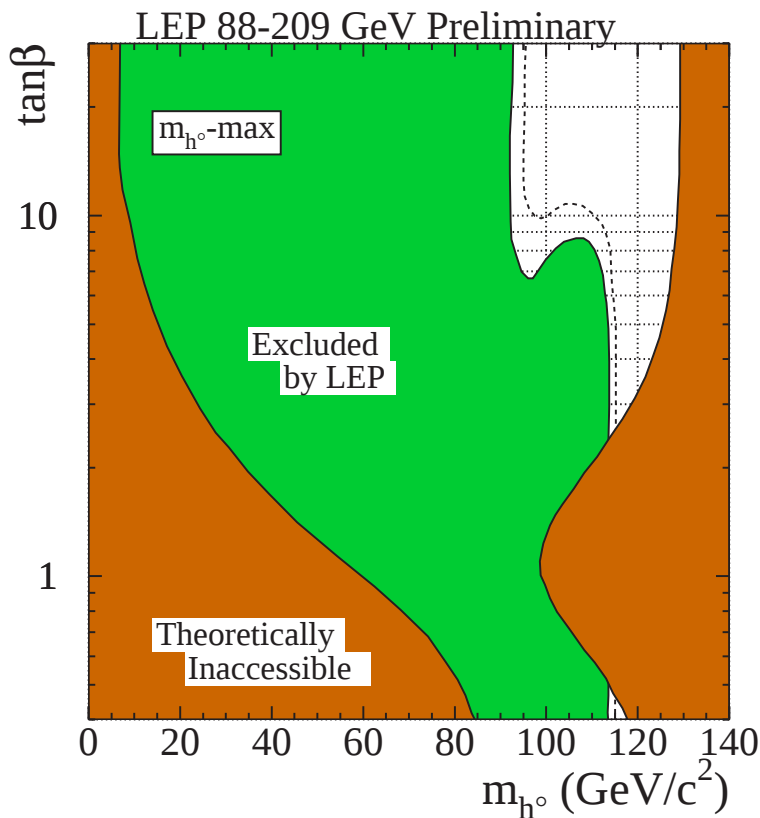
SM Higgs: Sensitivity vs Luminosity



MSSM Higgs: Mission Quite Possible

- The MSSM is well known to predict at least one **light neutral Higgs**
- Large regions of parameter space currently **consistent with SM measurements and EW predictions**.
- The price to pay is more free parameters, making the final conclusion of searches somewhat less stringent
- At **LEP**, production **cross sections** of neutral Higgses were generally **smaller** than the SM cross section
- At Tevatron, production cross section grows with the free parameter $\tan\beta$

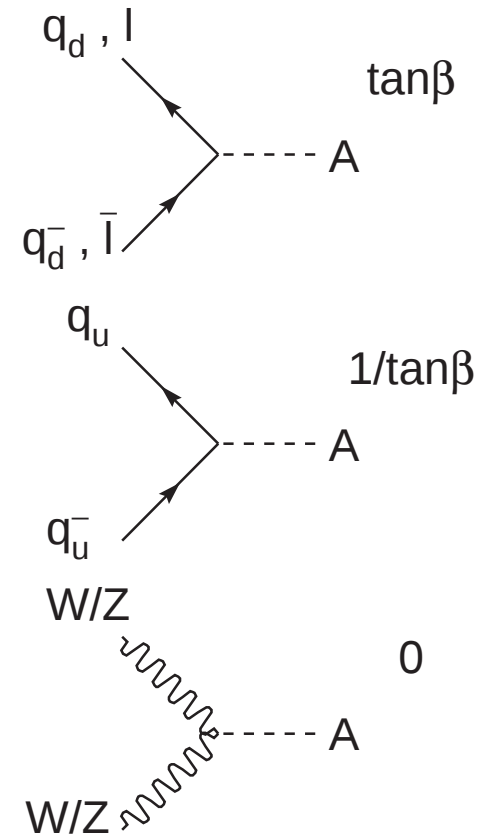
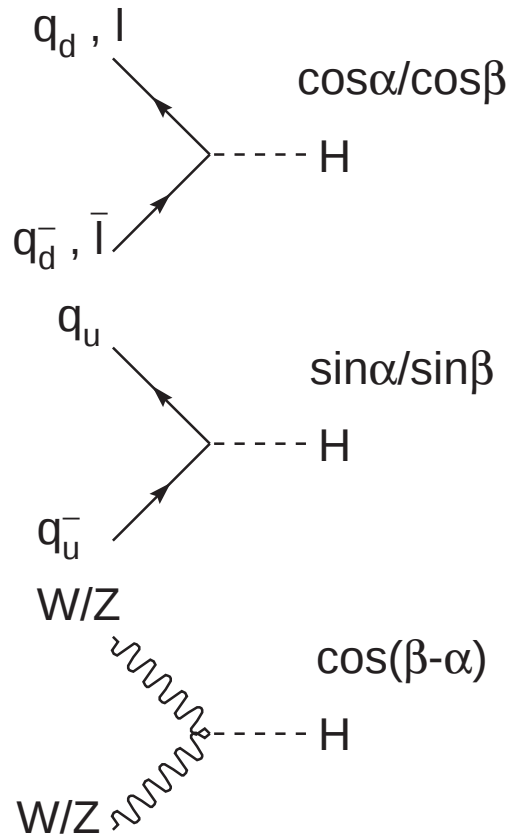
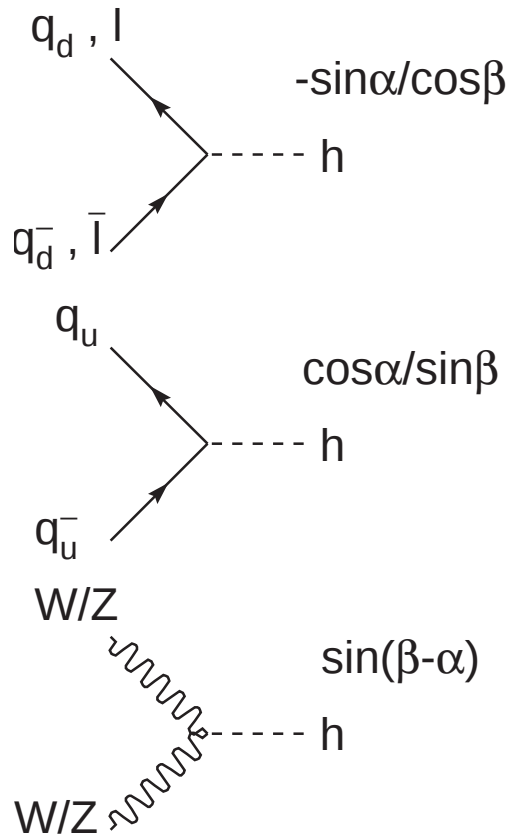
MSSM Higgs: Current State of Affairs



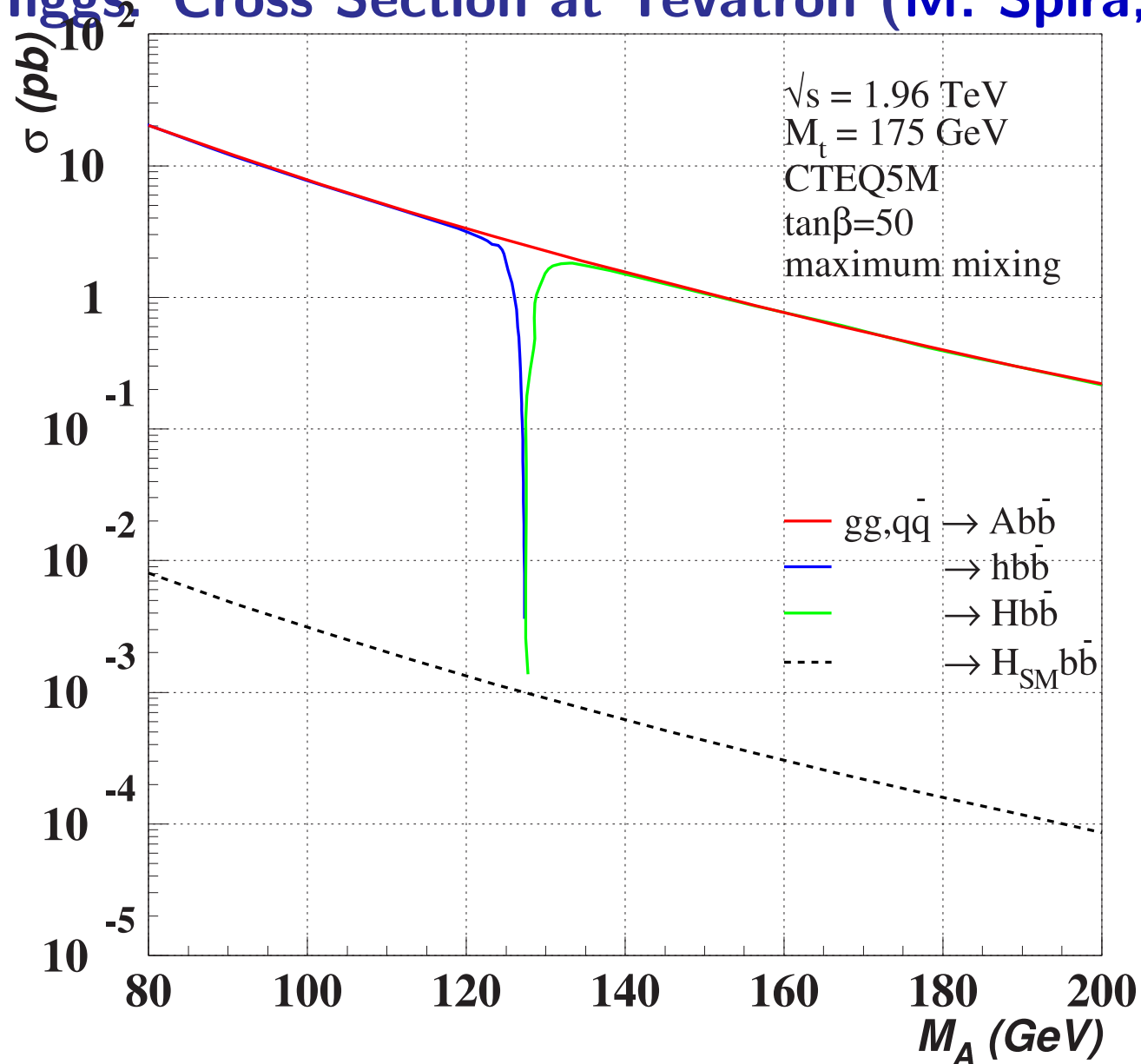
- $\sim$ Final LEP limits:
 $m_h > 91.0 \text{ GeV}$,
 $m_A > 91.9 \text{ GeV at } 95\%CL$
- CDF Run1 limits m_h and m_A for values of $\tan\beta \gtrsim 50$

MSSM Higgs: Production Modes at Tevatron

Why look at bbbb channel? MSSM couplings to down-type quarks enhanced like $\tan\beta$ relative to SM



MSSM Higgs: Cross Section at Tevatron (M. Spira, HIGLU)



Need less int. lumi for discovery compared to SM Higgs

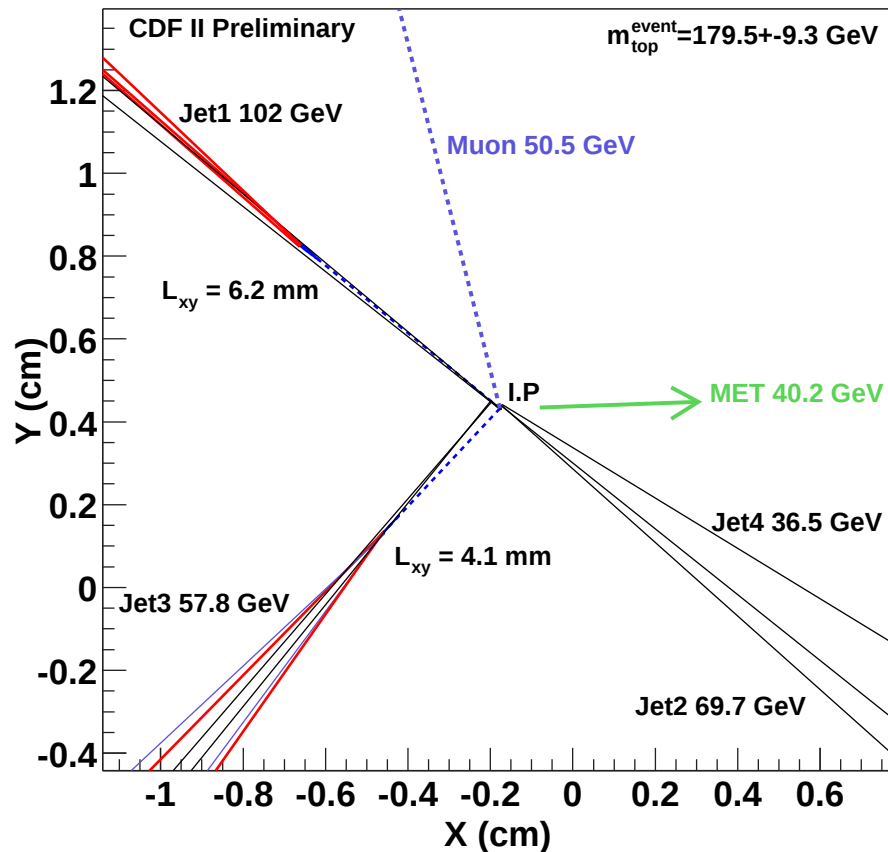
Game On

- Enhancement of $b\bar{b}A$ vertex of $\tan\beta$, compared to SM
- MSSM Higgs production at TeV is complimentary to LEP
 $\Rightarrow$ orthogonal sensitivity in $(\tan\beta, m_A)$ plane
- Branching into b's remains large: $A/h \rightarrow b\bar{b} \sim 85 - 90\%$,
 $A/h \rightarrow \tau^+\tau^- \sim 8 - 10\%$
- Game is to trigger on and reconstruct multijet events containing multiple b-jets
- Understanding and using the silicon detector is crucial for trigger and reconstruction

Silicon Detector is Key

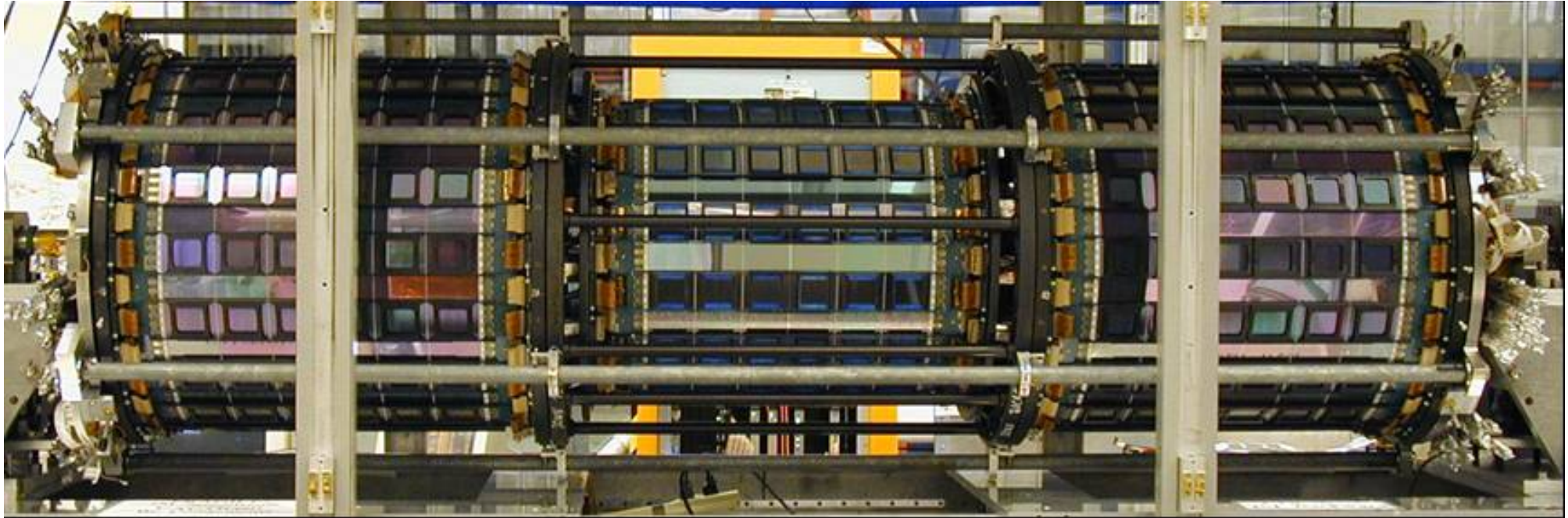
- Si detector used online & offline to ID b's.
- Many different ways to tag b-jets, but Si detector best at lifetime reconstruction
- Need to measure in data and model in simulation:
 - Coverage
 - Efficiency
 - Resolution
 - Alignment
 - Material
 - Tracking efficiency
- Then we can tag b-jets!

General Idea of B-Tagging



- Average b hadron lifetime is 1.56 ps.
- Most lighter flavored hadrons either have no discernible lifetime or are very long lived (K_S^0, K_L^0, Λ^0).
- Charm and tau lifetimes are typically less than half as long as b lifetime.
- At TeV the hadrons are highly boosted $\Rightarrow$ b decay lengths $\mathcal{O}(3 \text{ mm})$.

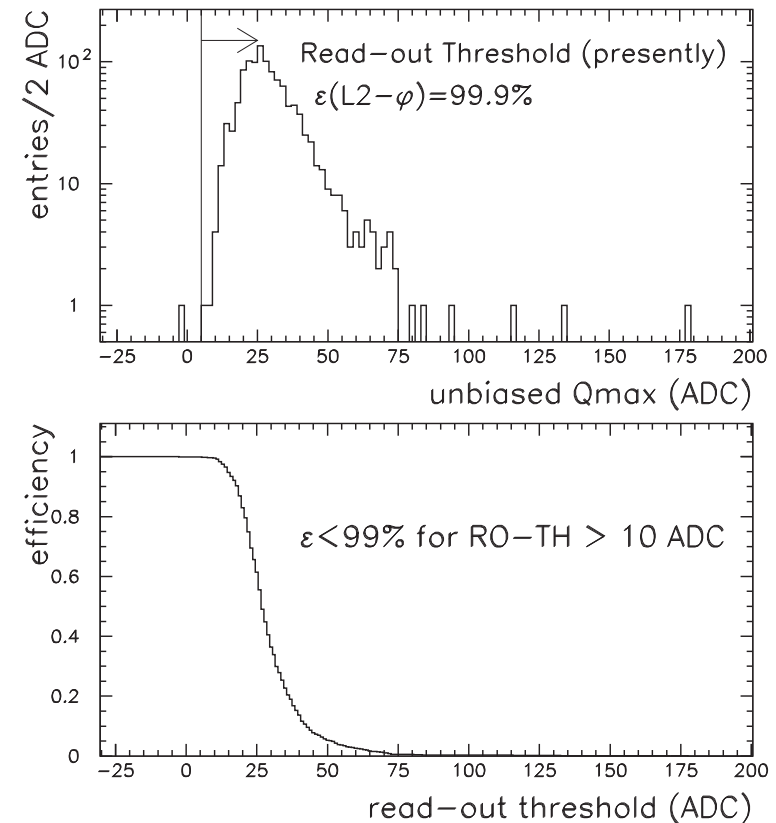
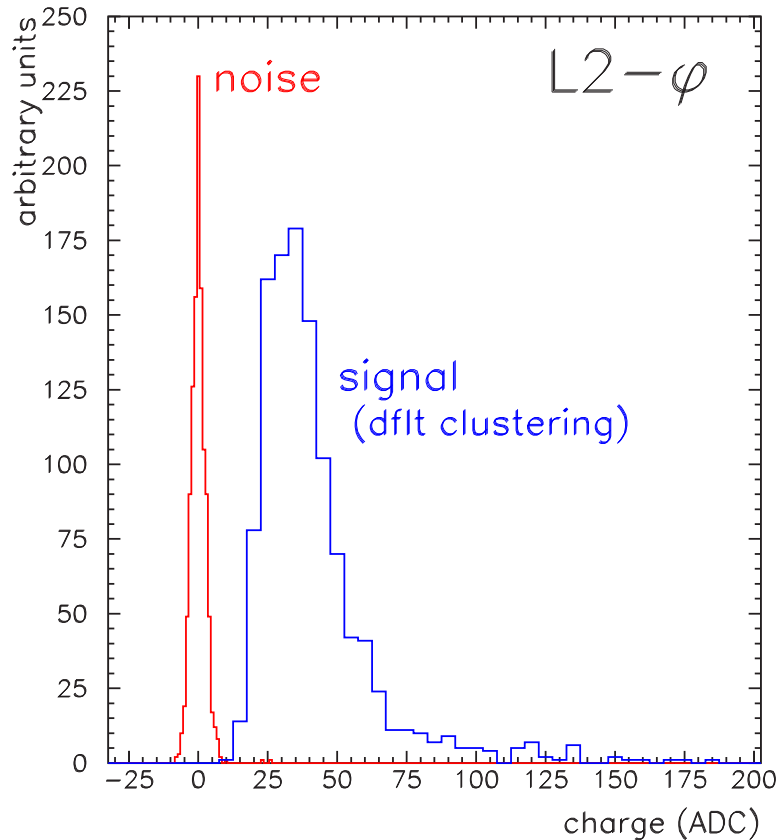
Silicon Detector is Key



- Over 750,000 Si channels!
- 7 double sided layers (3 at 90° , 4 at 1.2°).
- Detector stable after commissioning period
- Inner layer on beampipe ($\sim$ commissioned)
- Coverage increased due to repairs
- Axial strip pitch $50\ \mu\text{m} - 112\ \mu\text{m}$, inner to outer

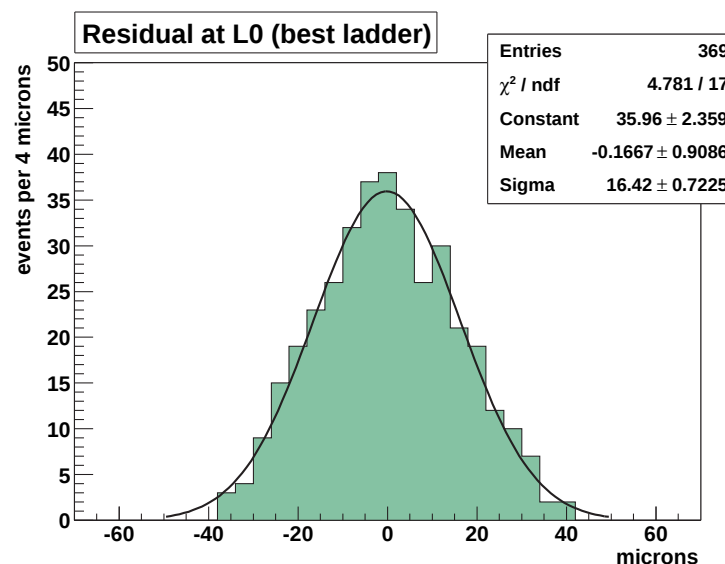
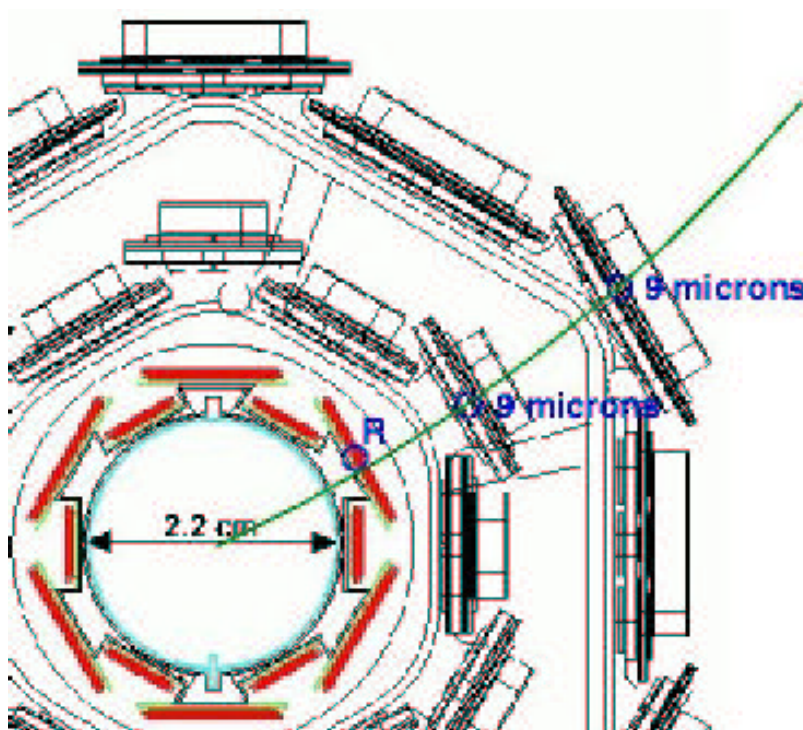
High Signal-to-Noise Device

read-out efficiency for physics



- Operation optimized for high S/N & eff • > 99% signal readout eff
- S/N of SVX axial 12:1, stereo 10:1 • With < 1% noise occupancy

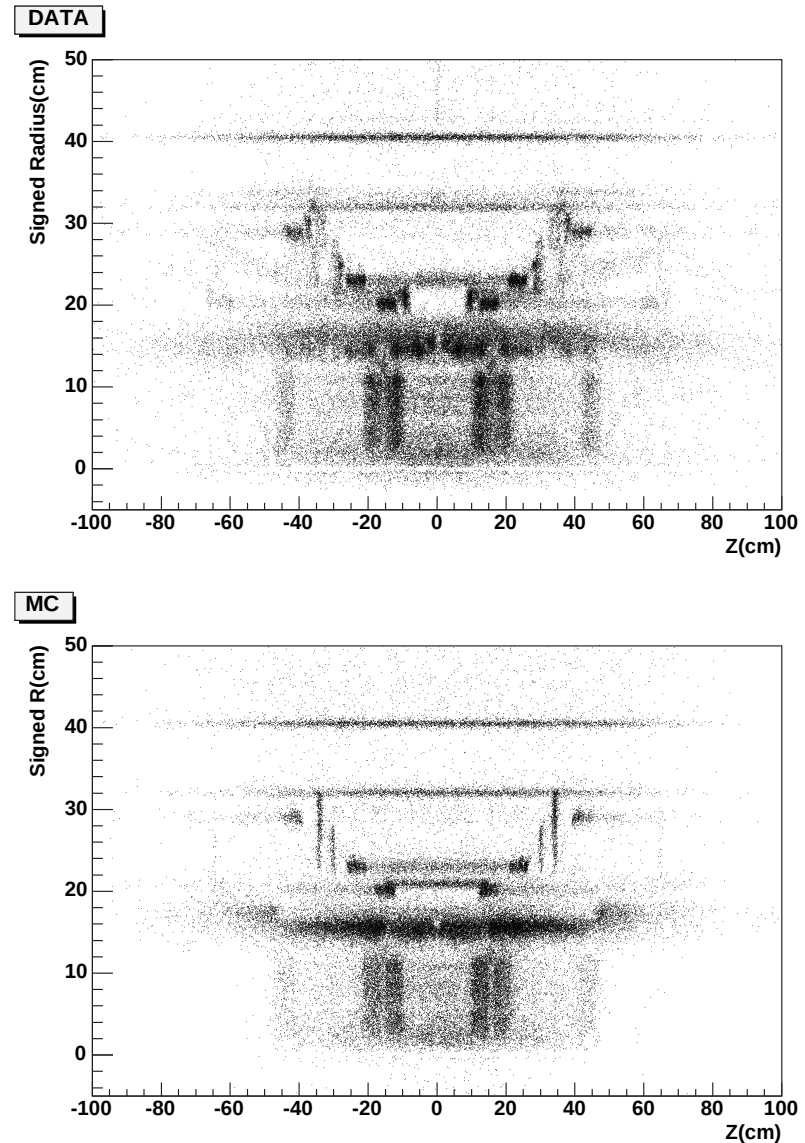
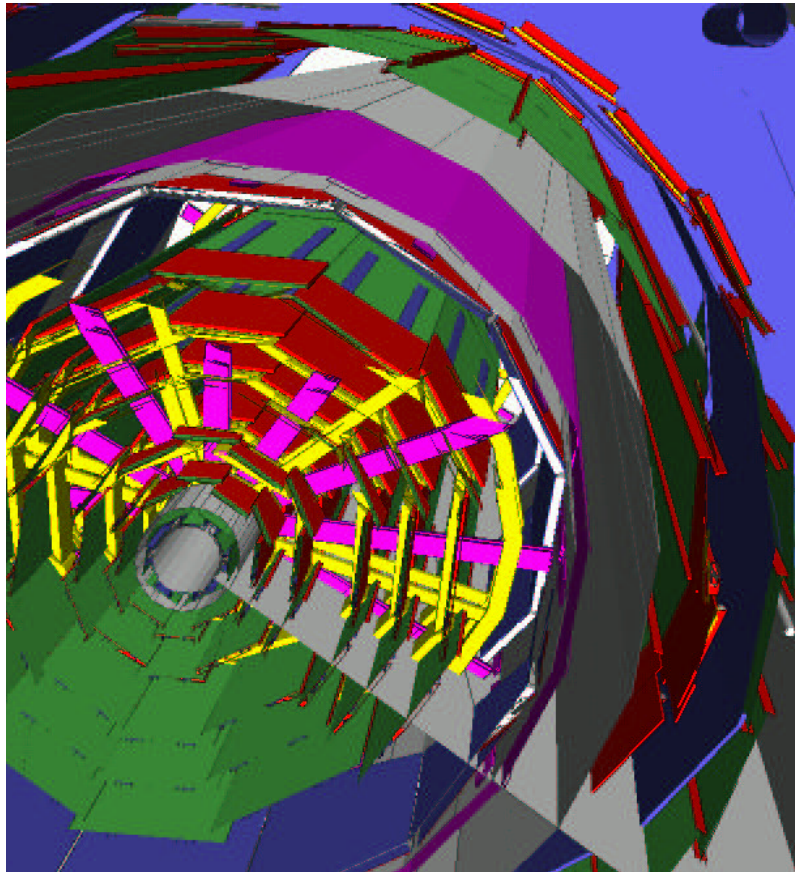
Silicon Tracking Resolution From High $P_T \mu$



Cluster Width	Measured resolution in μm		
	L00	SVX Axial L1-L5	SVX 90° L1,4
1 strip	18.4 ± 0.3	13.6 ± 0.3	29.5 ± 0.5
2 strips	10.1 ± 1.9	9.5 ± 0.1	23.0 ± 0.3
3 strips	17.2 ± 1.8	13.4 ± 0.2	34.3 ± 0.8
4+ strips	23.5 ± 2.8	18.7 ± 0.4	64.3 ± 1.8

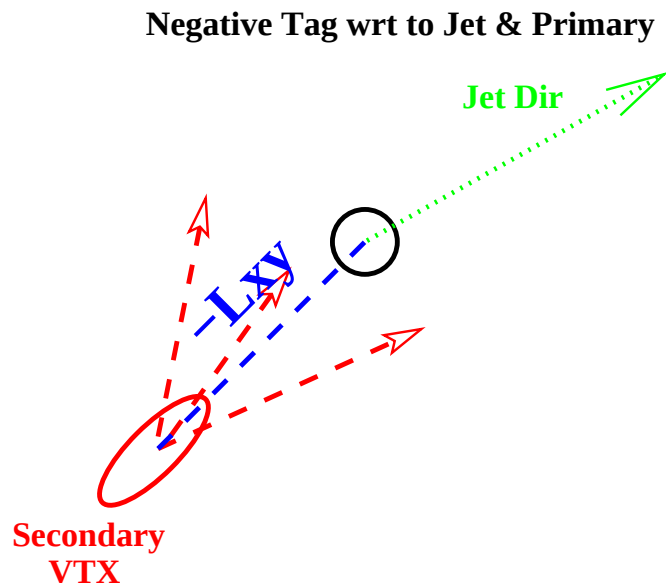
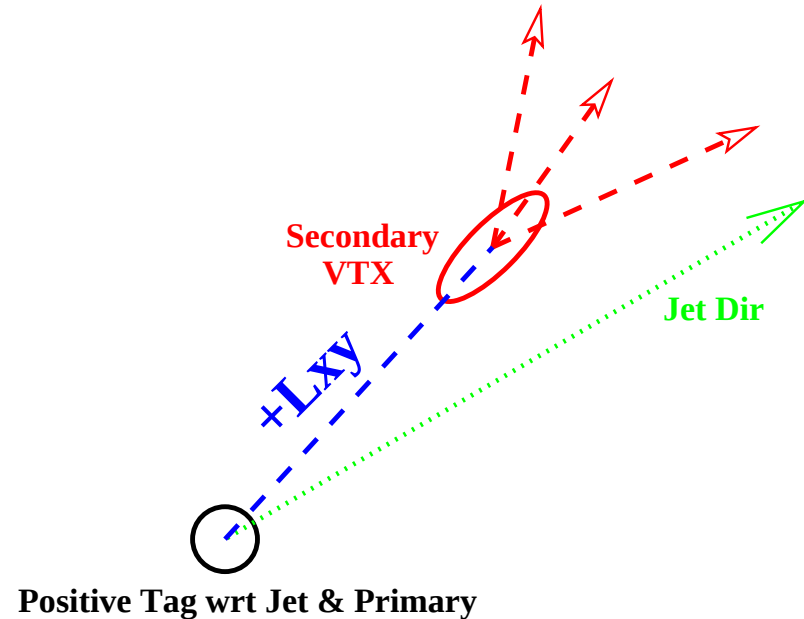
L00 resolutions are new result & will improve with alignment/study

Silicon Material Map in Reconstruction and Simulation



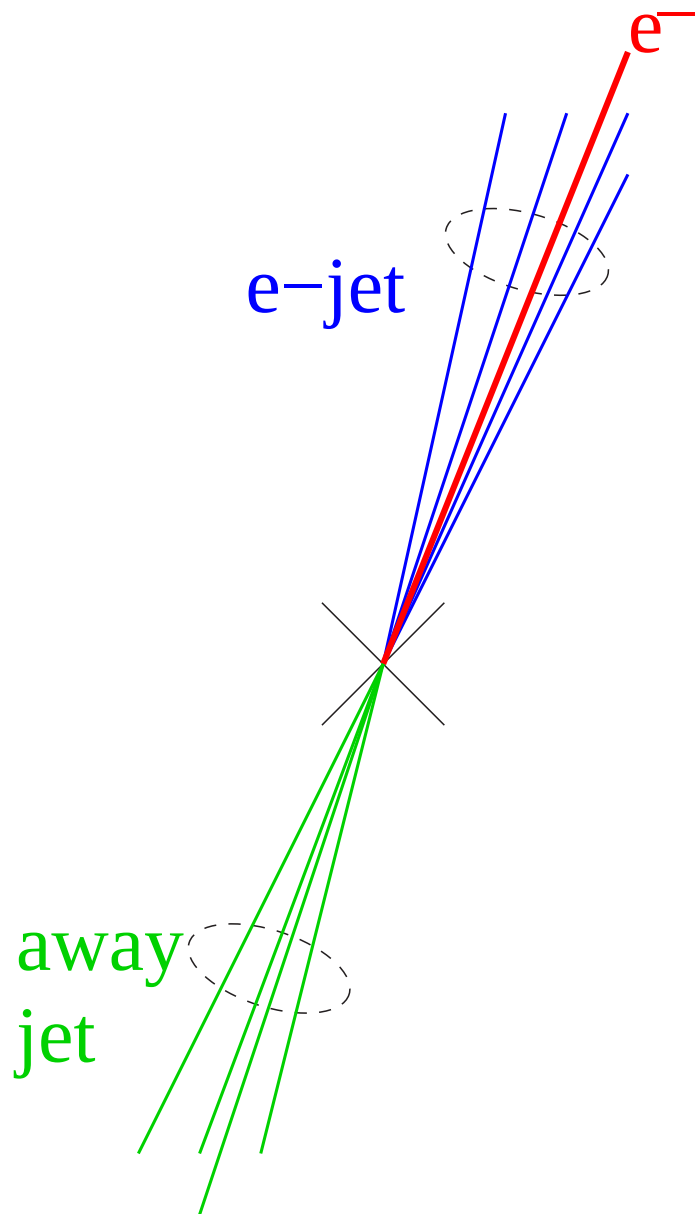
- Accounting for all material allows precise knowledge of energy loss and **mass reconstruction**
- Helps simulation get false lifetime from conversions correct

B-Tagging



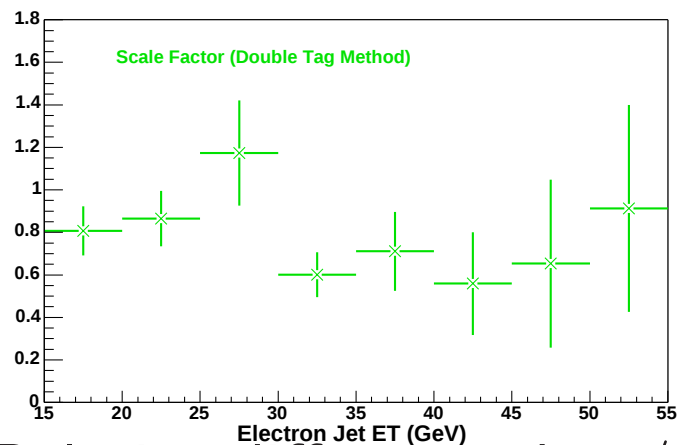
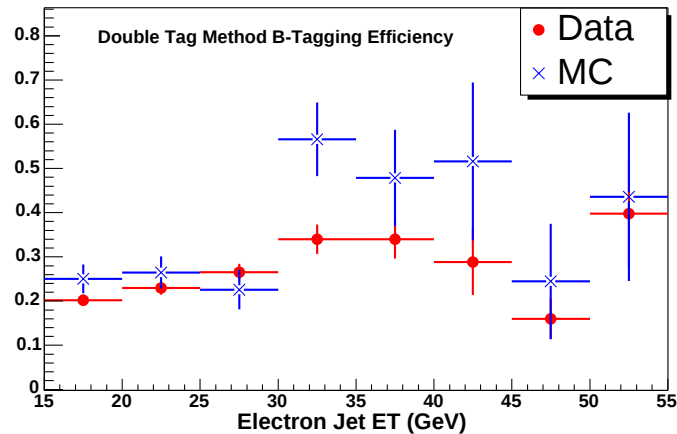
- **Displaced vertexes:** All combinations of at least 2 good tracks
- Jet is tagged as b-jet if $L_{xy}/\sigma_{xy} > 3$ (typical $\sigma_{xy} \sim 150 \mu\text{m}$)
- Measure eff and fake rate in incl lepton & generic jet data
- (Looser tagger used in Higgs analysis: SecVtx falling back to 1% CL of impact parameters in jet to be consistent with zero)

Measuring B-Tag Efficiency



- Knowing eff to tag b-jet key to any analysis using b-tag for cross section
- **Double-tag technique** to measure b-tag eff
- Start with sample enhanced in heavy flavor: **8 GeV inclusive electrons** in data/MC
- Enrich b-content by requiring **away-jet to be tagged**
- **Eff of b-tagging e-jet** determined by ratio of double-to-single tagged events
- Method less sensitive to knowledge of heavy-flavor fraction of e-jet

High- P_t B-Tagging: Efficiency

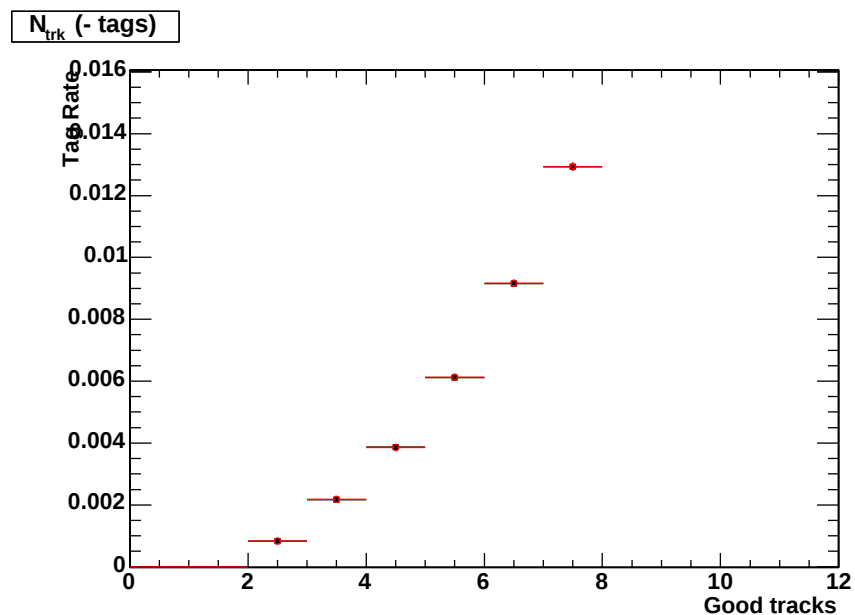
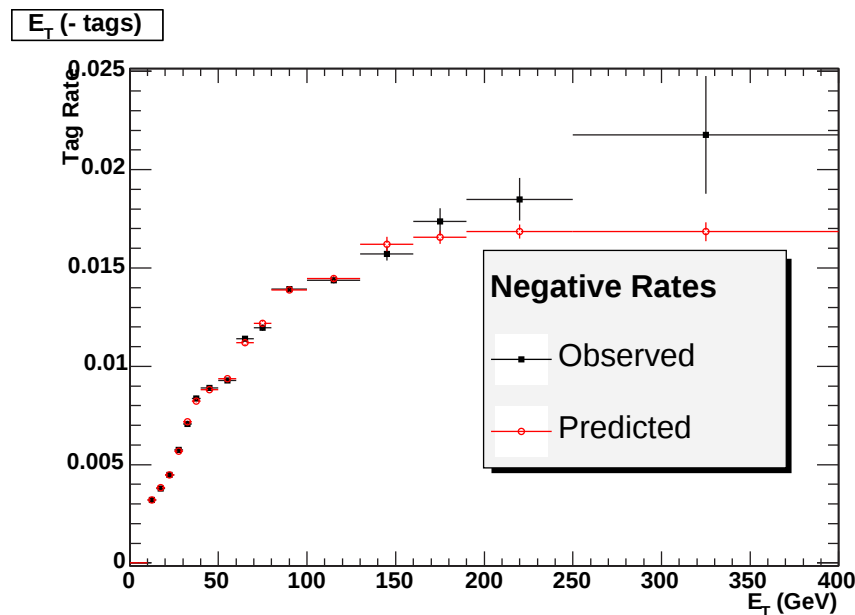


- Need 2 things about sample of jets to measure eff:
 1. Net tag rate, $r = (N_{\text{pos}} - N_{\text{neg}})/N_{\text{tot}}$
 2. Frac of jets containing HF, F_B
- Eff is then $\varepsilon = r/F_B$
- Measure r^a and F_B^a in e-jets when away jet is tagged
- Account for away-jets tagged **but e-jet is light-flavor**
- This QCD contribution measured in sample when e-jet identified as photon-conversion
- Assumes **heavy flavor** production in away-jet **independent** of e coming from **conversions/fakes**

$$\varepsilon = \frac{(N_{a+}^{e+} - N_{a+}^{e-}) - (N_{a-}^{e+} - N_{a-}^{e-})}{(N_{a+} - N_{a-})} \cdot \frac{1}{F_B^a}$$

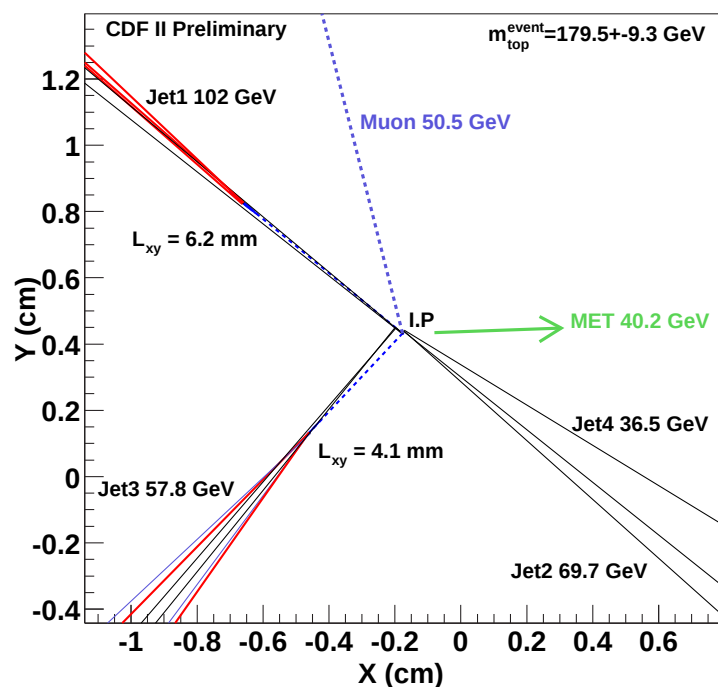
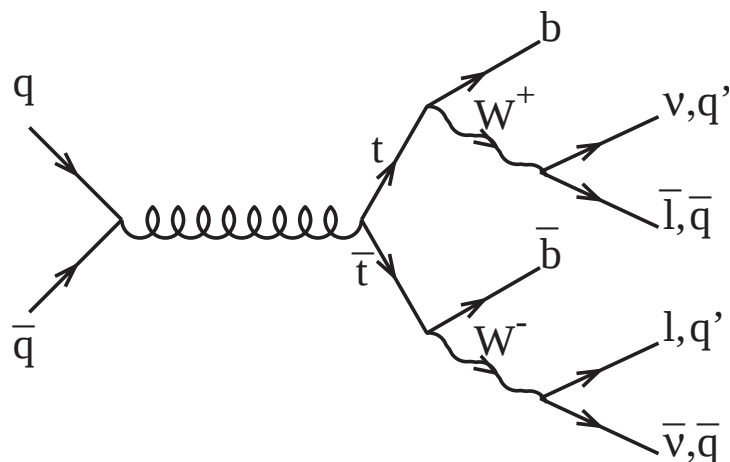
- Relative difference data/MC for tagging b-jets $81\% \pm 7\%$
- Eff to tag a $t\bar{t}$ event $52.9\% \pm 0.3\% \pm 4.6\%$
- Now measure prob to tag *light-flavor jet* as b-jet (fake tag)

High- P_t B-Tagging: Fake Rate



- Can't rely on absolute MC rate for tagging light partons
- Use negative tag rate in inclusive jet sample to determine "fake rate"
- Parameterize rate as function of 5 observables
 - E_T : Vtx method better for large E_T
 - $\sum E_T^{\text{jets}}$: Removes some sample dependence
 - $N_{\text{good}}^{\text{trk}}$: Tracking eff
 - ϕ, η : Detector coverage
- Use parameterization to predict negative tag rates in different samples
- Fake rate 1 – 1.5% for top-candidates

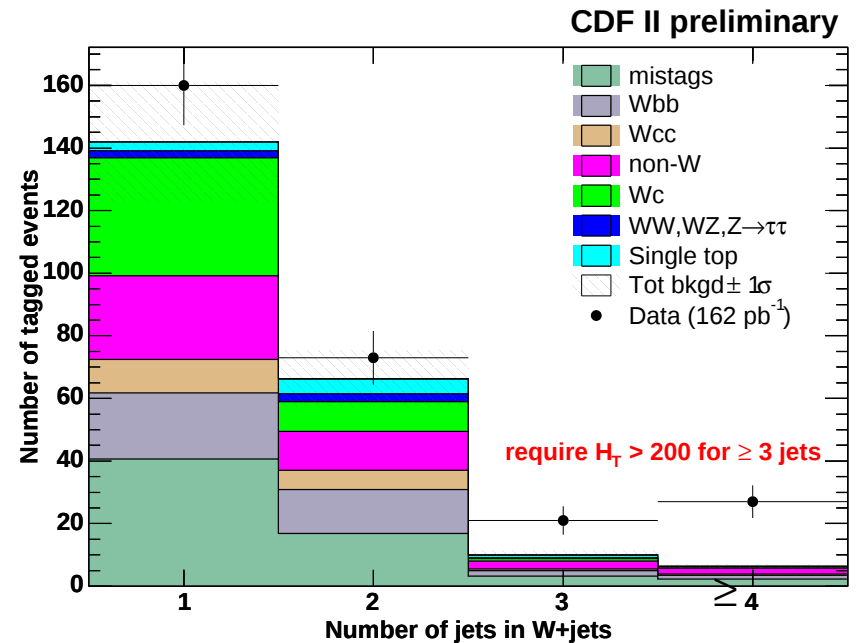
Re-Measuring the Top Cross Section



- For the purposes of the **Higgs search**, the top quark is bkg, but more importantly presents a known **high P_T** physical process involving **b-jets**
- Reestablishing lepton+jets top cross section give us confidence that the **b-tag is working**

Top: Lepton+Jets Cross Section

- Signature:
 - 1 high- P_t isolated lepton
 - Veto conversions, Z's, cosmuics
 - Large missing E_t
 - At least 3 high- E_t jets
 - $H_t > 200$ GeV
 - At least 1 b-tag
- B-tag improves S/B from 1/6 to 3/1



- Find 48 candidate events in 162 pb $^{-1}$
- Expect 13.8 ± 2.0 bkg events
- $\sigma_{t\bar{t}} = 5.6 \pm 1.2(\text{stat}) \pm 0.8(\text{syst})\text{pb}$
- $\sigma_{t\bar{t}}(\text{NLO}) = 6.7^{+0.71}_{-0.88}$ pb (Cacciari *et al.*)

Now on towards the Higgs

- Si detector tuned up
- B-Tag implemented
- Jets+Lepton top cross section reestablished
- *Now let's see what has to be done for MSSM Higgs search*

4b Search: Roadmap

- Online

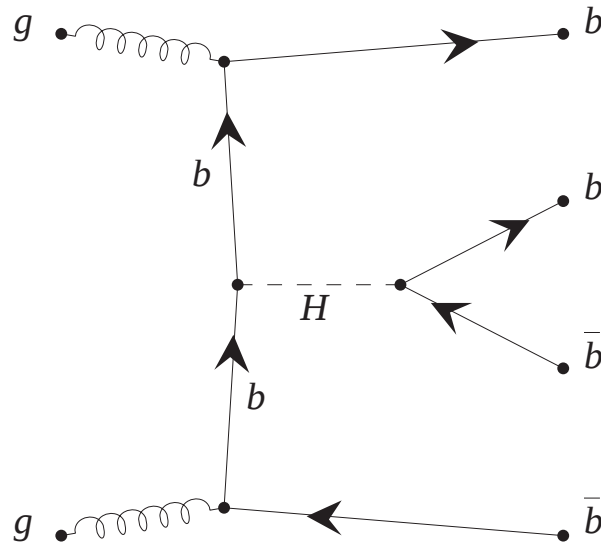
- Trigger is crucial.
- High bkg rates, this will always be somewhat low eff

- Offline

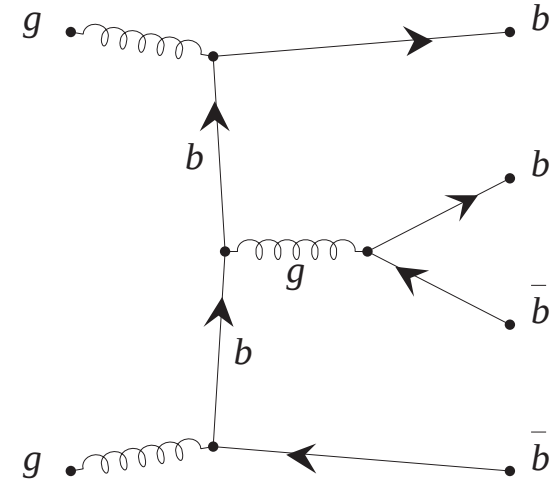
- Veto isolated high- P_T leptons from Z & W
- Require 4 jets, with $E_T > 10$ GeV
- Estimate “fake tags” from mistag matrix, like top analysis
- Estimate QCD from fit to 2-tag spectrum in data
- Harsh b-tag requirement: 3 or more positive tags!
- Dijet pairing $\Rightarrow$ mass window cuts
- Dijet mass isn't great, essentially counting exp

Triggering on 4b Events with CAL+SVT

Signal

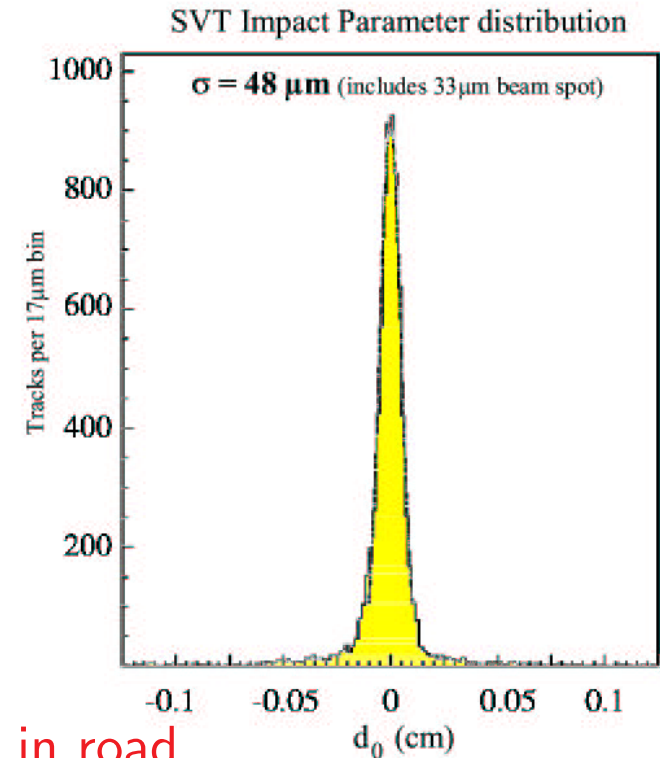
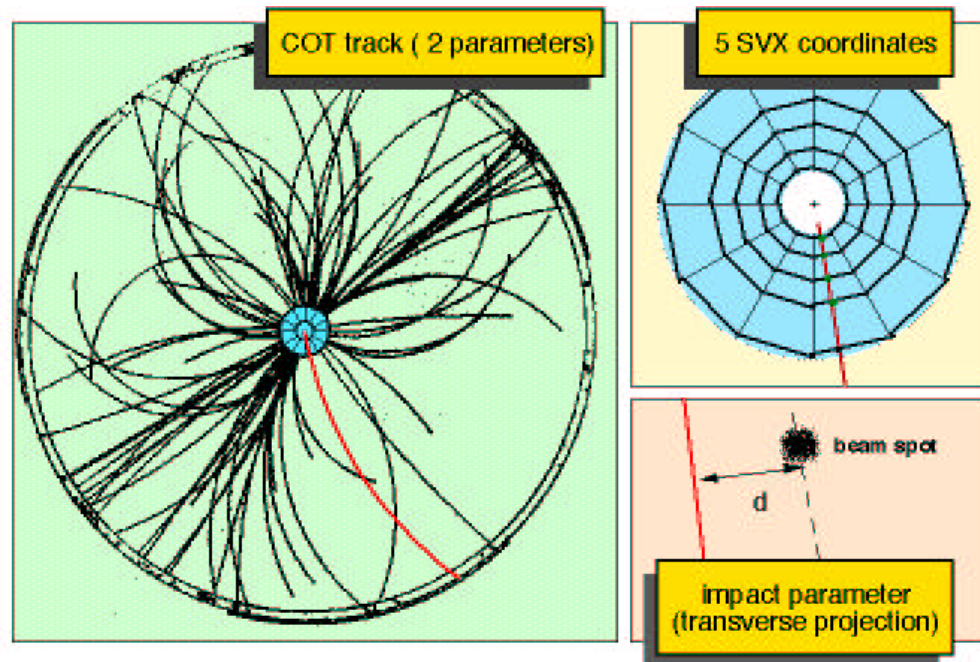


QCD 4b Background



- Signature: 4 b-jets in final state with lots of visible energy
- Dominant background: QCD processes giving 4 real b-jets in final state
- Trigger:
 - 3 jets with $E_T > 10$ GeV
 - $\sum E_T > 100$ GeV
 - Heavy flavor present (use SVT)

Triggering on Heavy Flavor with SVT



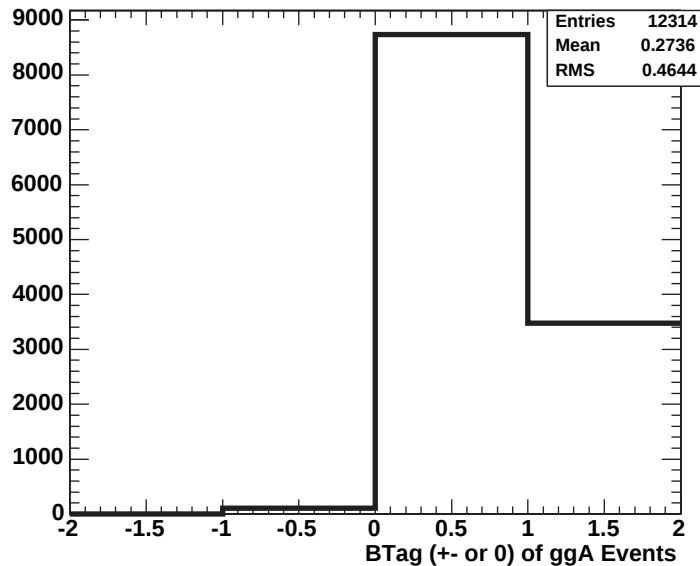
- Takes L1 tracking info from COT and finds Si hits in road
- Fits beamline position online, for IP reference
- IP resolution = $35 \mu\text{m} \oplus 33 \mu\text{m}(\text{beam})$ compares to offline resolution quite well
- System is $\sim$ deadtimeless: 25 μsec /event for silicon readout, clustering, track fitting
- 70% eff for 4/4, 80% eff for 4/5

Beginning Studies with MC and Blinded Data

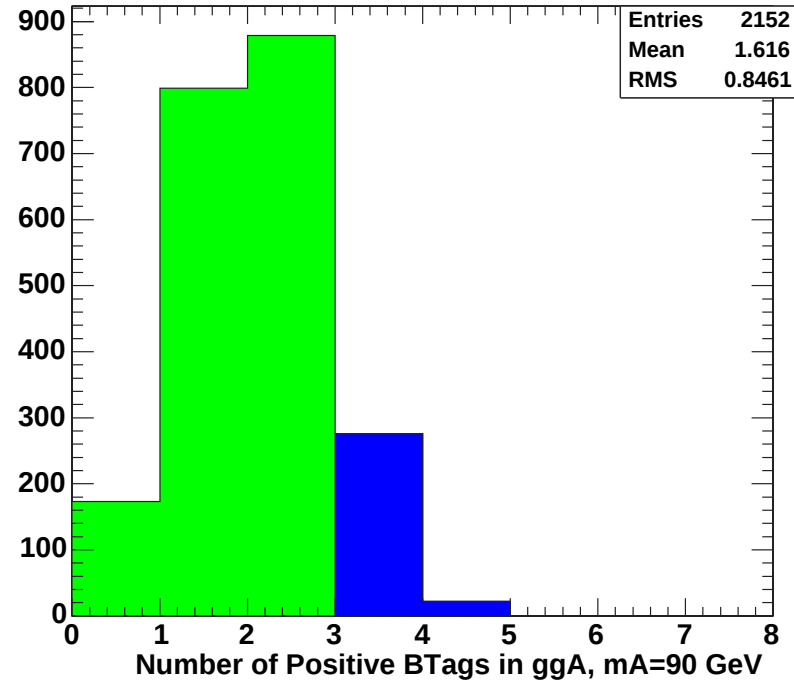
- Begun MC-level studies of 4b signals in m_A range 90 GeV to 130 GeV (where LEP left off)
- Using background dominated data to study fake tags
- Haven't used data to measure signal (**blinded**), but made first estimate of expected signal and background rates
- Comparable to **previous study** (J. Valls) of expected rates
⇒ **Use as baseline** for expected sensitivity
- Everything is very preliminary

Estimated Efficiencies on Signal

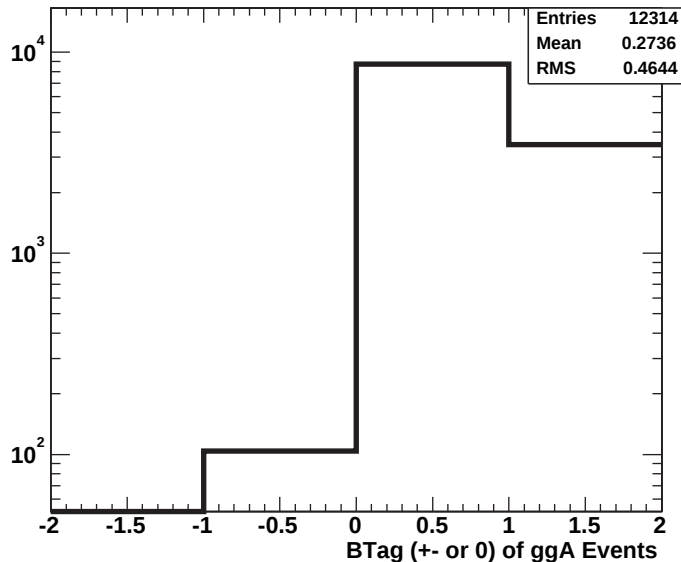
Jet Tags After L3 Trig Cuts



NPos tags After L3 Trig Cuts

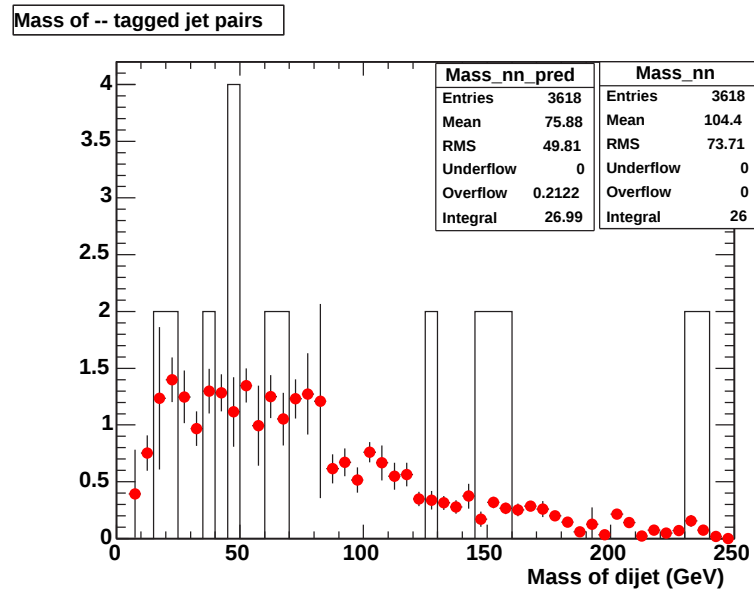
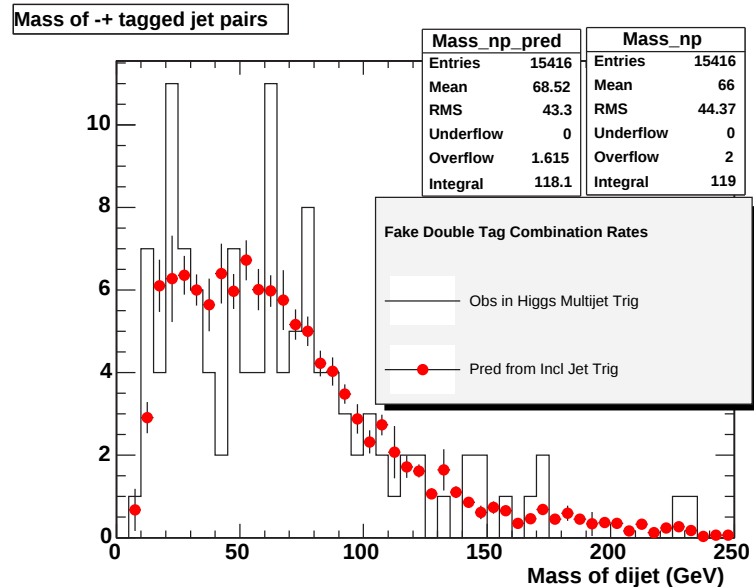


Jet Tags After L3 Trig Cuts



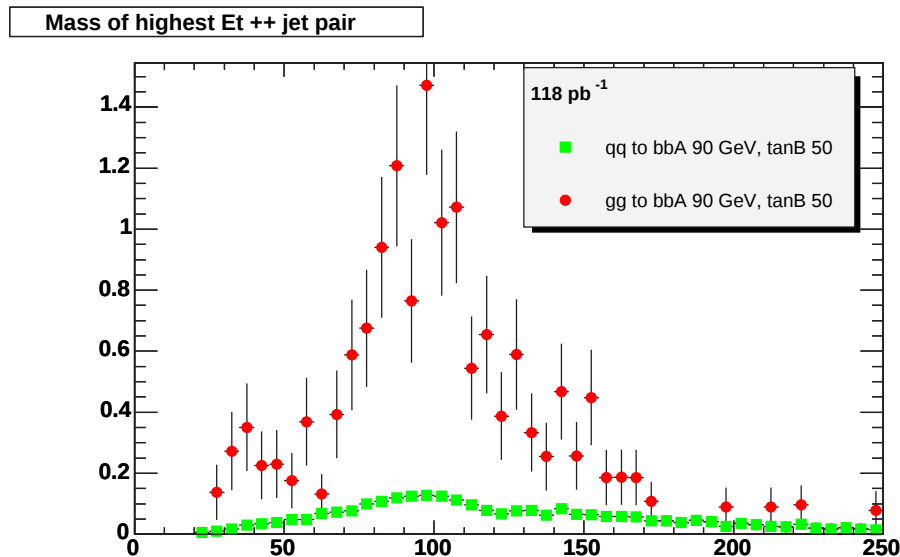
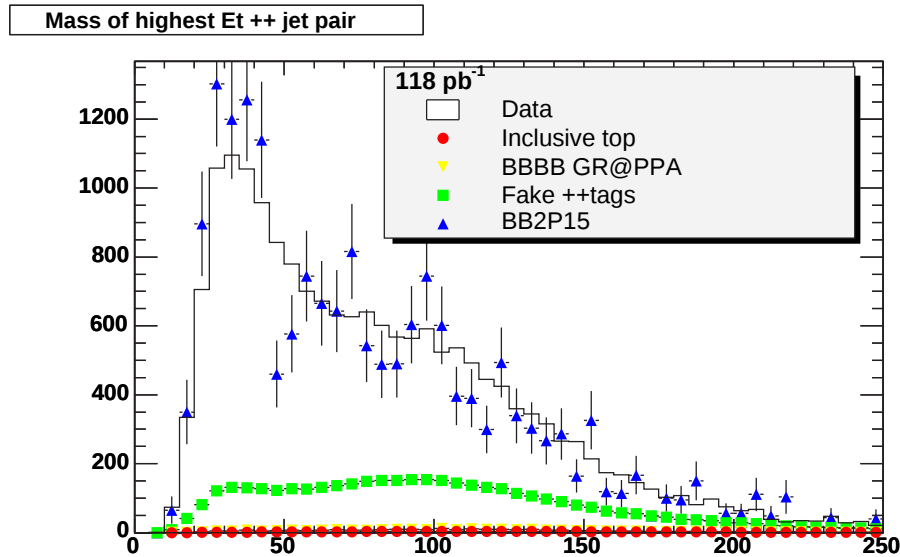
Requirement	$m_A = 90 \text{ GeV}, \tan\beta = 50$	
	$gg \rightarrow bbA$	$qq \rightarrow bbA$
Passes L1&L2&L3	1.5%	37.7%
2+ offline b-tags	32%	47.5%
3+ offline b-tags	9.5%	18.5%
Total eff	0.14%	7.0%
gg+qq eff	0.2%	

Estimate Fake Tags Like Top Analysis: Fake Matrix



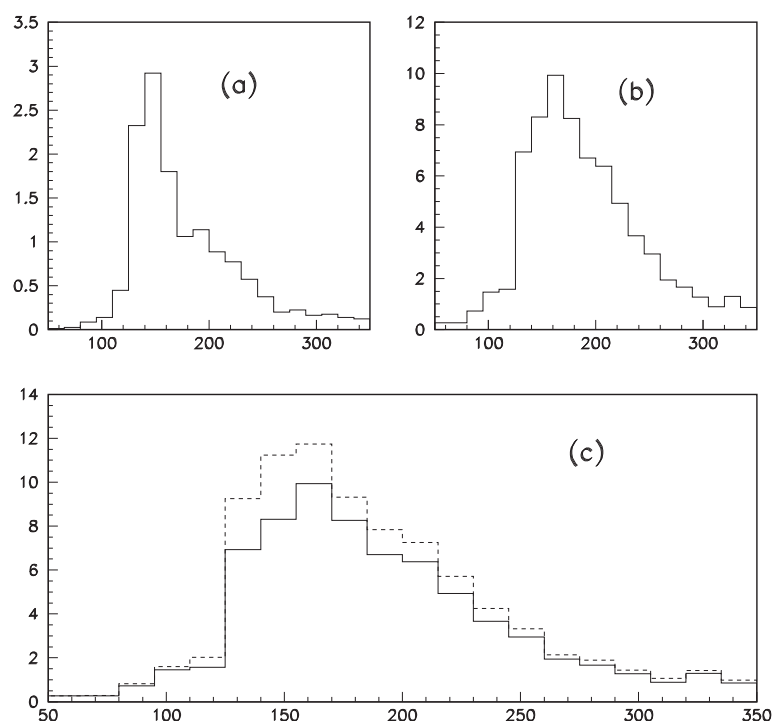
- n_{+-} :
 - Obs 121
 - Pred 119.7 ± 3.6
 - Ratio: 1.01 ± 0.09
- n_{--} :
 - Obs (26)/2
 - Pred $(27.2 \pm 1.6)/2$
 - Ratio: 0.96 ± 0.19
- Fake multitag prediction seems to work (for dijet masses above ~ 50 GeV)

Example of Fitting QCD Bkg from Data



- Use LO ME generators (ALPGEN, GR@PPA) for QCD b events (bbjj for double-tag, bbbb for triple-tag)
- Absolute cross section must come from data
- Fit double-tag data dijet mass spectrum, with known normalizations for fakes, top, smaller bkg, but let QCD float

Use Results of Analysis of 4b Events from RunII Study



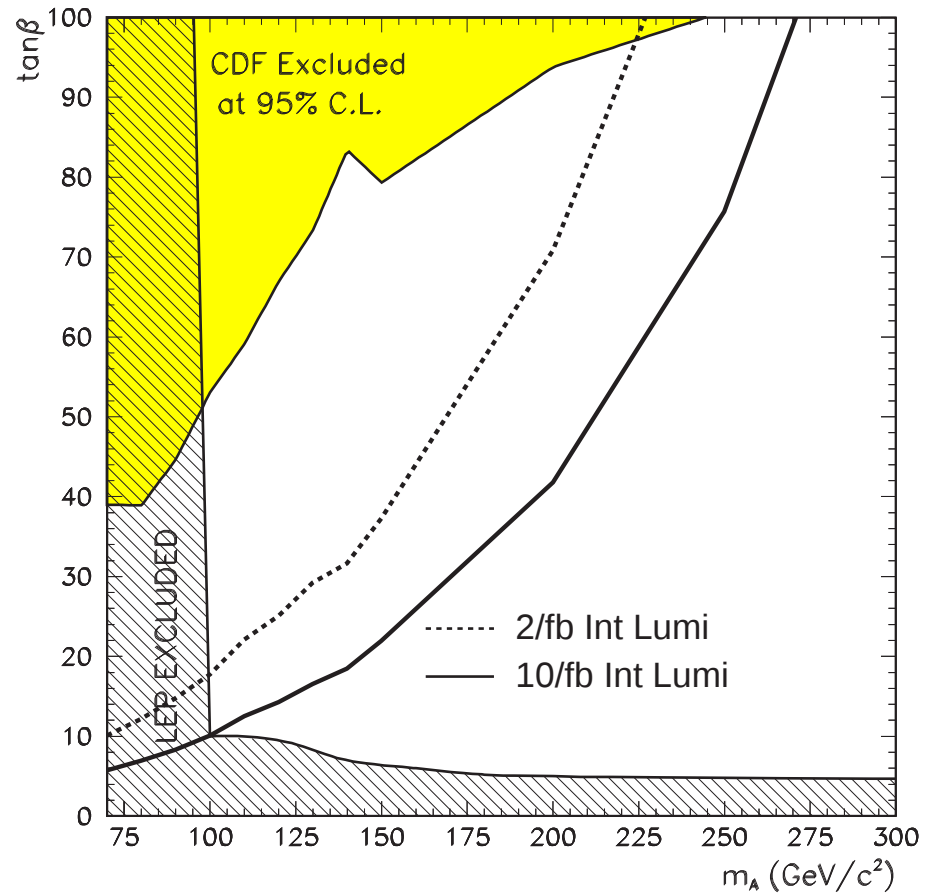
- After the trigger, require triple b-tag
- Reconstruct double-tagged dijet mass: $\sim 15\%$ resolution on signal
- Very little difference between signal (a) and bkg (b) in dijet spectrum, essentially a counting experiment
- (c) signal+bkg for $m_A = 130$, $\tan\beta = 40$ for 1 fb^{-1}

Expected Signal+Background in 1 fb^{-1}

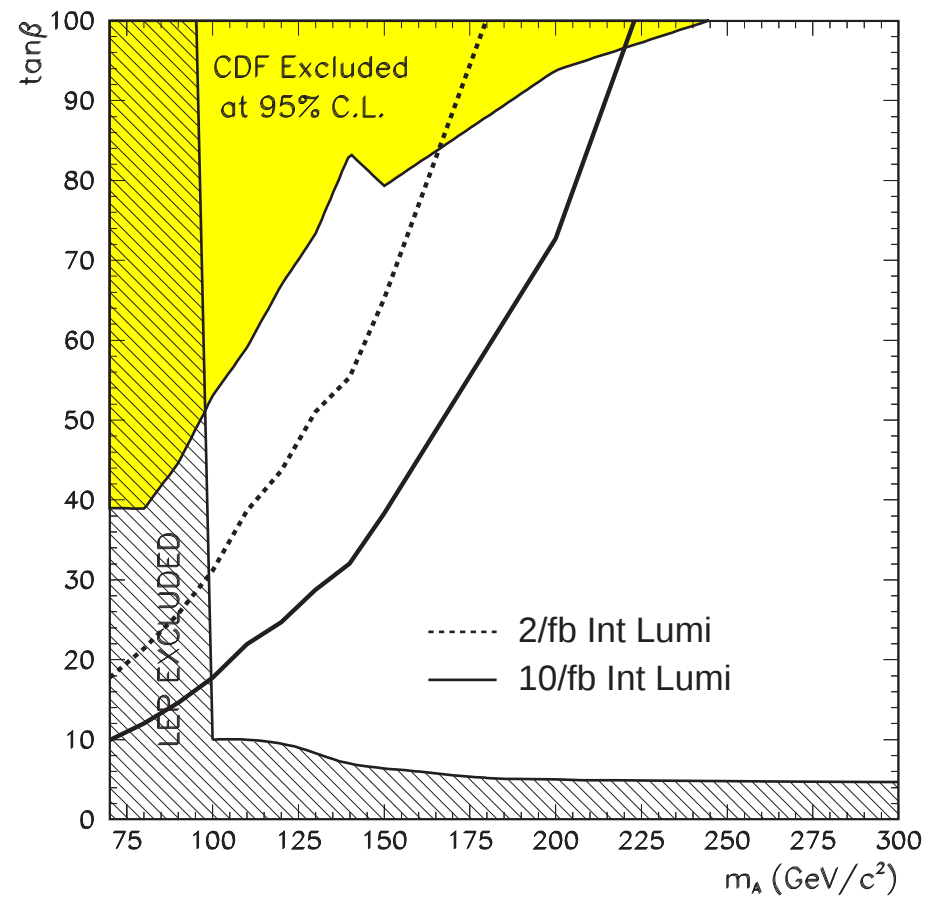
m_A GeV	signal at $\tan\beta = 40$	$\text{QCD}_{\text{heavy}}$	$\text{QCD}_{\text{fakes}}$	top	other	total
90	62.4 ± 1.5	56 ± 12	12 ± 10	13.4 ± 3.4	6.6 ± 1.7	88 ± 16
130	13.7 ± 0.5	45 ± 11	7 ± 5	12.2 ± 3.2	3.4 ± 1.4	68 ± 13

Outlook

95% CL Exclusion



5σ Discovery



Summary

- Should be able to **exclude SM Higgs to ~ 120 GeV**
- Have **$\sim 200 \text{ pb}^{-1}$** data on tape with MSSM Higgs trigger
- Systematic progress in **understanding b-tagging in RunII**
- Higgs multijet trigger performing adequately, room for improvement
- Expect to have new MSSM exclusion potential down to $\tan\beta \sim 50$ for $m_A = 90$ GeV with data in hand
- Large region of parameter space with **potential for discovery in MSSM**

Near Future at Tevatron

- Finish first round of search for $gg \rightarrow b\bar{b}A/h \rightarrow b\bar{b}b\bar{b}$
- Implement more efficient trigger
- Combined search
 - Willinbrock predicts $gg \rightarrow bA \rightarrow b\bar{b}\bar{b}$ is ~ 10 times bigger than $4b$ final state. Measure similar process $p\bar{p} \rightarrow Zb$ first.
 - $b\bar{b}\tau\tau$ channel is 10 times smaller, but still helpful at high $\tan\beta$.
 - Also combine $gg \rightarrow A \rightarrow \tau^+\tau^-$
 - Confirmation in τ -channel would be key!
 - Can combine results with D0 a'la LEPHWG for more sensitivity
- Combine with other SUSY searches, esp $B_s \rightarrow \mu^+\mu^-$ for *global MSSM search*
- MSSM Higgs search seems quite promising

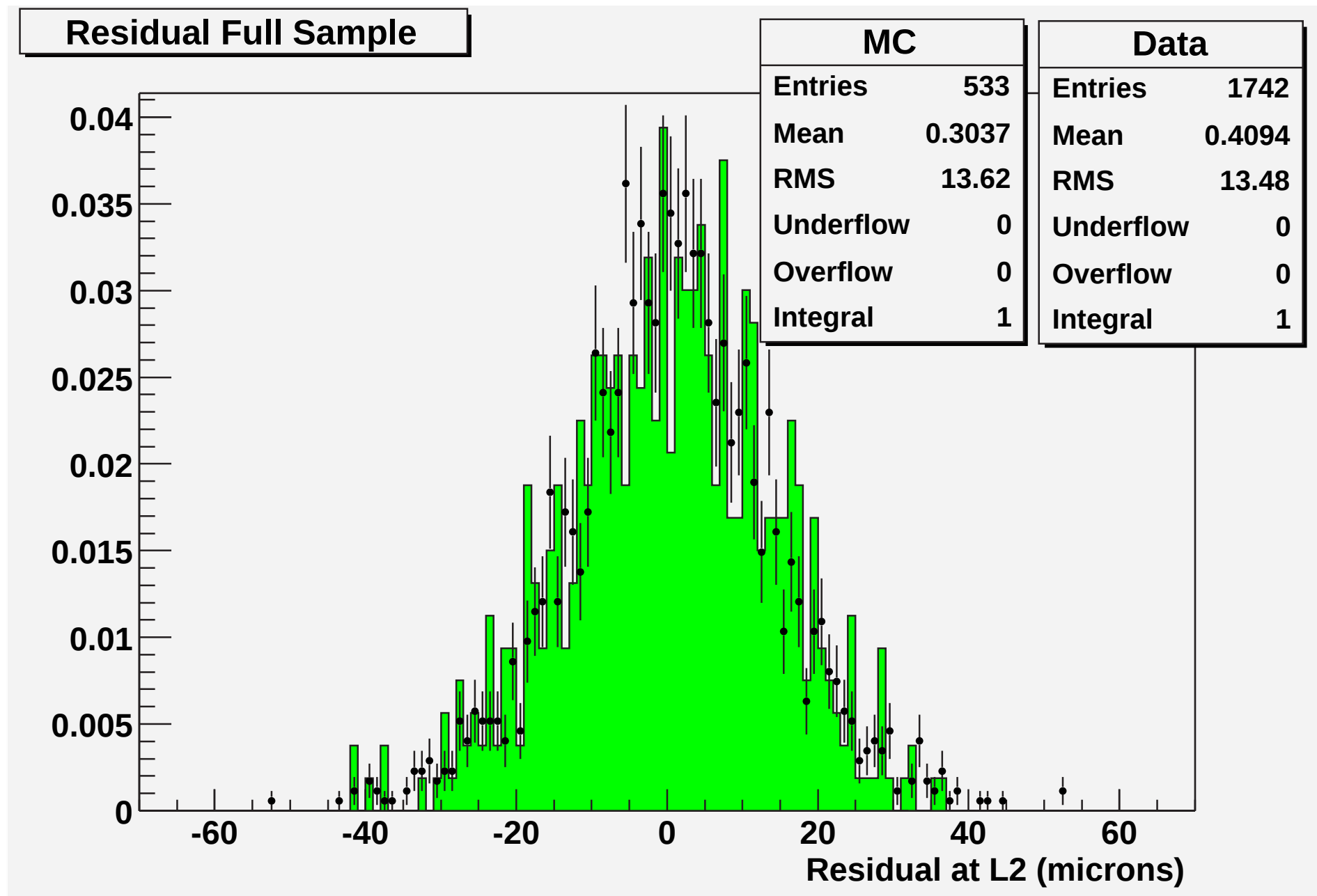
Backup Slides

Higgs Lagrangian

$$\mathcal{L}_{\text{Higgs}} =$$

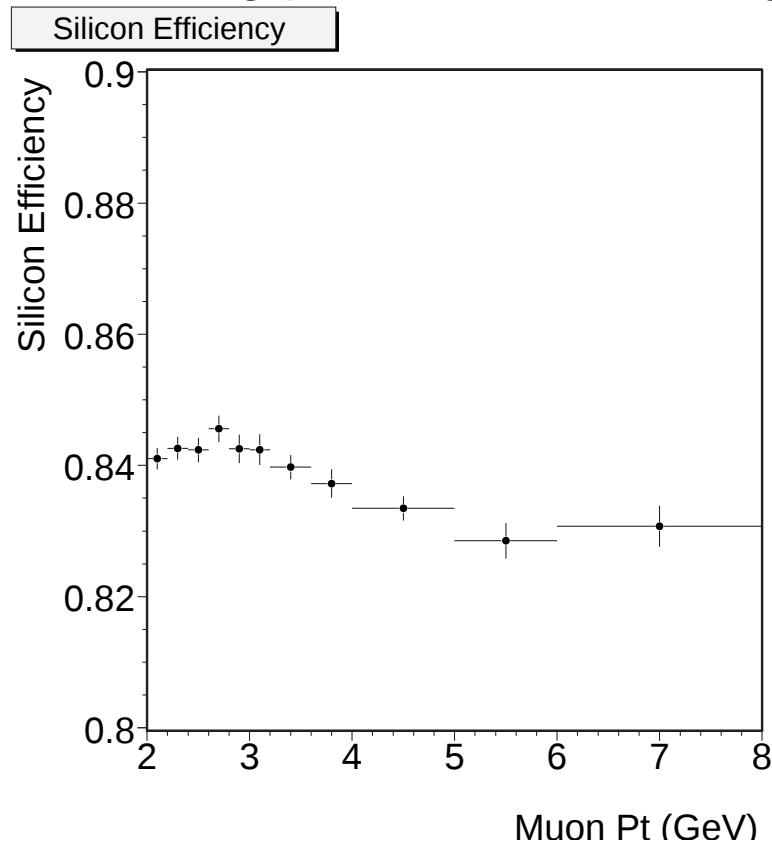
$$\begin{aligned}
 & (D_\mu \phi)^\dagger (D_\mu \phi) && \left\{ \begin{array}{l} \text{Gauge-Higgs coupling} \end{array} \right. \\
 & - \mu^2 (\phi^\dagger \phi) - \lambda (\phi^\dagger \phi)^2 && \left\{ \begin{array}{l} \text{Mass term and} \\ \text{quartic coupling} \end{array} \right. \\
 & + k_e (\bar{\ell}_L \phi) e_R + k_e \bar{e}_R (\phi^\dagger \ell_L) && \left\{ \begin{array}{l} \text{Lepton-Higgs} \\ \text{Yukawa term} \end{array} \right. \\
 & + k_d (\bar{d}_L^c \phi) d_R^c + k_d \bar{d}_R^c (\phi^\dagger d_L^c) + && \left\{ \begin{array}{l} \text{Quark-Higgs} \\ \text{Yukawa terms.} \end{array} \right. \\
 & k_u (\bar{u}_L^c \tilde{\phi}) u_R^c + k_u \bar{u}_R^c (\tilde{\phi}^\dagger u_L^c) &&
 \end{aligned}$$

Silicon Tracking Resolution Data vs MC

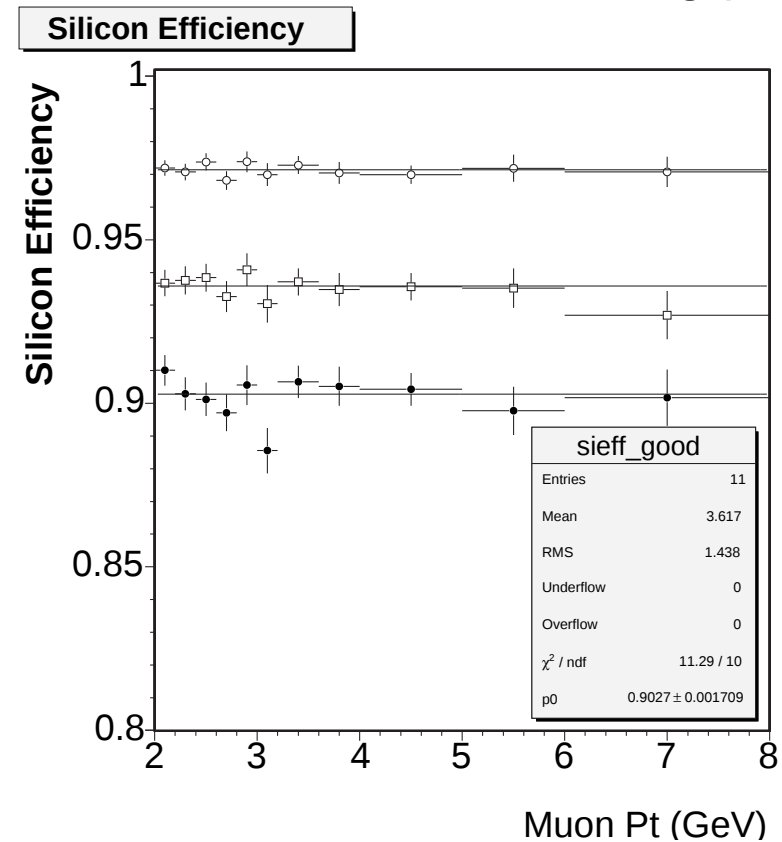


Silicon Tracking Performance

Including pre-stable-data-taking period



After stable-data-taking period

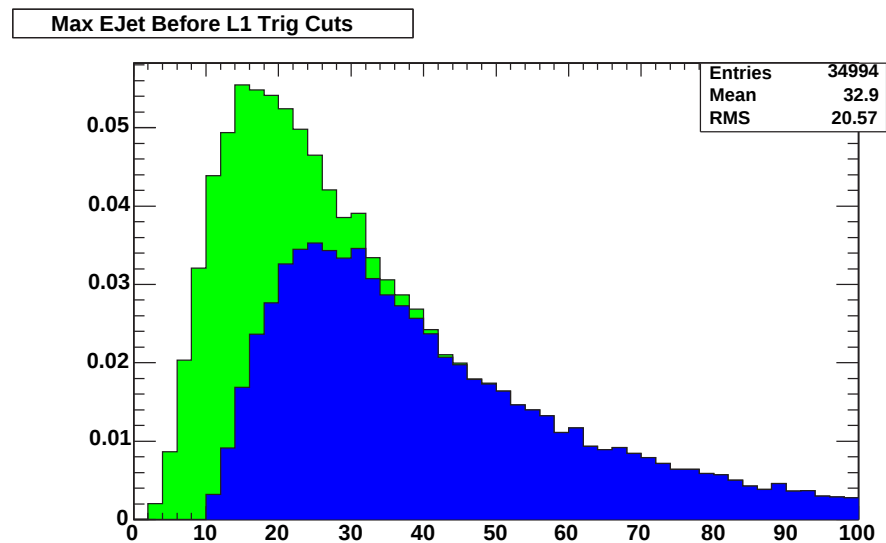
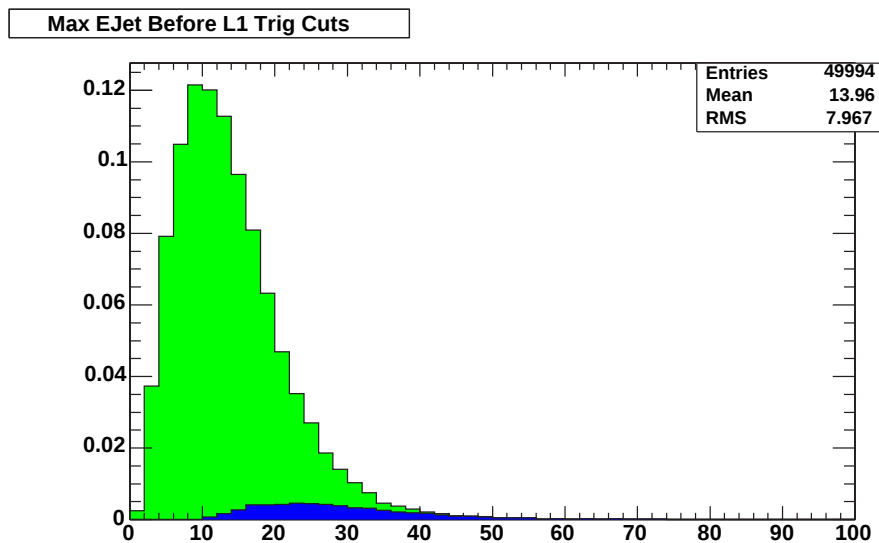
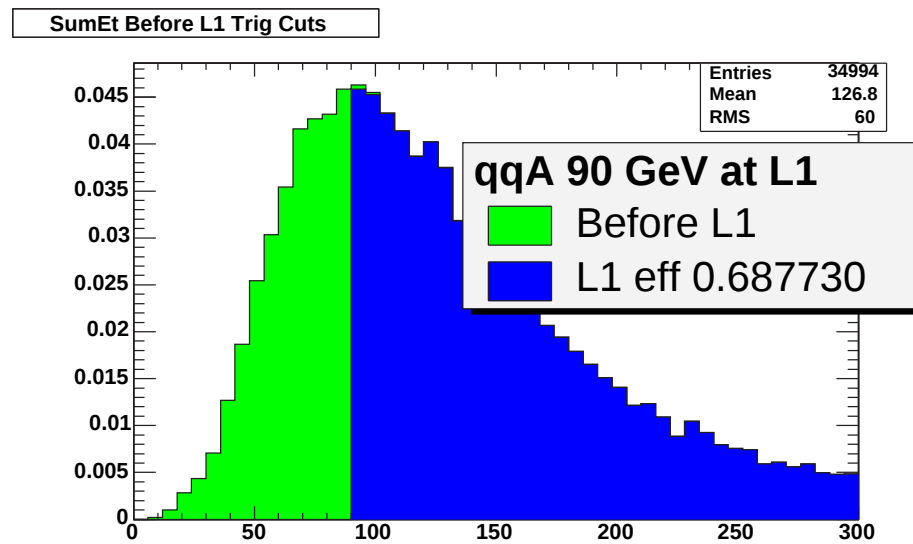
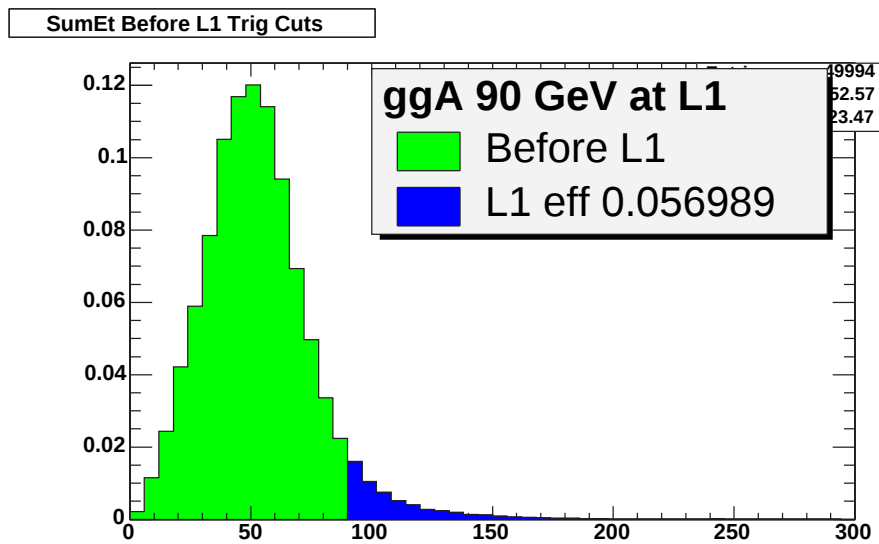


- Eff to attach $\frac{N-1}{N}$ $R\Phi$ -Si hits to good COT tracks from $J/\psi \rightarrow \mu^+ \mu^-$ events
- 5% **readout errors** (have reduced some)
- 4% **bad strips** (irreducible)
- 5% **dead wedges** (have recovered some)
- Have improved tracking/alignment

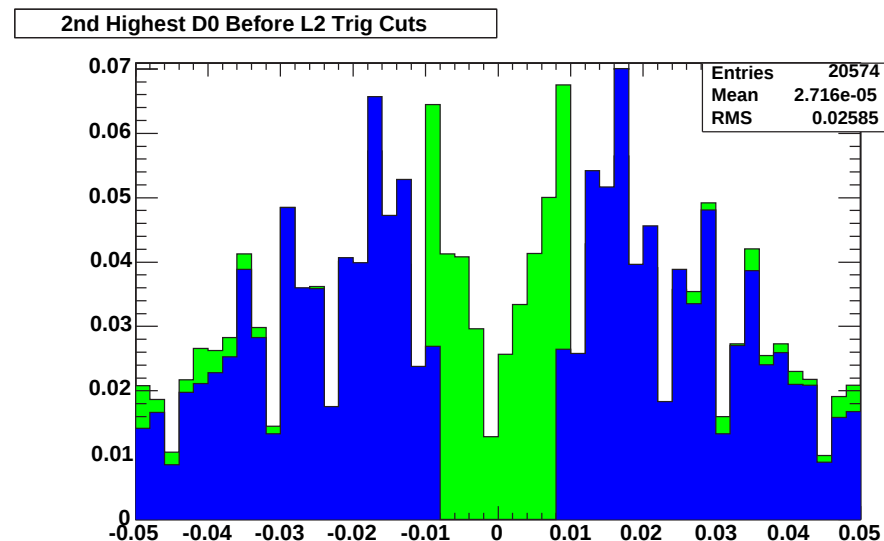
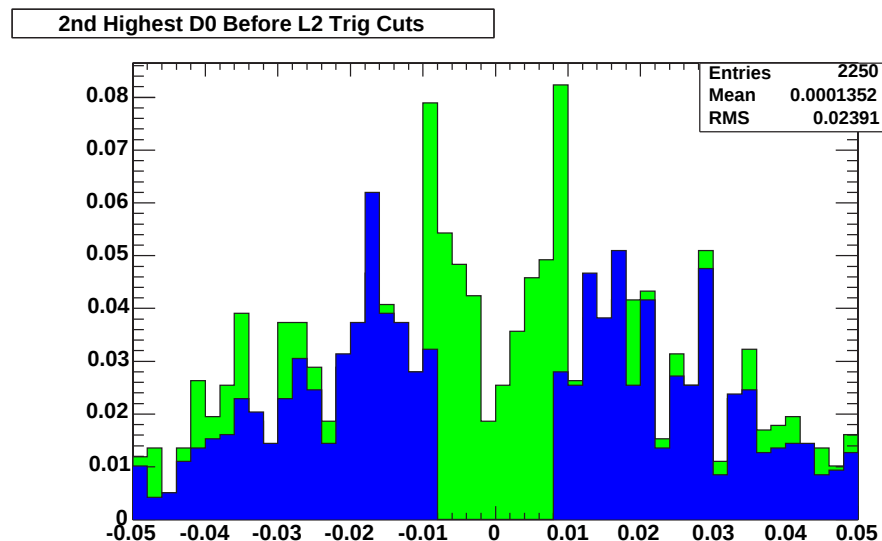
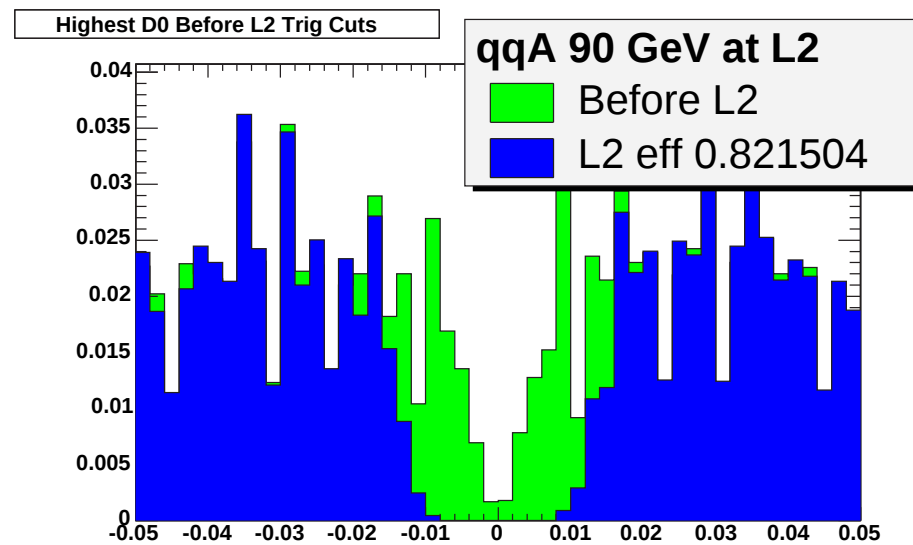
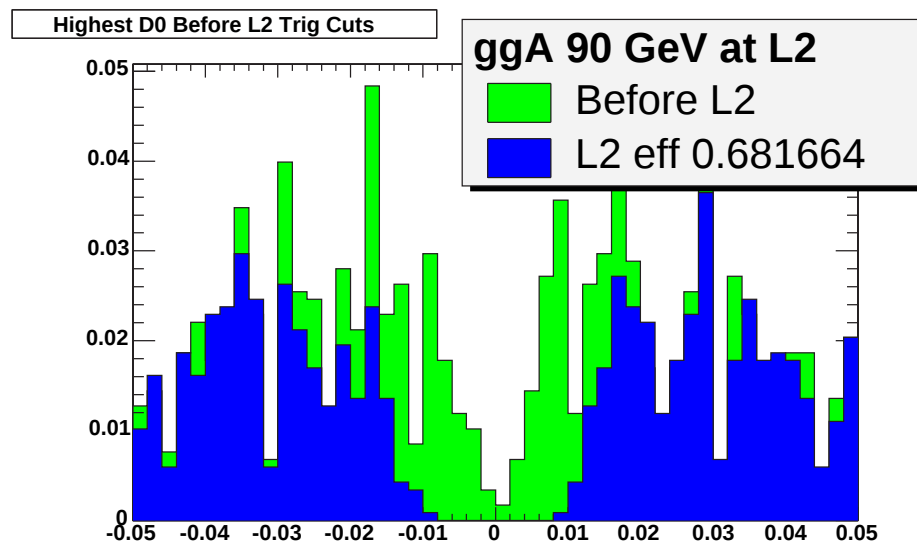
3-Level Higgs Trigger

- **L1_JET10_&_SUMET90_v-1**: Requires one 10 GeV E_T trigger jet from central or plug in coincidence with 90 GeV $\sum E_T$
- **L2_TWO_TRK2_D100_L1_JET10_&_SUMET90_v-1**: Two tracks each with $100 \mu\text{m} < d_0 < 1 \text{ mm}$, $\chi^2 < 25$ and $P_t > 2 \text{ GeV}$ from SVT.
- **L3_THREE_JET10_SUMET100_TWO_SVT_v-1**: Using cone size of 0.4, require three jets of 10 GeV E_T with total jet $\sum E_t > 100 \text{ GeV}$
- Trigger was designed before data taking began.
- Collected 200 pb^{-1} with this trigger. Looking at implementing more efficient trigger for next data taking period.
- **Run1 trigger used for MSSM Higgs was 1.7% efficient on signal**

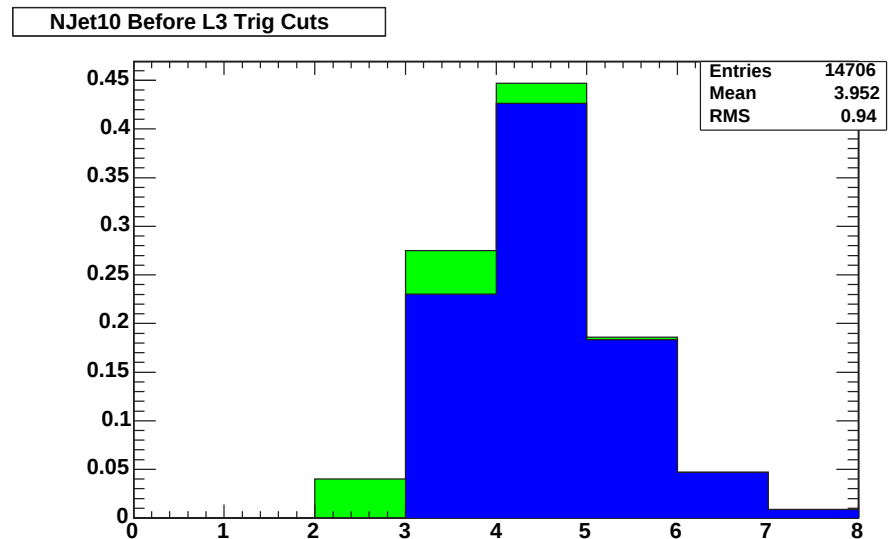
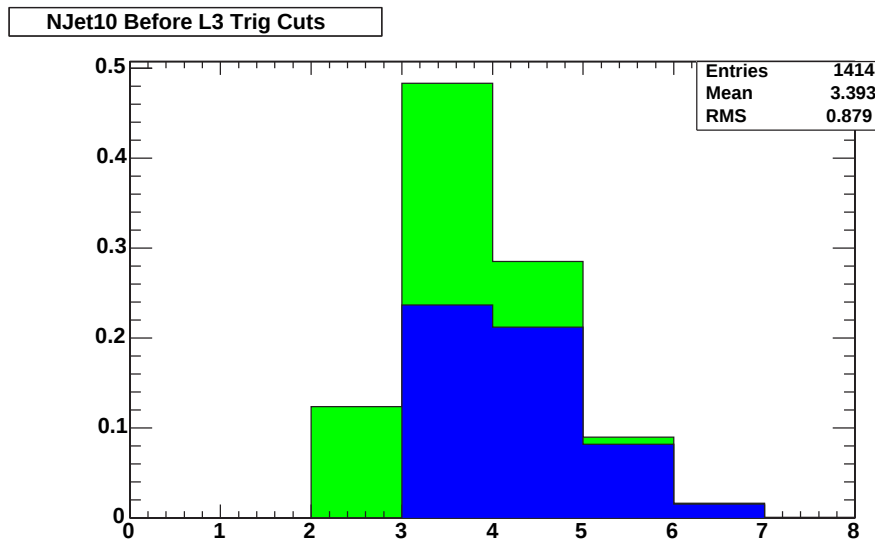
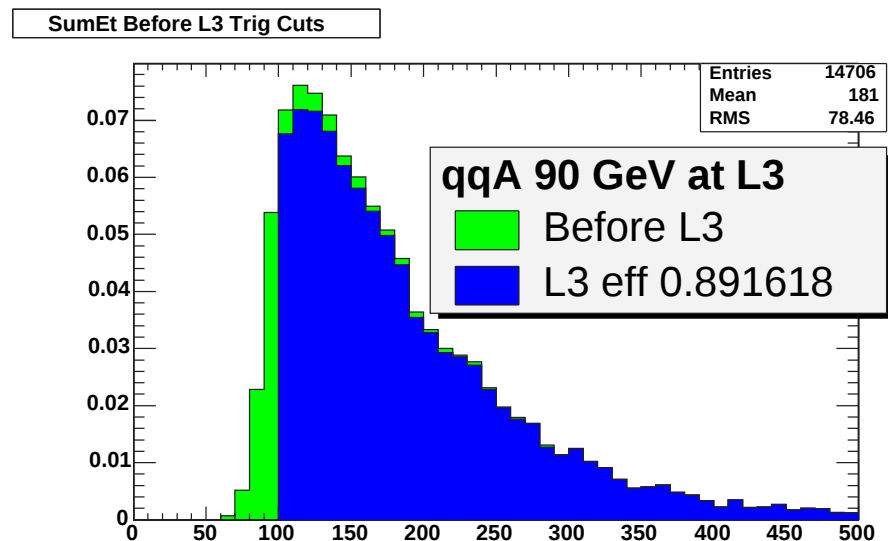
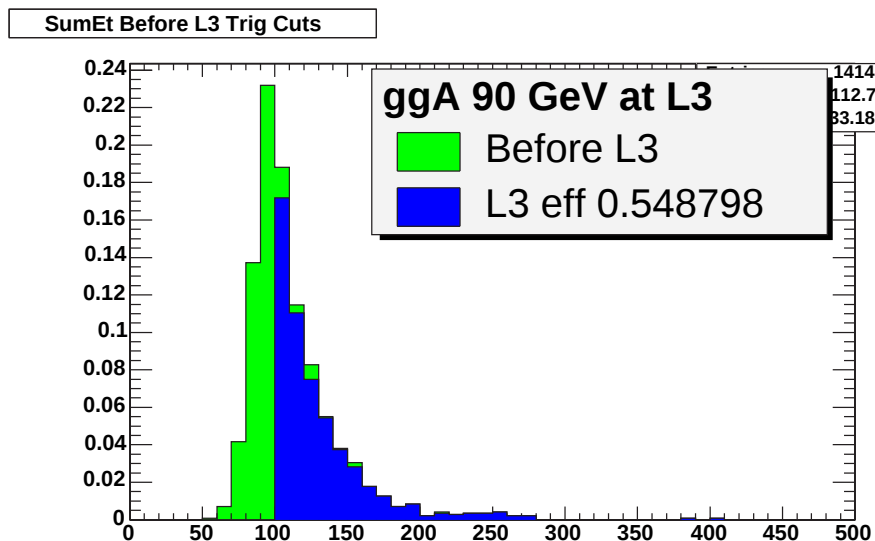
L1 Trigger Efficiency on Signal



L2 Trigger Efficiency on Signal

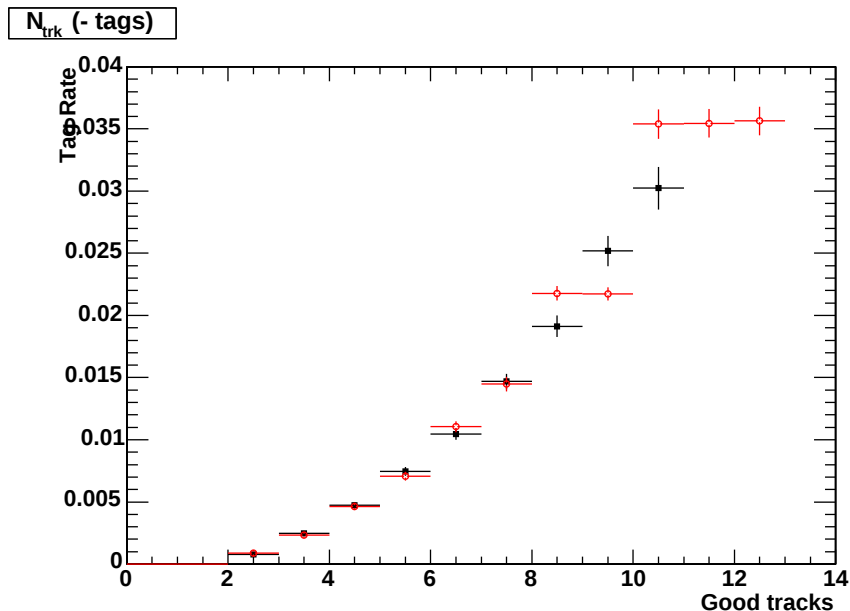
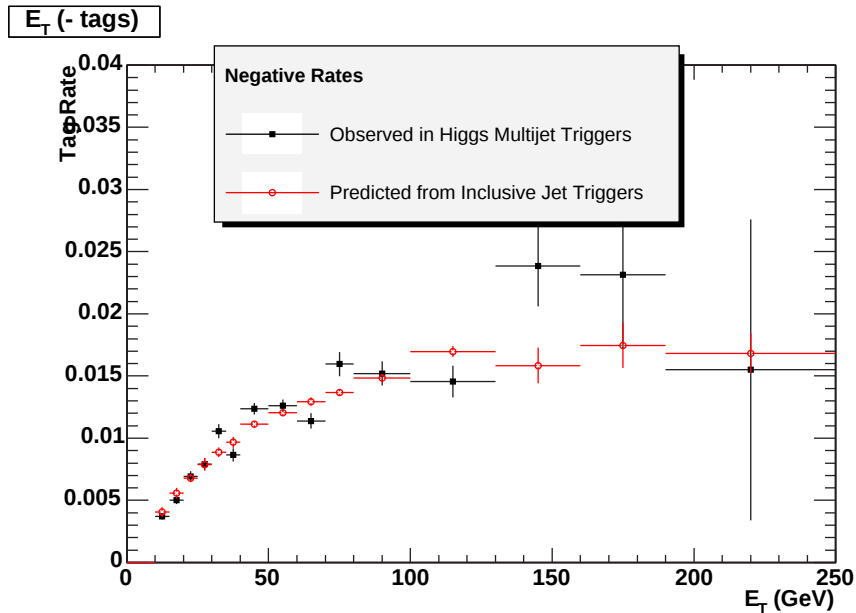


L3 Trigger Efficiency on Signal



Full trigger $\sim 1.6\%$ eff on 90 GeV signal

Fake Double-Tag Rate Prediction in Data



- Negative single-tag rate in incl. jet sample to determine fake multi-tag rate in data ($\text{QCD}_{\text{fakes}}$ in following)
- Fake double-tag is double-positive-tag with at least one light flavored jet

– Consider light-light Neg = Pos = ϵ :

$$P_{--} = \epsilon^2$$

$$P_{+-} = 2\epsilon^2$$

$$P_{++}^{\text{fake}} = \epsilon^2 = P_{+-} - P_{--}$$

– Light-heavy Neg = ϵ , Pos = η :

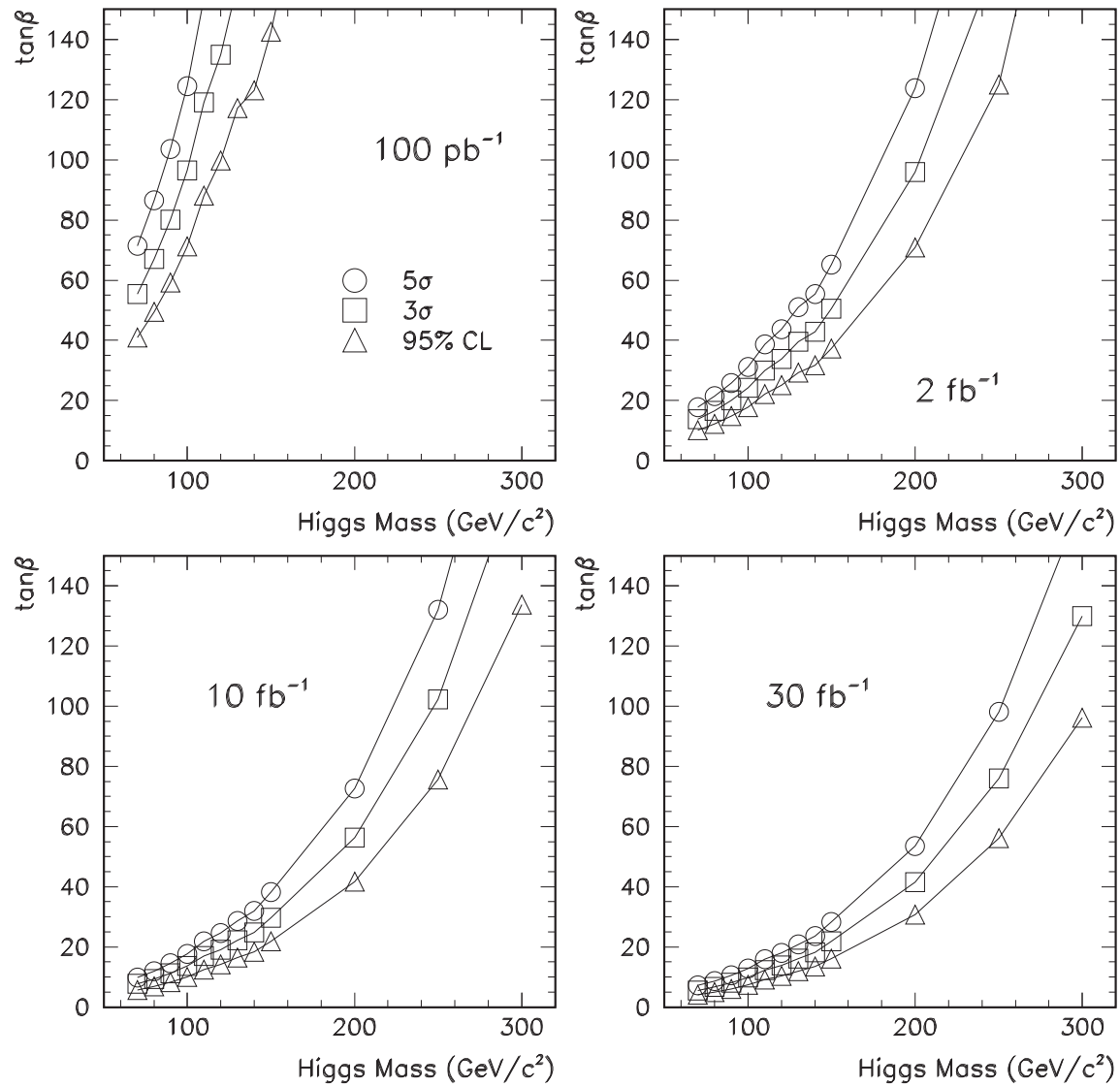
$$P_{--} = \epsilon\eta$$

$$P_{+-} = 2\epsilon\eta$$

$$P_{++}^{\text{fake}} = \epsilon\eta = P_{+-} - P_{--}$$

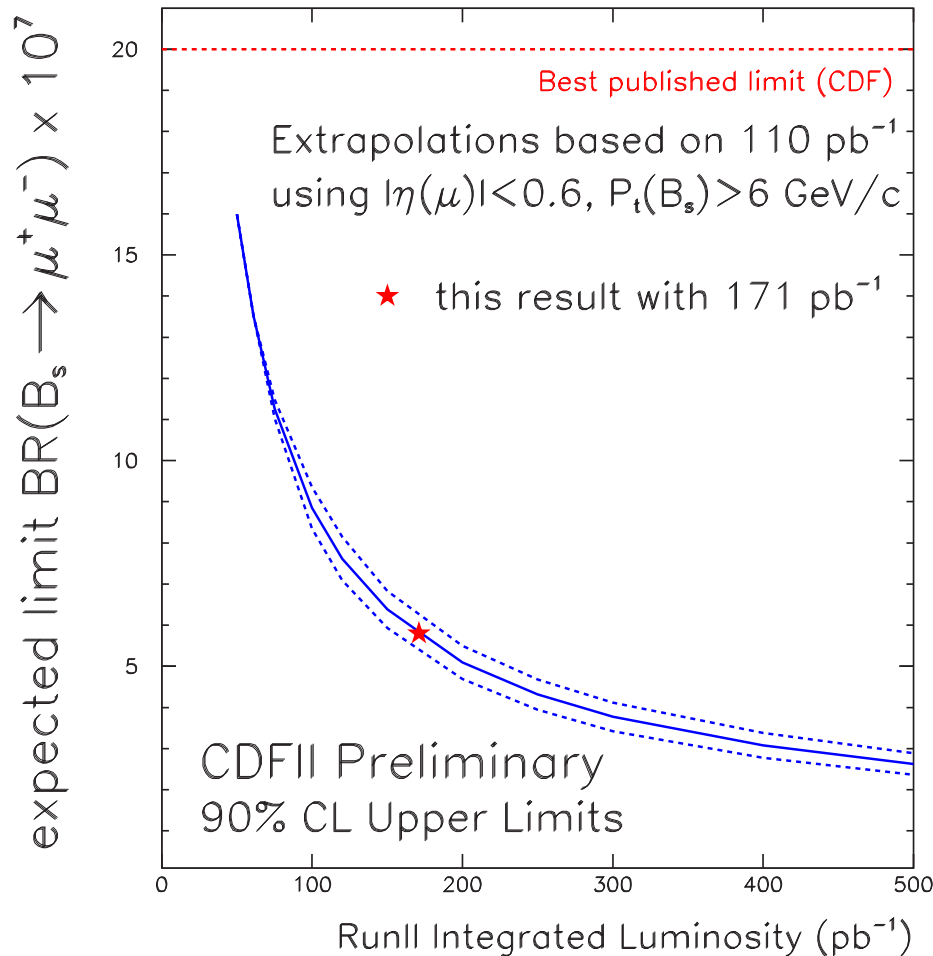
- $P_{+++}^{\text{fake}} = P_{++-} - P_{+--} + P_{---}$

Outlook



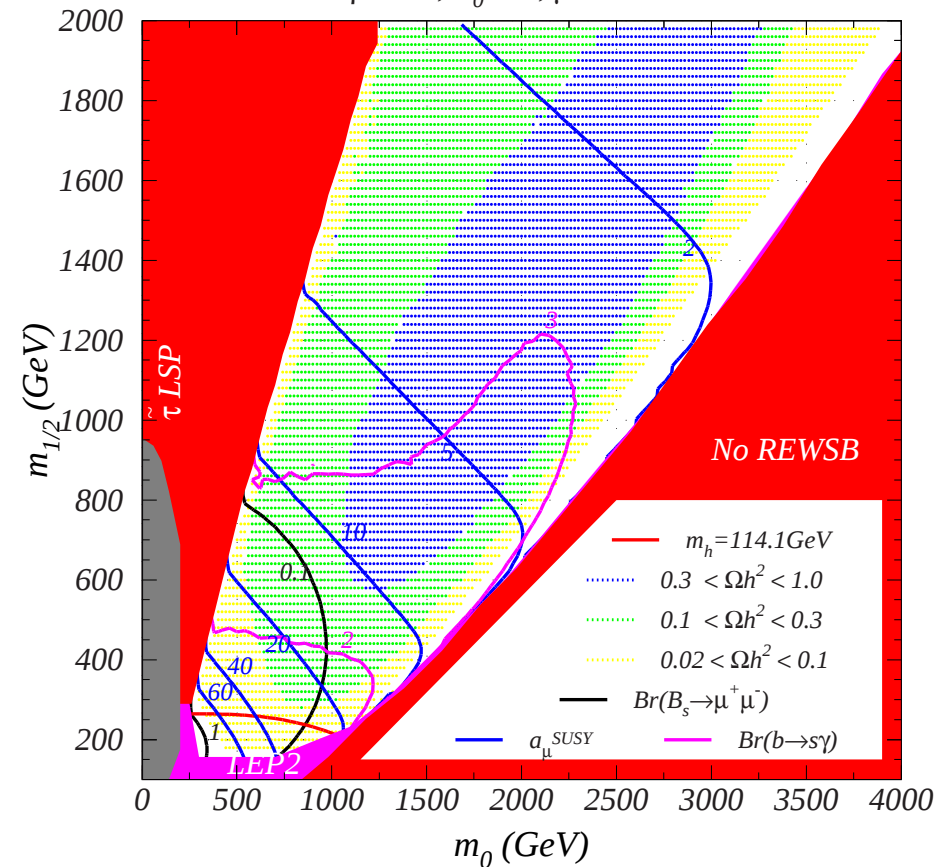
Combine with $B_s \rightarrow \mu^+ \mu^-$: Global MSSM search

From Matt Herndon & Doug Glenziksi



Baer *et al.* JHEP07 (2002) 050

$\tan\beta = 52, A_0 = 0, \mu > 0$



Both high $\tan\beta$ MSSM Higgs search and $B_s \rightarrow \mu^+ \mu^-$ limit same corner of parameter space