Propects for Discovery of Neutral Higgs Bosons in RunII Data

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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)

		I	II	III
Quarks	Particle	u	c	t
	Charge	+2/3	+2/3	+2/3
	Mass	1.5-4.5	~1200	174300
	Particle	d	s	b
	Charge	-1/3	-1/3	-1/3
	Mass	5-8.5	80-155	~4250
Leptons	Particle	e	μ	τ
	Charge	-1	-1	-1
	Mass	0.511	105.7	1777
	Particle	ν_e	ν_μ	ν_τ
	Charge	0	0	0
	Mass	~0	< 0.19	< 18.2

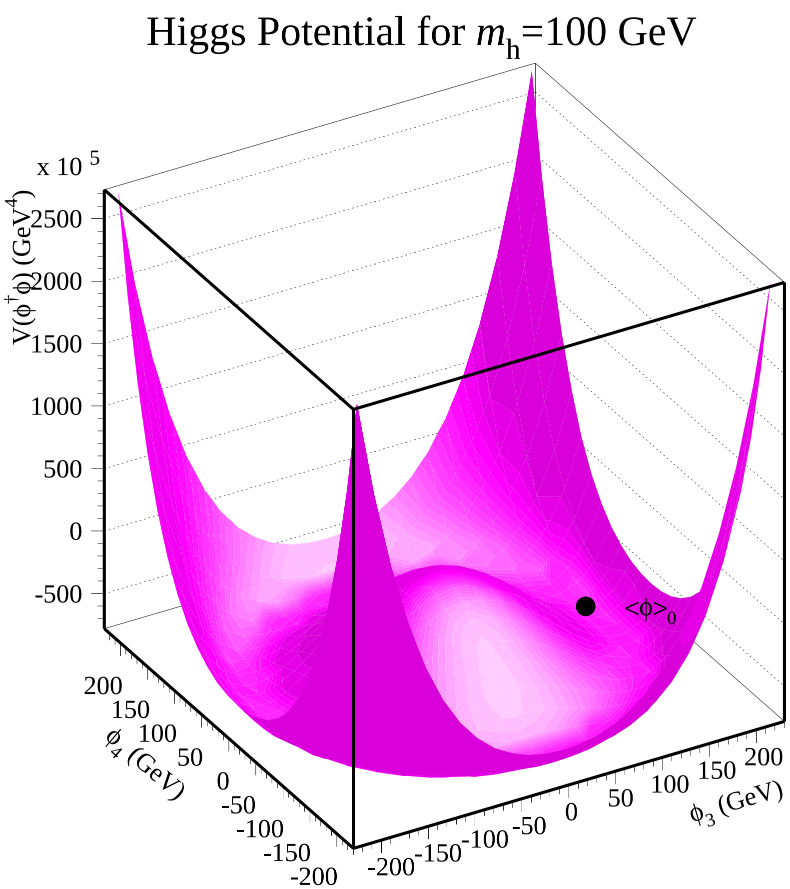
Force Carriers (Bosons)

Force	Particle	Charge	Mass
Electro-magnetic	γ	0	0
Strong	g	0	0
Weak	Z	0	91188
Weak	W	± 1	80425

and allows for mass

Add Potential Term from Neutral Spin 0 Massive Particle

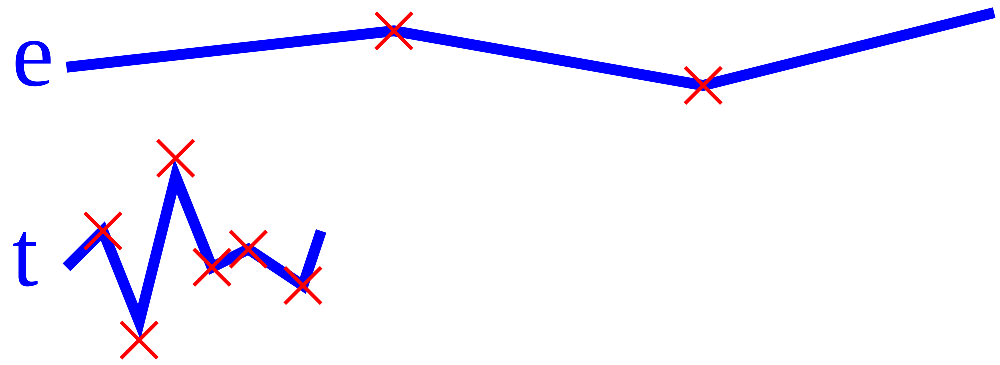
$$V = \mu^2(\phi^\dagger\phi) + \lambda(\phi^\dagger\phi)^2$$



- 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 $m_{\rm h}$ (tree-level) related to coefficients of potential
- Higher order corrections to $m_{\rm h}$ are "unstable" or divergent
- Requires subtracting huge numbers ($\sim 10^{30}\ {\rm GeV}^2$) to get $m_{\rm h} \sim 100\ {\rm GeV}$
- Basic problem is poor co-existence of fundamental (Plank) scale and electroweak scale ($\sim$ 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!

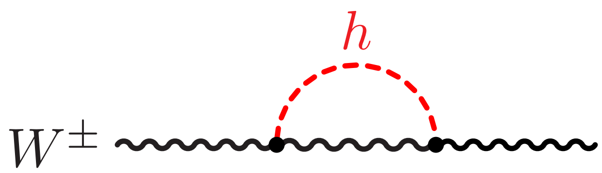
- Have chance of extending LEP's SM Higgs limit
- And good chance of discovering MSSM Higgs at the Tevatron

The High Energy Frontier

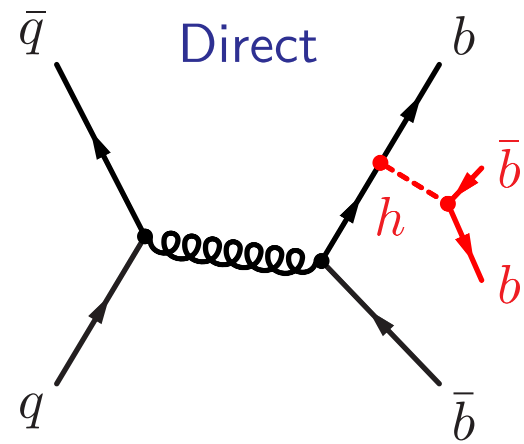
- 980 GeV protons colliding with 980 GeV antiprotons
- Initial luminosities of 5-6E31 $\mathrm{cm}^{-2}\mathrm{s}^{-1}$
- Beam crossings every 396 ns

Direct and Indirect Searches

Indirect: Quantum Corrections



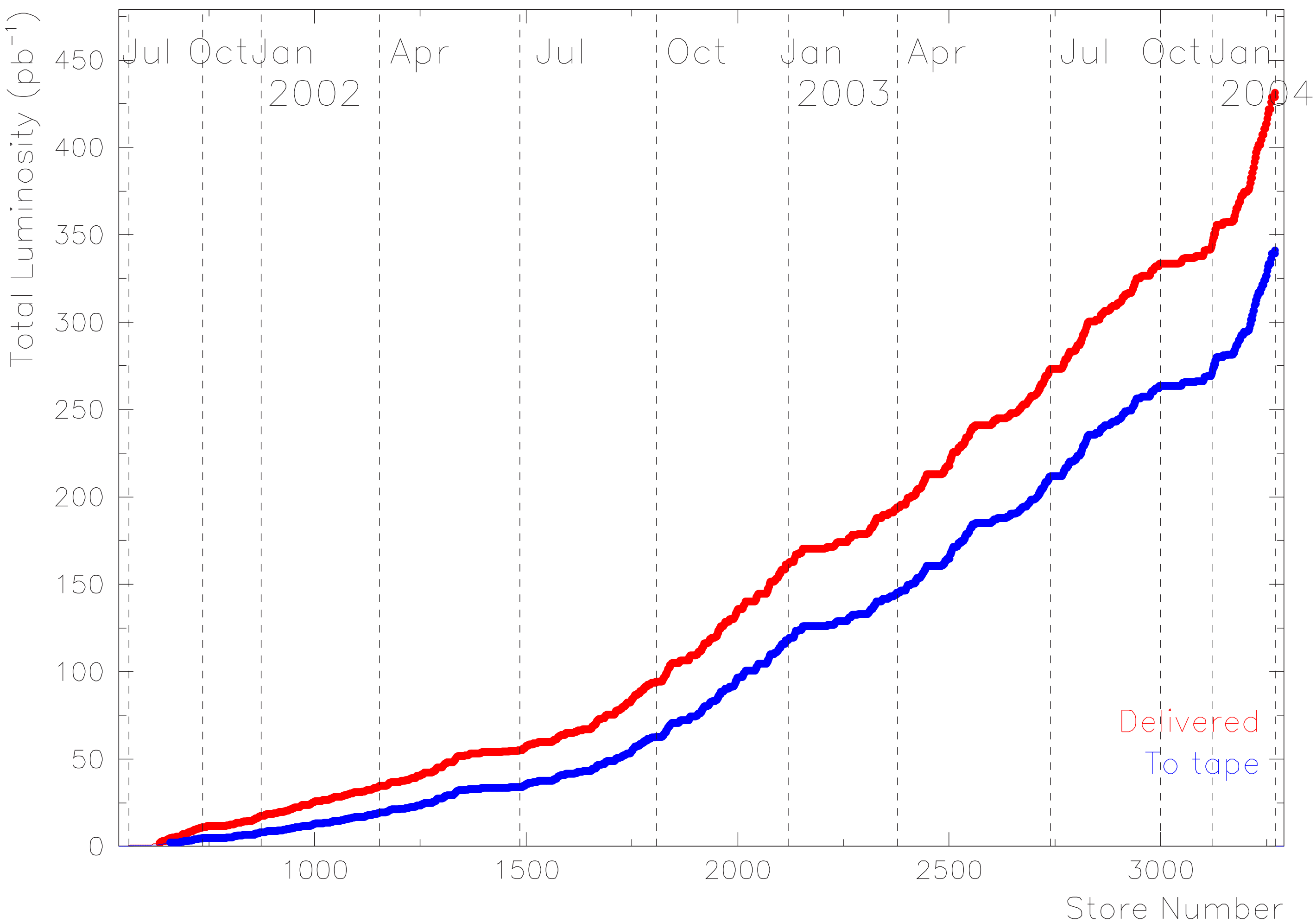
Direct



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

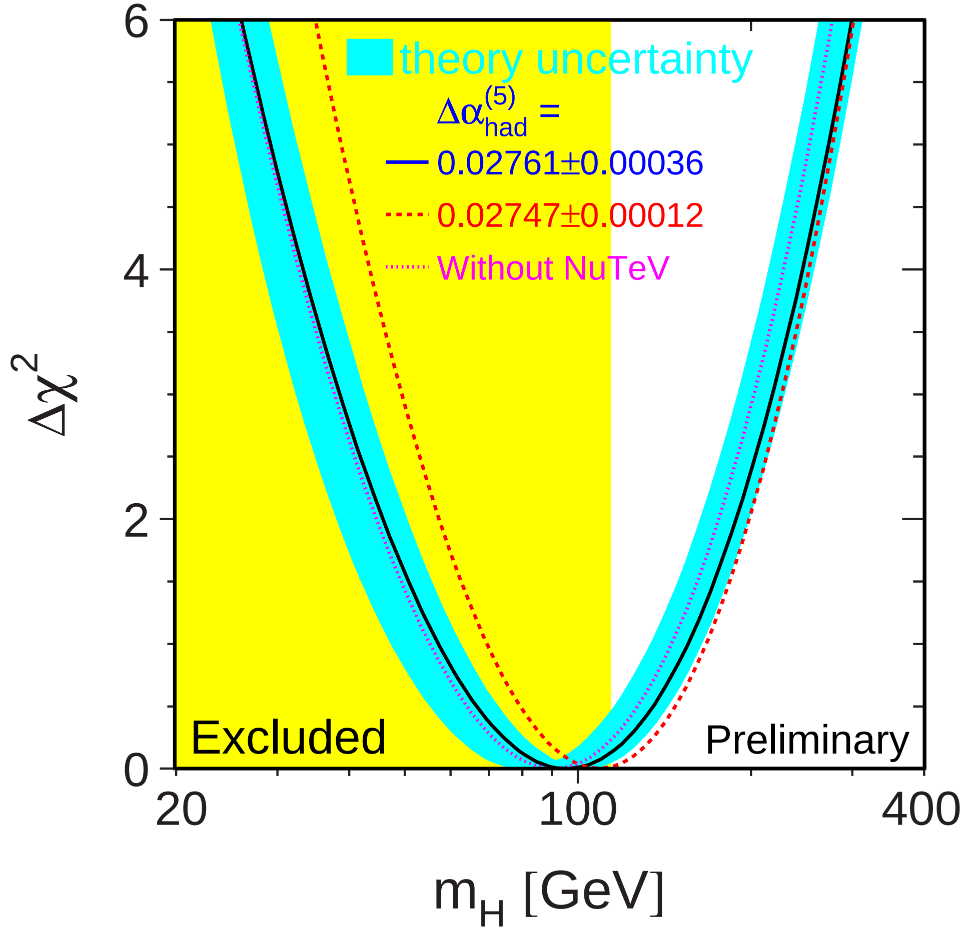
- At LEP and now the Tevatron, we could in principle make Higgs bosons directly
- Higgs will decay into heaviest kinmatically accessible particle
- Will consider mass range where $\mathrm{Br}(h \to b\bar{b}) \sim 90\%$

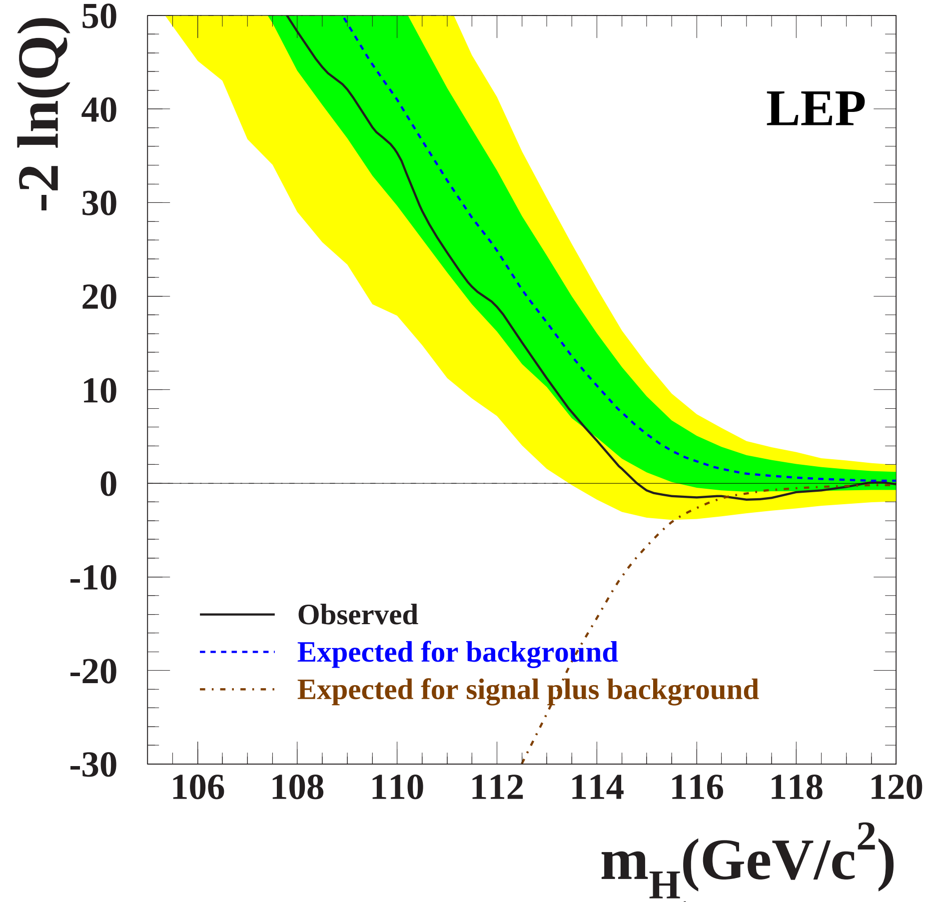
RunII Well Under Way!



- 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?

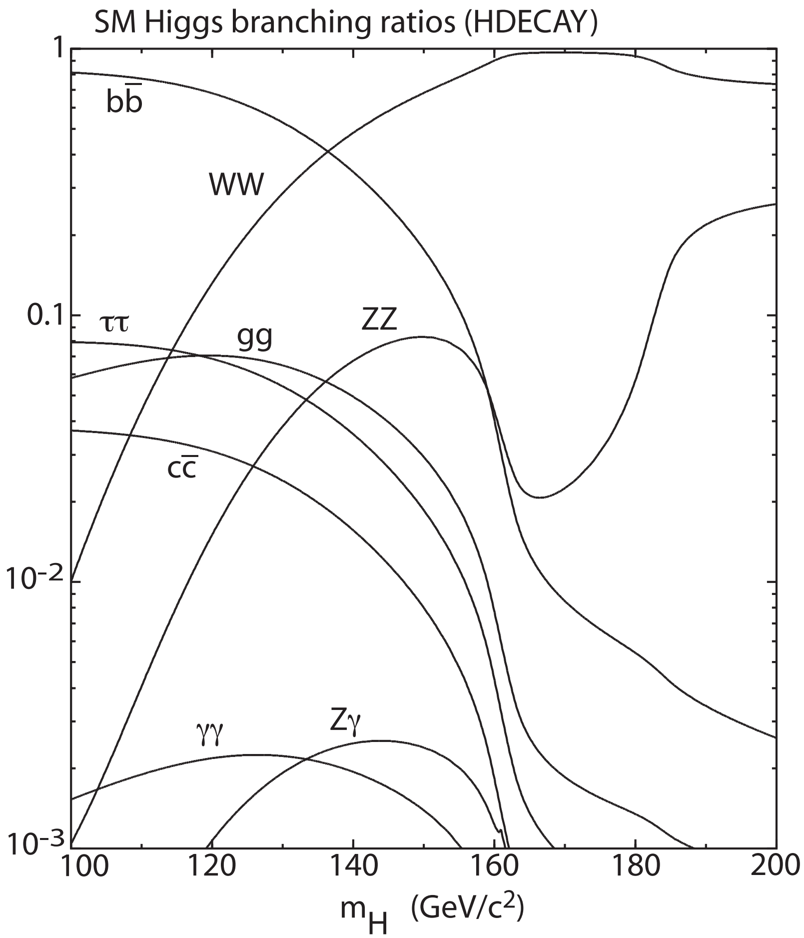
SM Higgs: Current State of Affairs

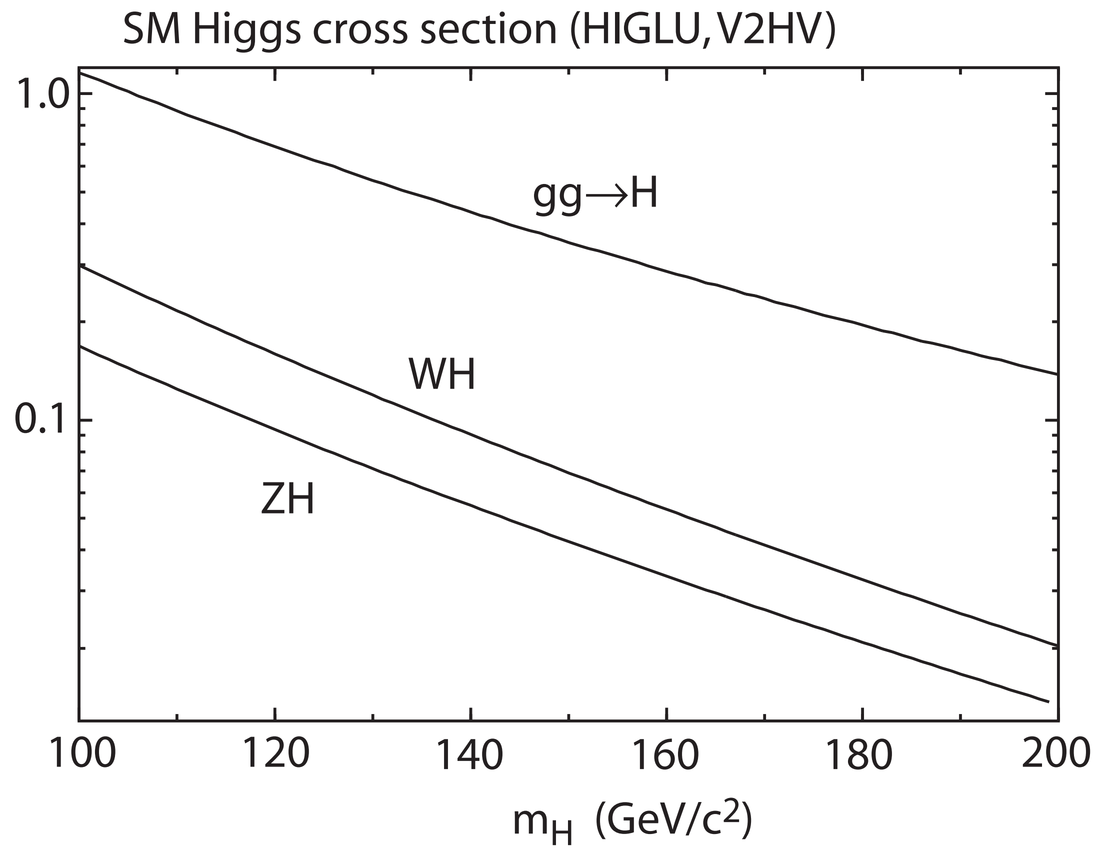




- EW Precision fits "predict" $m_H < 219$ GeV, $95\% CL$
- One set of measurements (A^b_{FB}) differ by 3σ and pull m_h fit high. But removing them leaves us with $m_h \approx 50$ GeV and $m_h \lesssim 110$ GeV $95\% CL$ (Chanowitz)
- LEP Combined search limits $m_H > 114$ GeV, $95\% CL$

SM Higgs: Mission Improbable





- Most promising SM discovery modes:
  - Associated production with Z/W
  - Followed by $W \to \ell\nu$ or $Z \to \nu\bar{\nu}$, with $H \to b\bar{b}$

- 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
  - $t\bar{t}$: $p\bar{p} \rightarrow t\bar{t} \rightarrow W^+ b W^- \bar{b}$. ~ 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

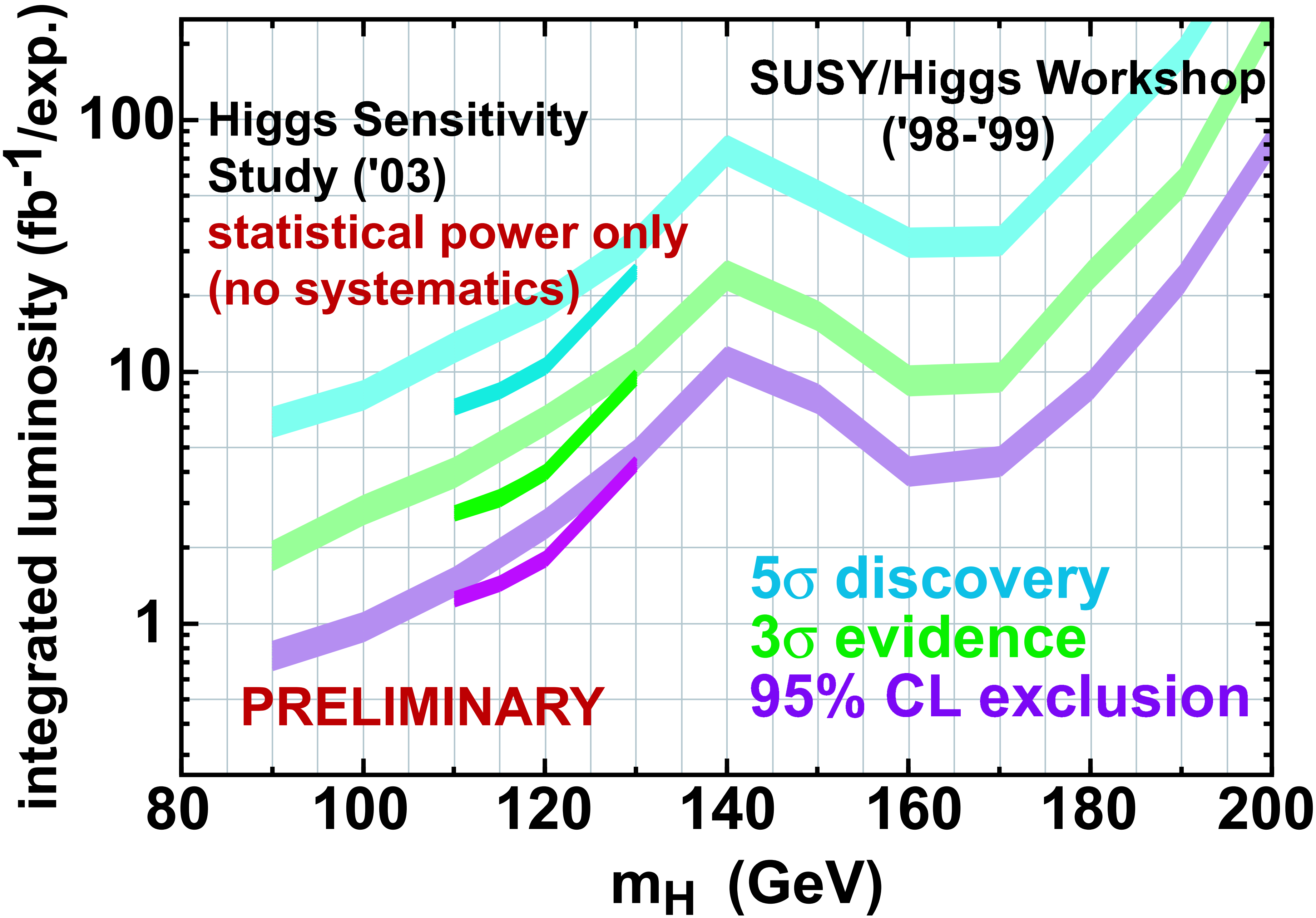
	WH (lnbb)		ZH (nnbb)	
	HSC	SHW	HSC	SHW
signal	3.7	4.6	3.5	5.5
tt	12.3	7.8	1.9	3.0
tqb/tb	6.9	5.3	1.0	5.0
Wbb/Zbb	20.9	7.7	2.9	13.8
WZ/ZZ	1.6	1.4	2.6	3.3
QCD	-	-	8.1	25.1
bkgd	42	22	16.5	50
S/÷B	0.57	0.98	0.86	0.78

mass window: 100-130 GeV

- "HSC" is new estimate with current algorithms for 1 fb^{-1} per Experiment

- Will be *very challenging*

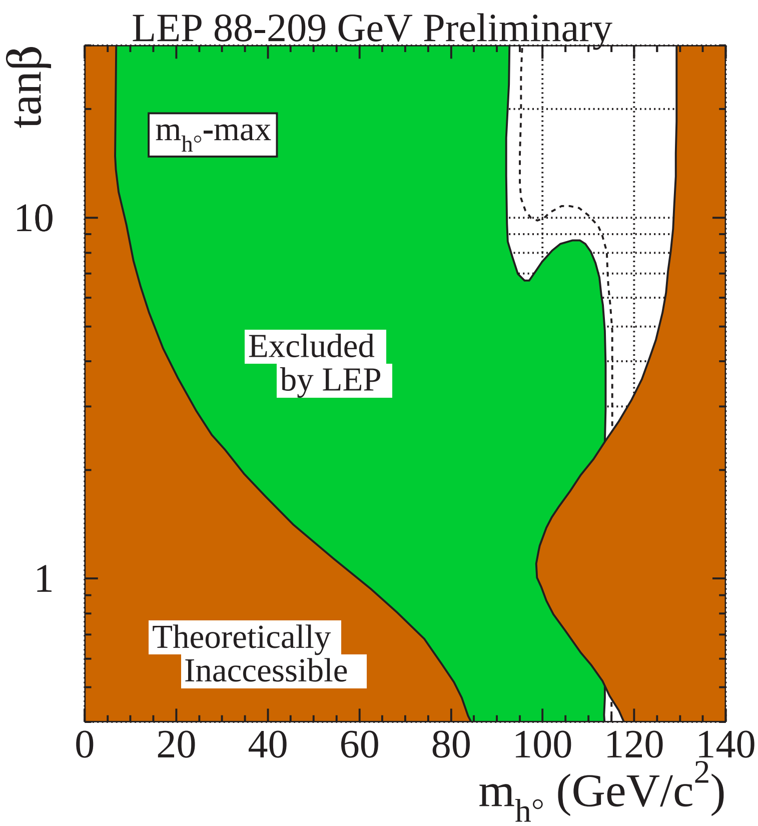
SM Higgs: Sensitivity vs Luminosity

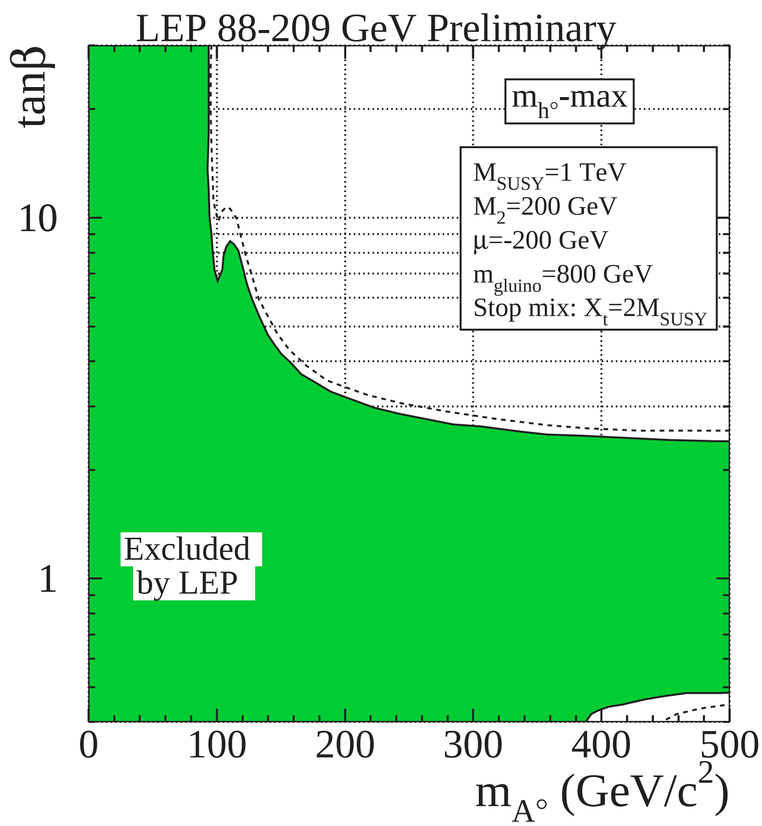


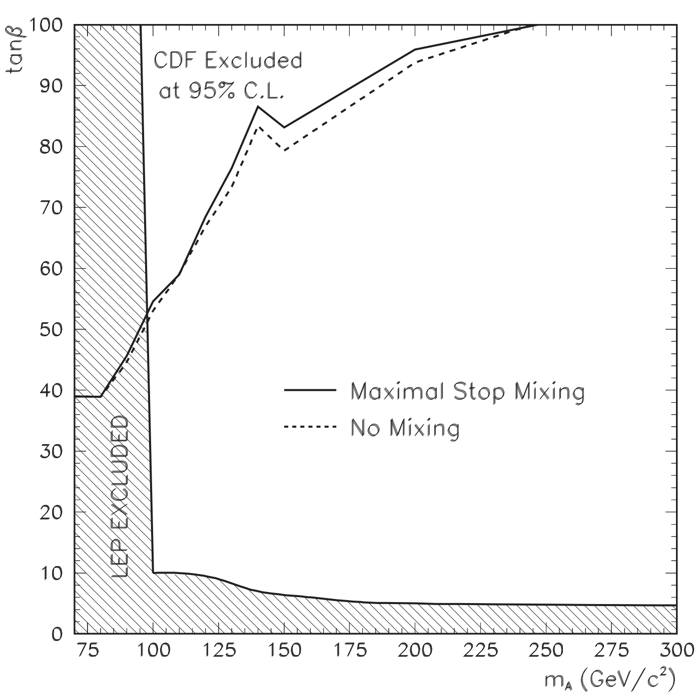
MSSM Higgs: Mission Quite Possible

- 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 Higges 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



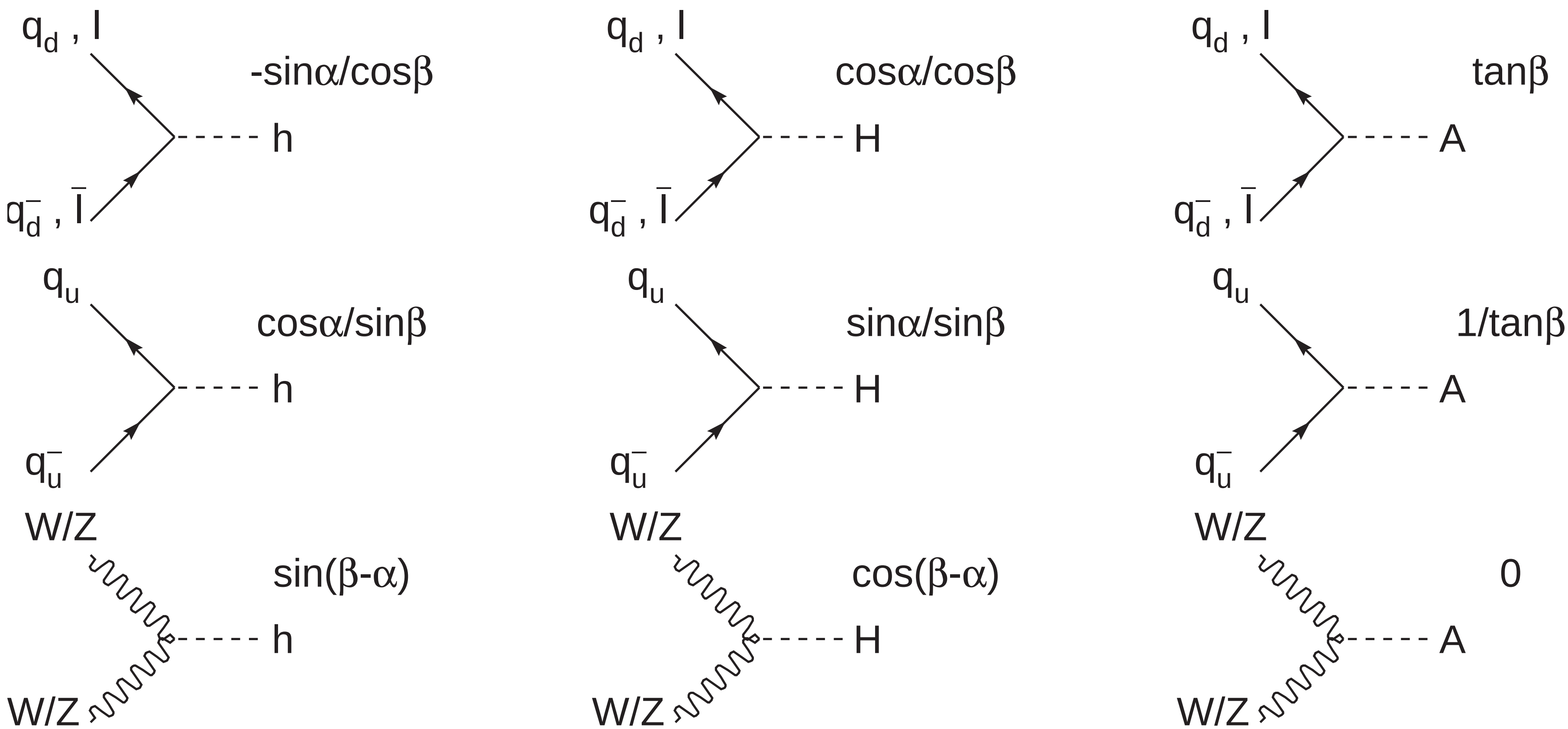




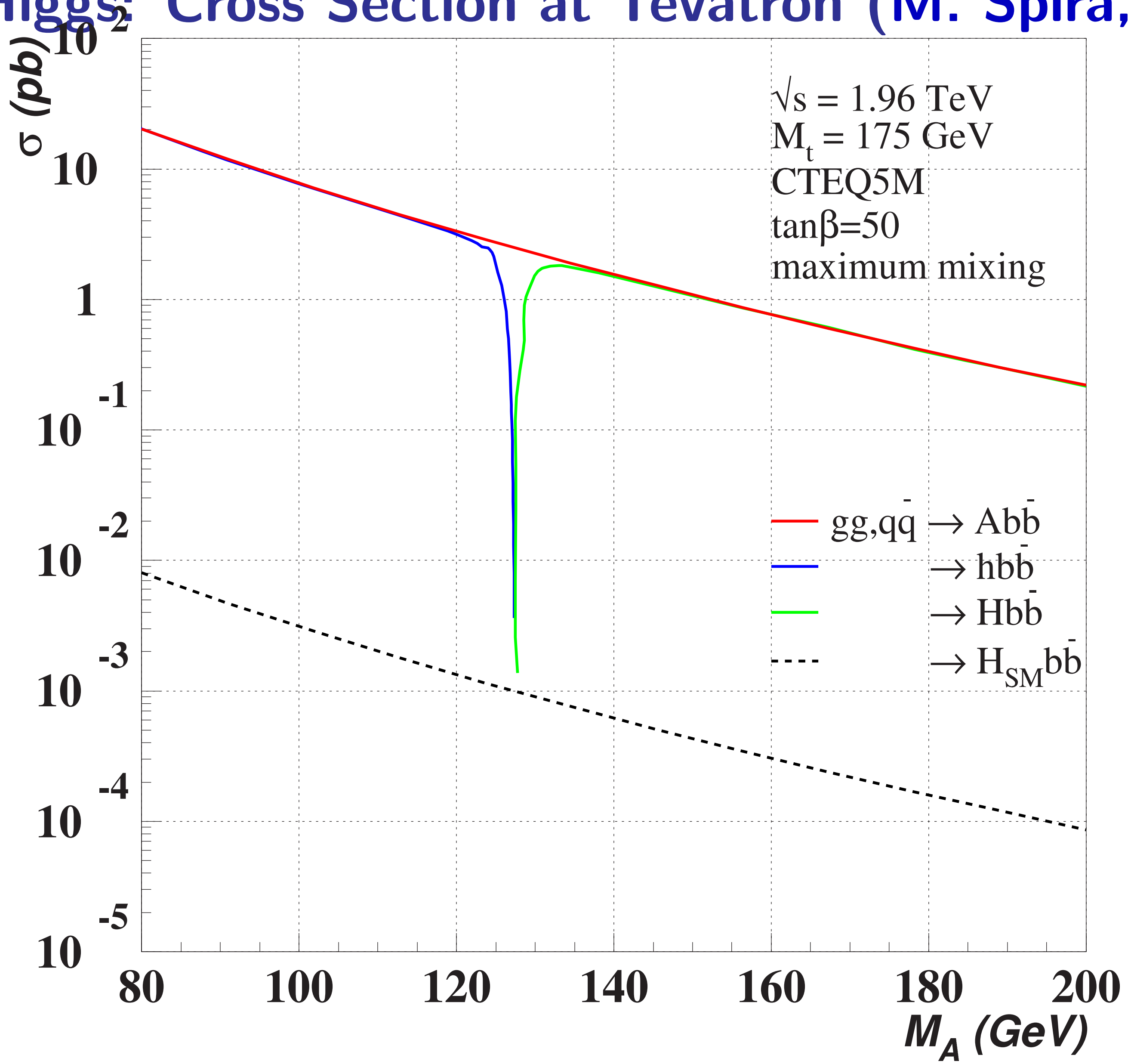
- ~Final LEP limits:
  $m_{\rm h} > 91.0$ GeV,
  $m_{\rm A} > 91.9$ GeV at $95\% CL$
- CDF RunI limits $m_{\rm h}$ and $m_{\rm A}$ for values of $\tan\beta \gtrsim 50$

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

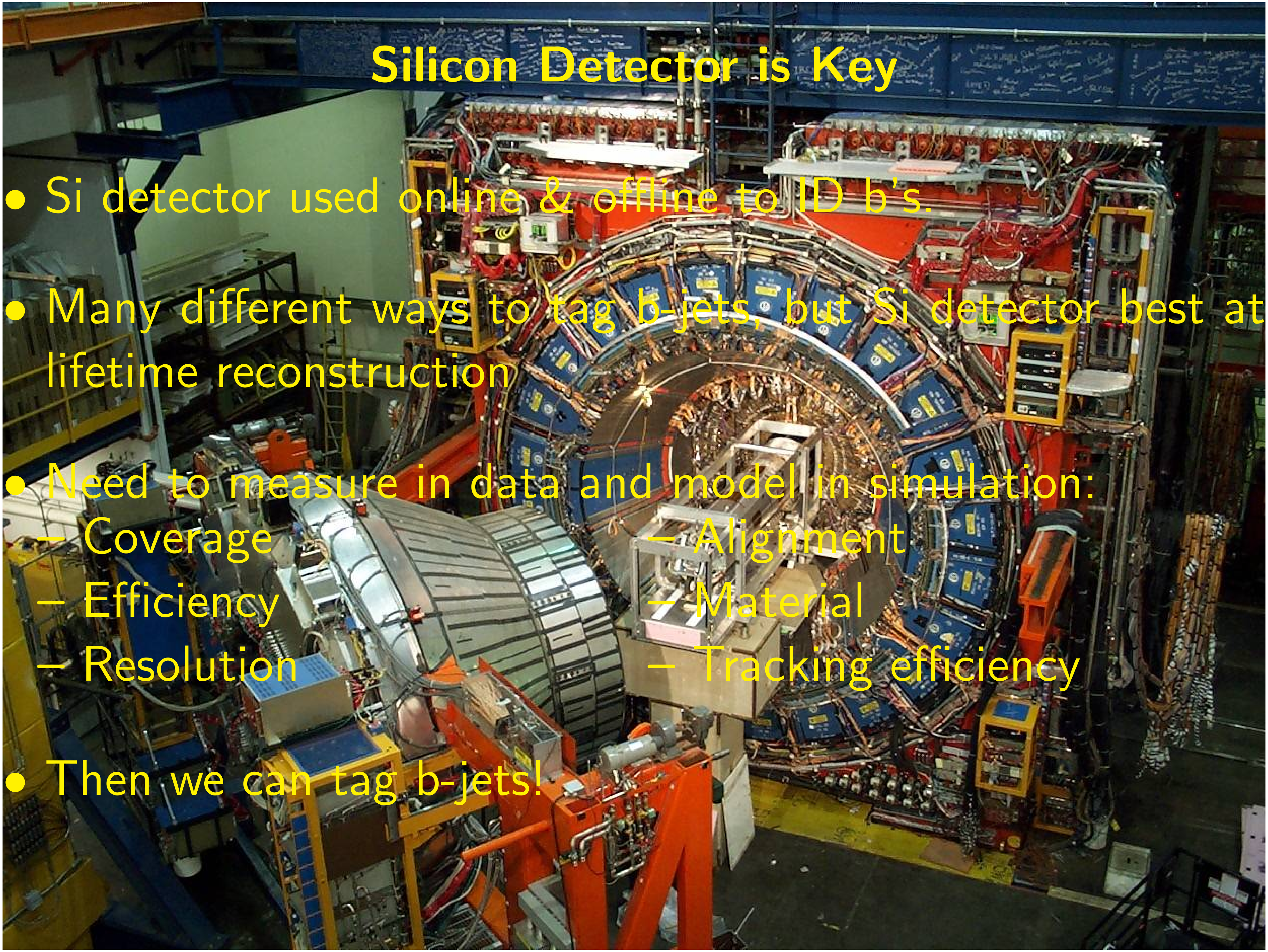
- Enhancement of $\mathrm{b\bar{b}A}$ vertex of $\tan\beta$, compared to SM

- MSSM Higgs production at TeV is complimentary to LEP $\Rightarrow$ orthogonal sensitivity in $(\tan\beta, m_{\mathrm{A}})$ plane

- Branching into b's remains large: $\mathrm{A/h \rightarrow b\bar{b}} \sim 85 - 90\%$, $\mathrm{A/h} \rightarrow \tau^{+}\tau^{-} \sim 8 - 10\%$

- Game is to trigger on and reconstruct multijet events containing multiple b-jets

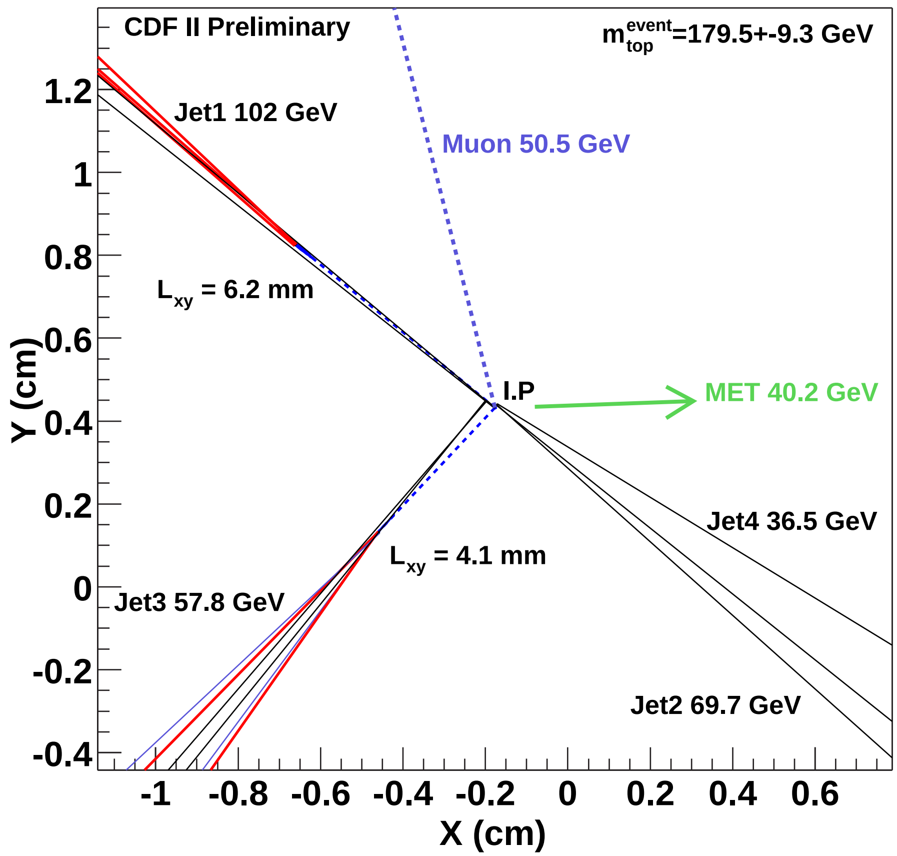
- Understanding and using the silicon detector is crucial for trigger and reconstruction



Silicon Detector is Key

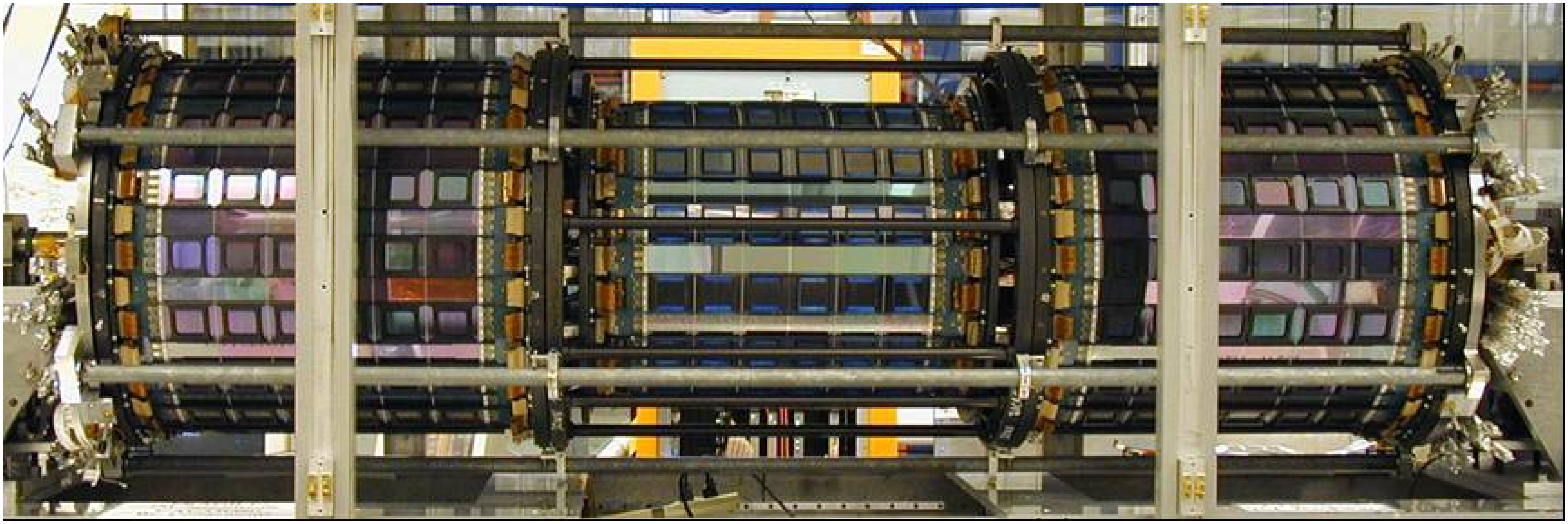
- Si detector used online & offline to ID b's.
- Many different ways to tag b-jets, but Si detector best at lifetime reconstruction
- Need to measure in data and model in simulation:
  - Coverage
  - Efficiency
  - Resolution
  - Alignment
  - Material
  - Tracking efficiency
- Then we can tag b-jets!

General Idea of B-Tagging



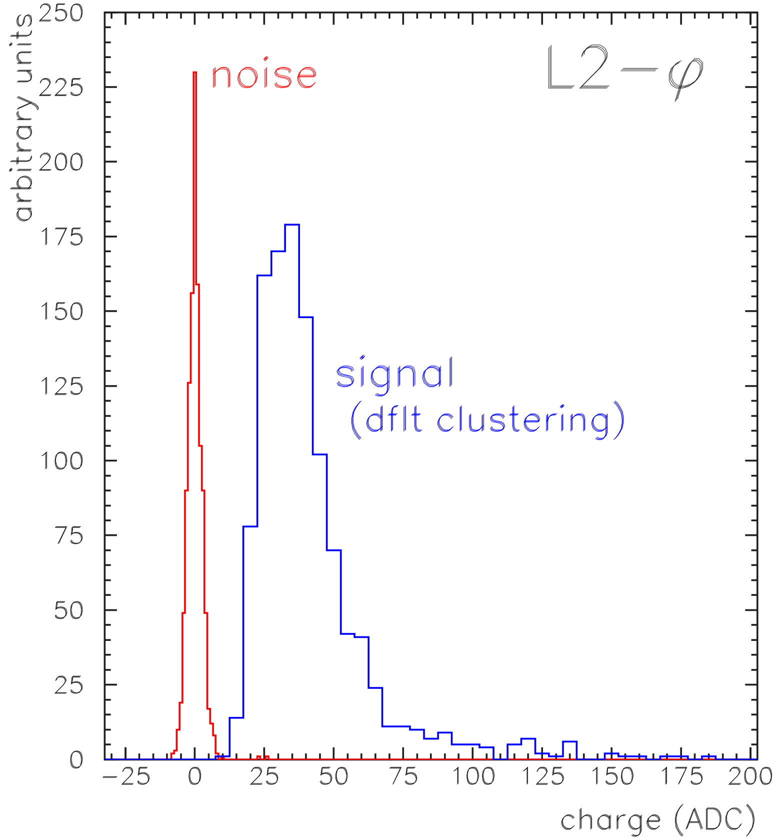
- Average b hadron lifetime is 1.56 ps.
- Most lighter flavored hadrons either have no discernible lifetime or are very long lived (K_S^0,K_L^0,Λ^0).
- Charm and tau lifetimes are typically less than half as long as b lifetime.
- At TeV the hadrons are highly boosted $\Rightarrow$ b decay lengths $\mathcal{O}(3\text{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

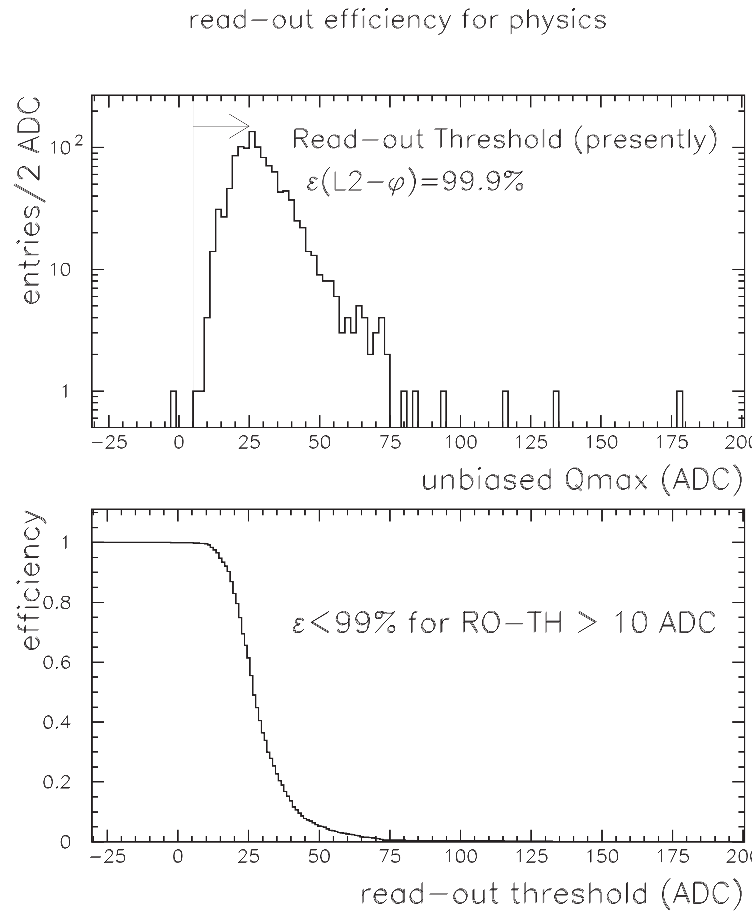
Silicon Detector is Key



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

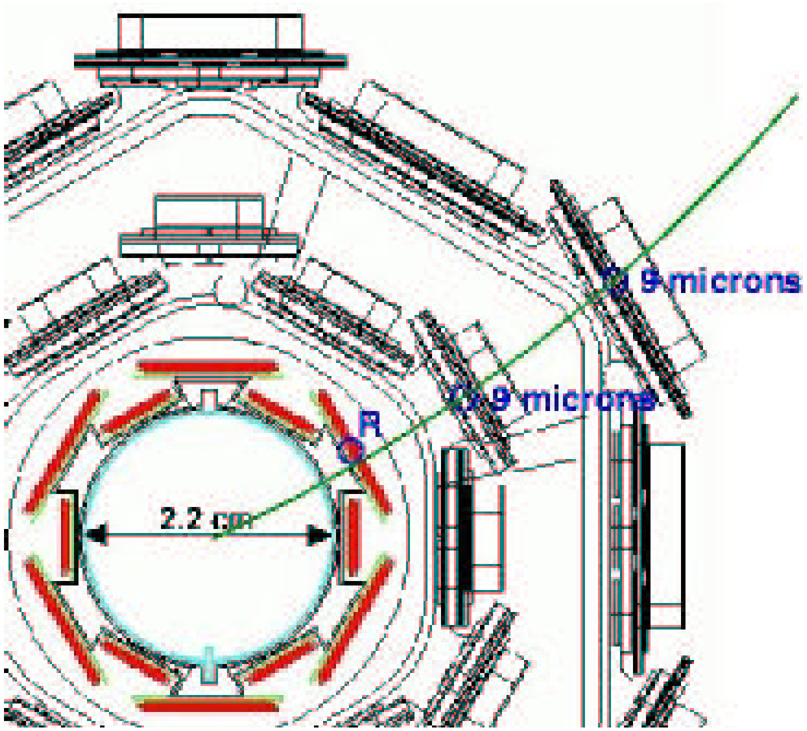
High Signal-to-Noise Device

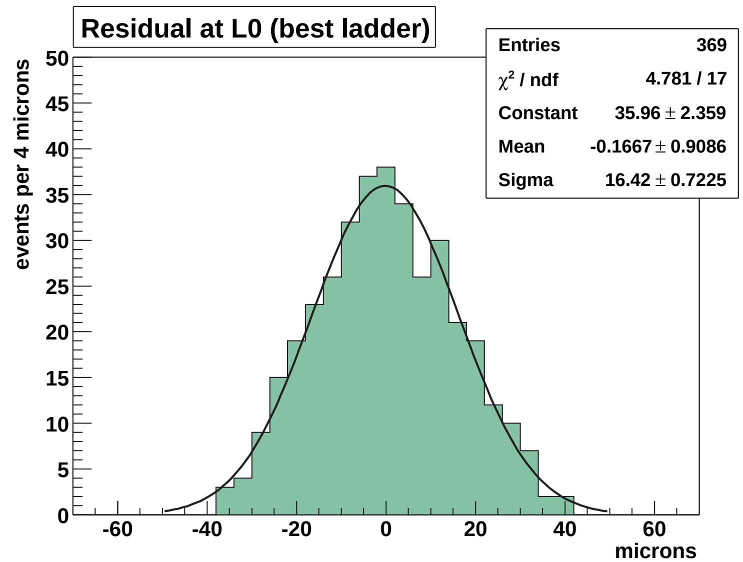




- Operation optimized for high S/N & eff
- $> 99\%$ signal readout eff
- S/N of SVX axial 12:1, stereo 10:1
- With $< 1\%$ noise occupancy

Silicon Tracking Resolution From High P_T μ

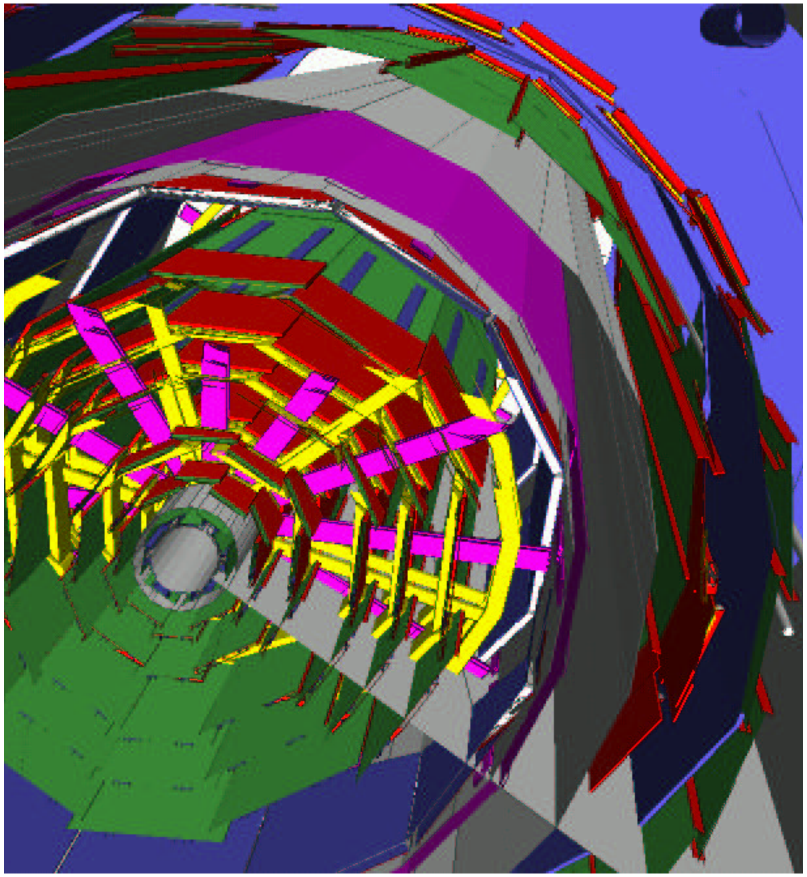


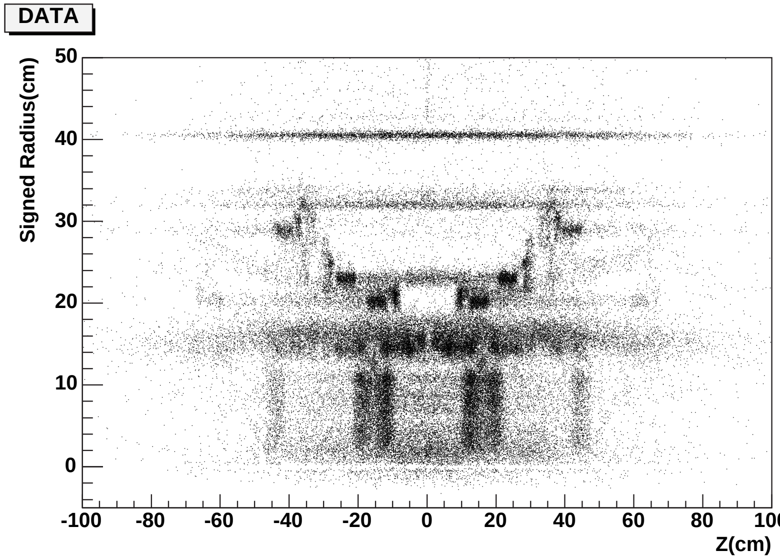


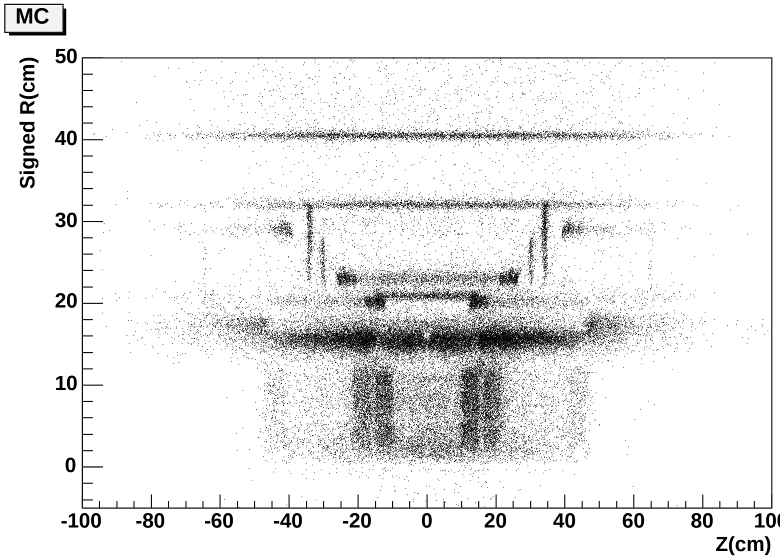
	Measured resolution in μm		
Cluster Width	L00	SVX Axial L1-L5	SVX 90° L1,4
1 strip	18.4 ± 0.3	13.6 ± 0.3	29.5 ± 0.5
2 strips	10.1 ± 1.9	9.5 ± 0.1	23.0 ± 0.3
3 strips	17.2 ± 1.8	13.4 ± 0.2	34.3 ± 0.8
4+ strips	23.5 ± 2.8	18.7 ± 0.4	64.3 ± 1.8

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

Silicon Material Map in Reconstruction and Simulation

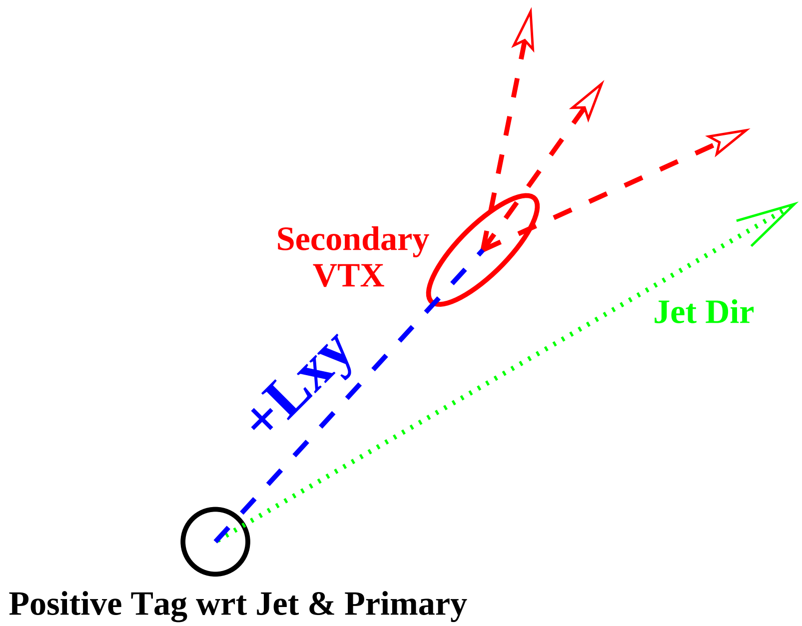


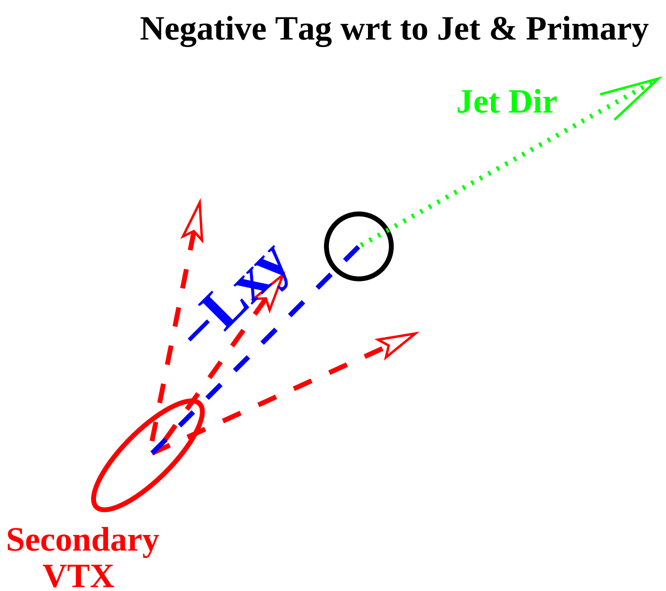




- Accounting for all material allows precise knowledge of energy loss and mass reconstruction
- Helps simulation get false lifetime from conversions correct

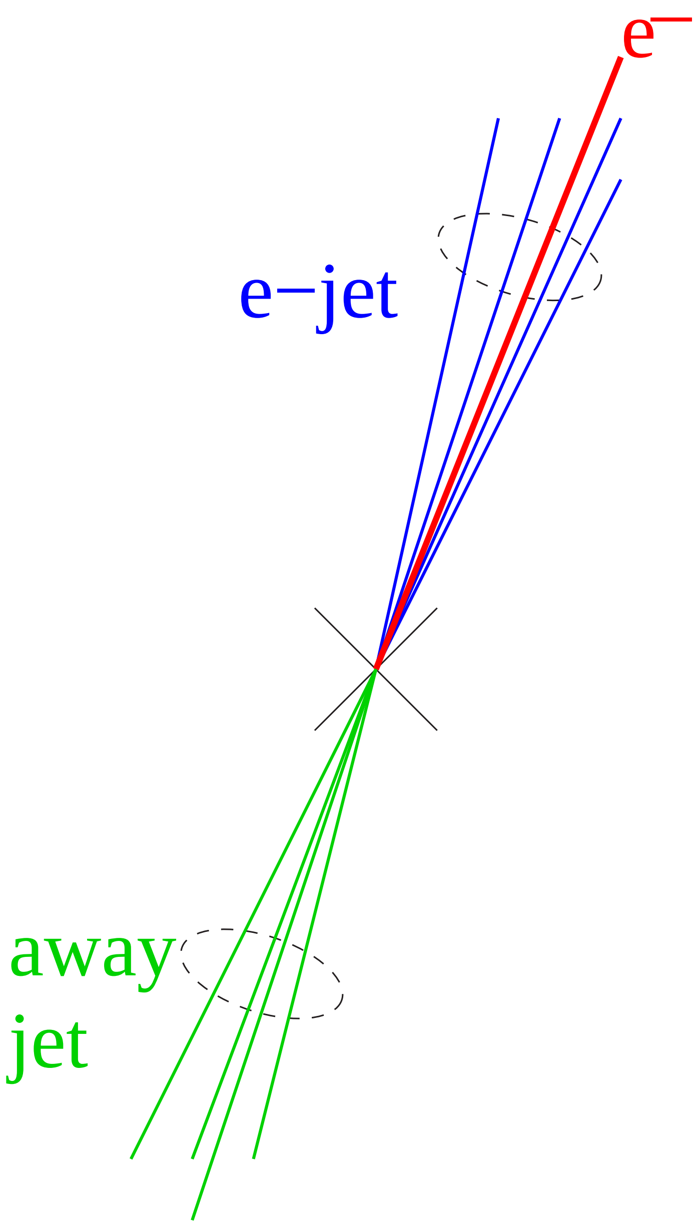
B-Tagging





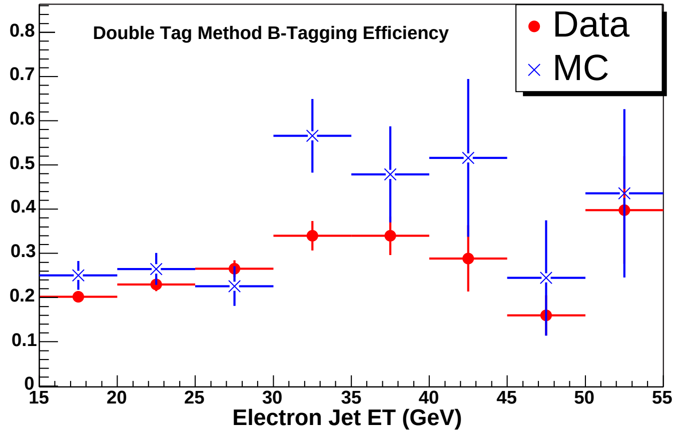
- Displaced vertexes: All combinations of at least 2 good tracks
- Jet is tagged as b-jet if $L_{xy}/\sigma_{xy} > 3$ (typical $\sigma_{xy} \sim 150\ \mu\text{m}$)
- Measure eff and fake rate in incl lepton & generic jet data
- (Looser tagger used in Higgs analysis: SecVtx falling back to 1% CL of impact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

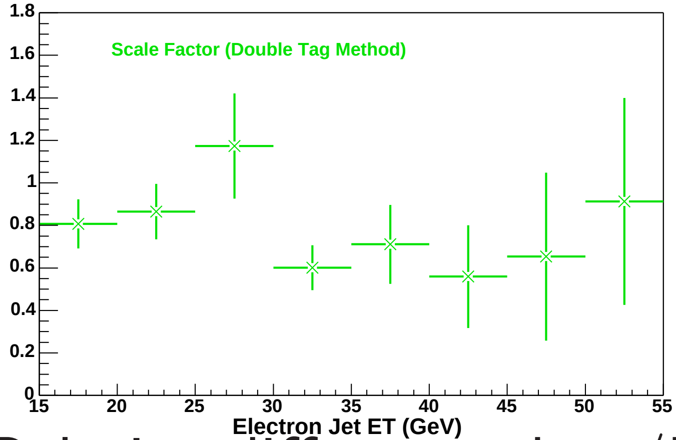
Measuring B-Tag Efficiency



- 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 sensistive to knowledge of heavy-flavor fraction of e-jet

High-$\mathrm{P_t}$ B-Tagging: Efficiency



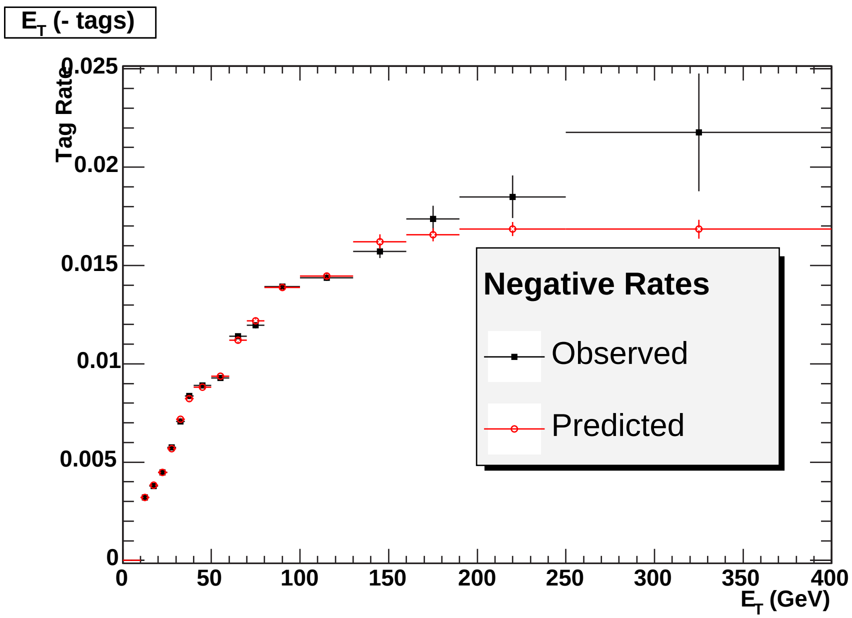


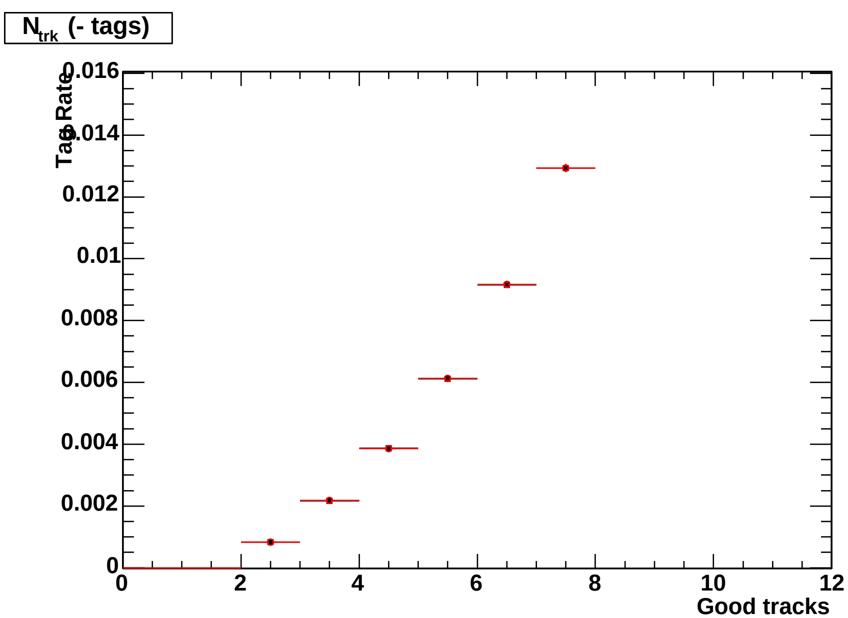
- Need 2 things about sample of jets to measure eff:
  1. Net tag rate, $r = (N_{\mathrm{pos}} - N_{\mathrm{neg}})/N_{\mathrm{tot}}$
  2. Frac of jets containing HF, F_{B}
- Eff is then $\varepsilon = r/F_{\mathrm{B}}$
- Measure r^{a} and $F_{\mathrm{B}}^{\mathrm{a}}$ in e-jets when away jet is tagged
- 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

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

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

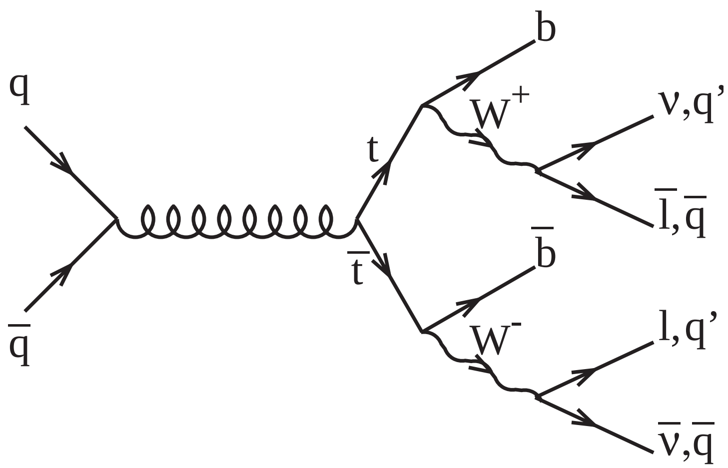
High-$\mathrm{P_t}$ B-Tagging: Fake Rate

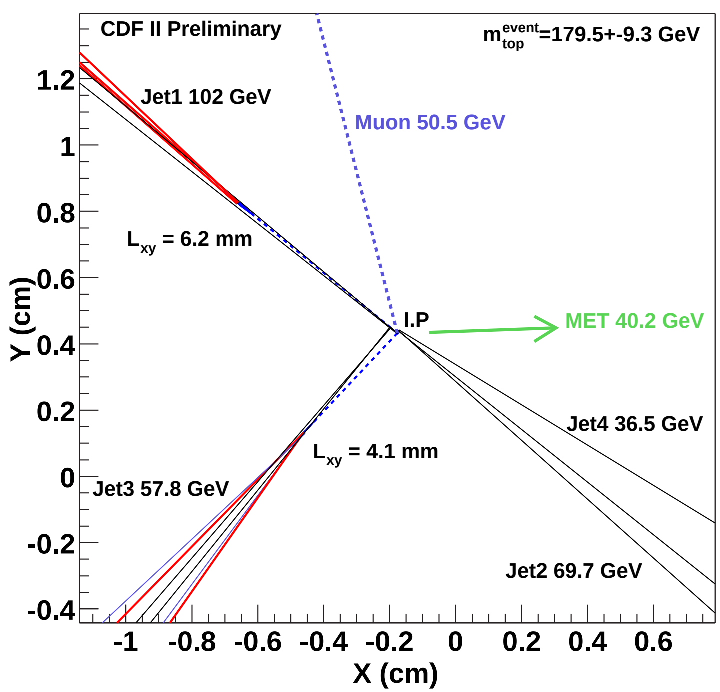




- Can't rely on absolute MC rate for tagging light partons
- Use negative tag rate in inclusive jet sample to determine "fake rate"
- Parameterize rate as function of 5 observables
  - E_T: Vtx method better for large E_T
  - $\sum E_T^{\mathrm{jets}}$: Removes some sample dependence
  - $N_{\mathrm{good}}^{\mathrm{trk}}$: 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





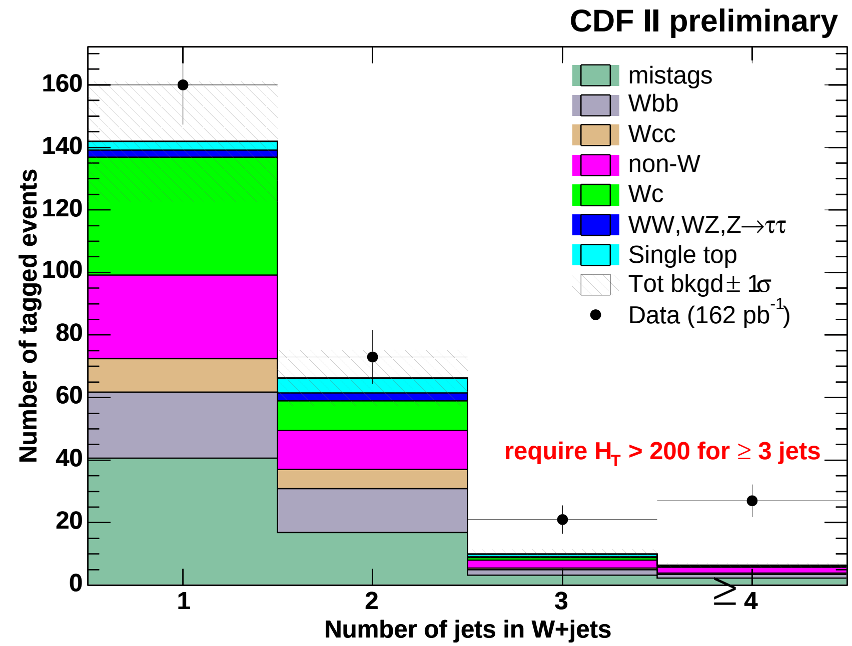
- For the purposes of the Higgs search, the top quark is bkg, but more importantly presents a known high P_T physical process involving b-jets

- 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, cosmics
  - 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

- $\sigma_{t\bar{t}} = 5.6 \pm 1.2(\mathrm{stat}) \pm 0.8(\mathrm{syst})\mathrm{pb}$

- $\sigma_{t\bar{t}}(\mathrm{NLO}) = 6.7^{+0.71}_{-0.88}$ pb (Cacciari *et al.*)

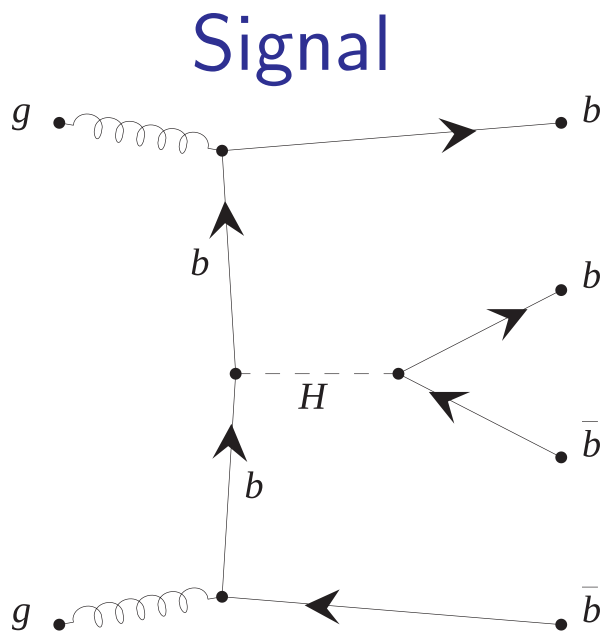
Now on towards the Higgs

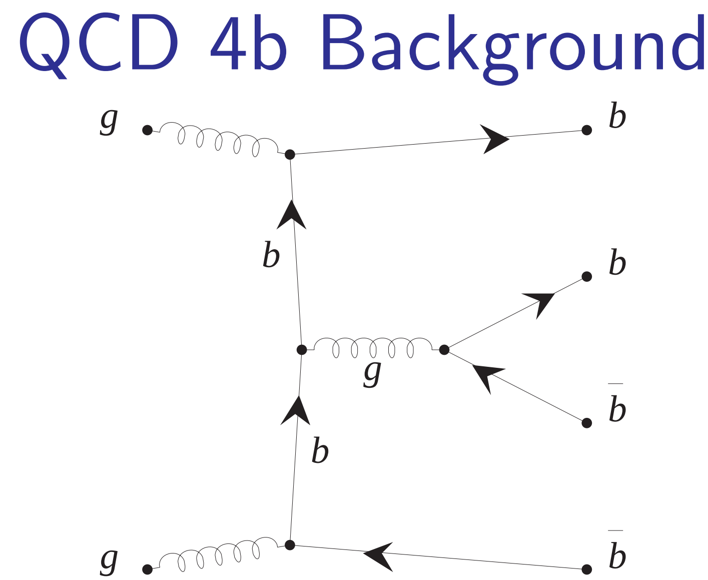
- Si detector tuned up
- B-Tag implemented
- Jets+Lepton top cross section reestablished
- *Now let's see what has to be done for MSSM Higgs search*

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

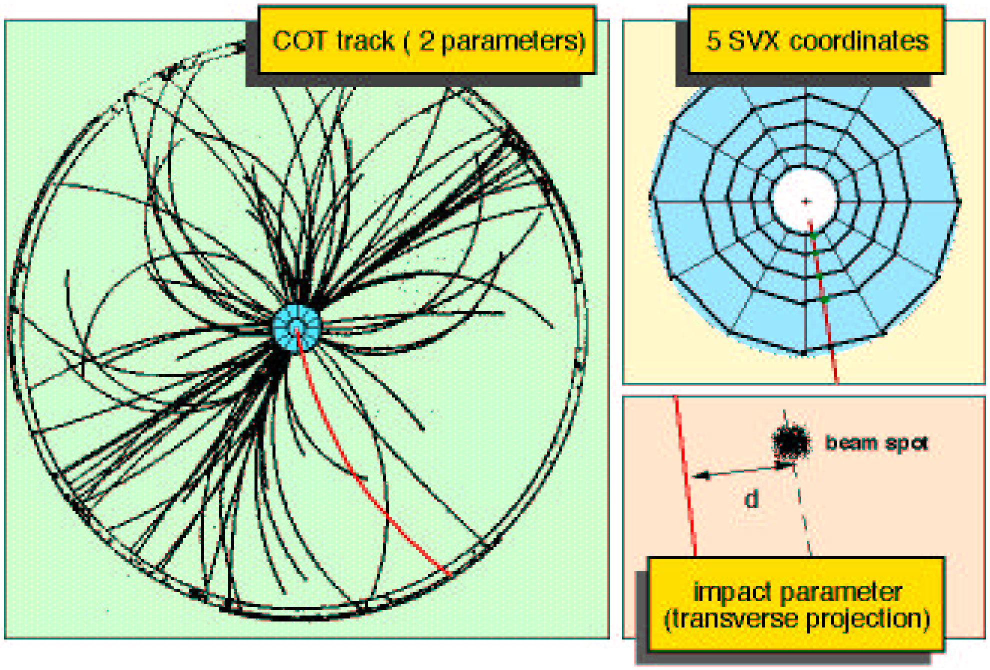
Triggering on 4b Events with CAL+SVT

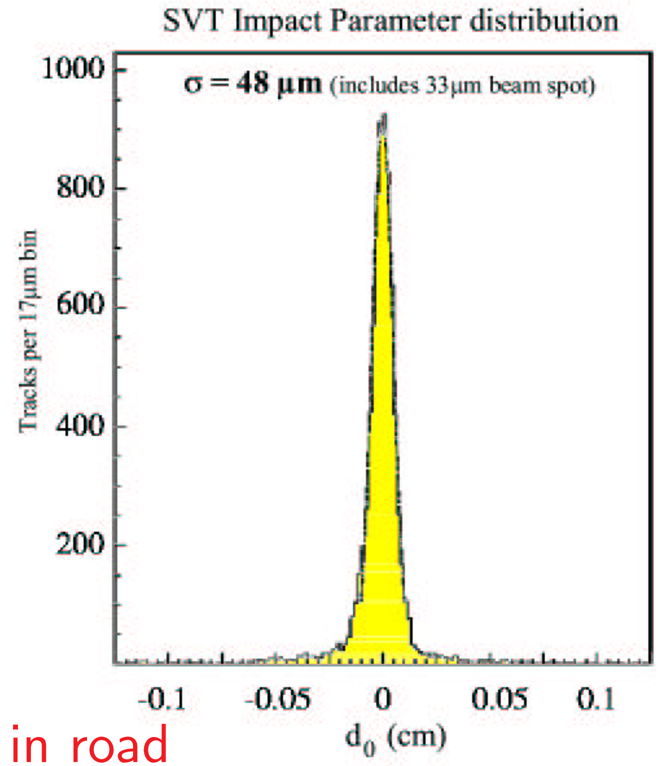




- Signature: 4 b-jets in final state with lots of visible energy
- Dominant background: QCD processes giving 4 real b-jets in final state
- Trigger:
  - 3 jets with $E_T > 10$ GeV
  - $\sum E_T > 100$ GeV
  - Heavy flavor present (use SVT)

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 $= 35\ \mu\mathrm{m} \oplus 33\ \mu\mathrm{m}(\mathrm{beam})$ compares to offline resolution quite well
- System is ∼deadtimeless: $25\mu\mathrm{sec}/\mathrm{event}$ 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)

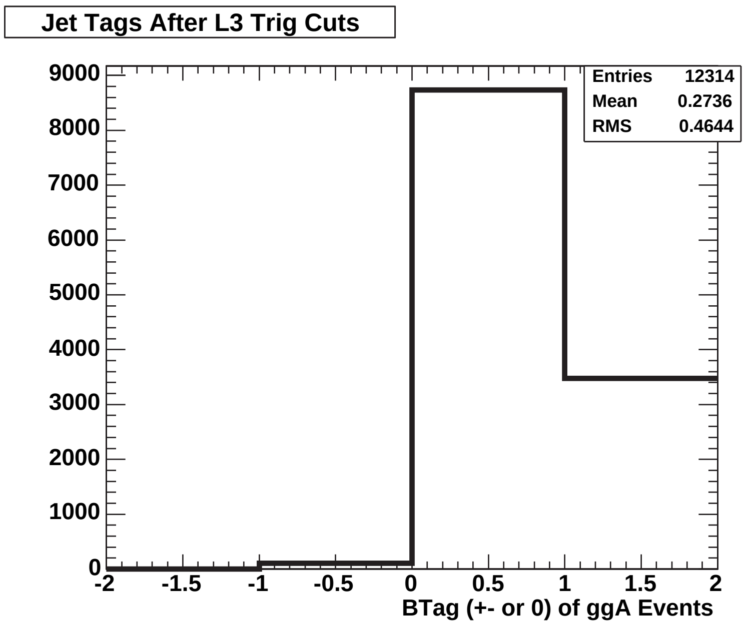
- Using background dominated data to study fake tags

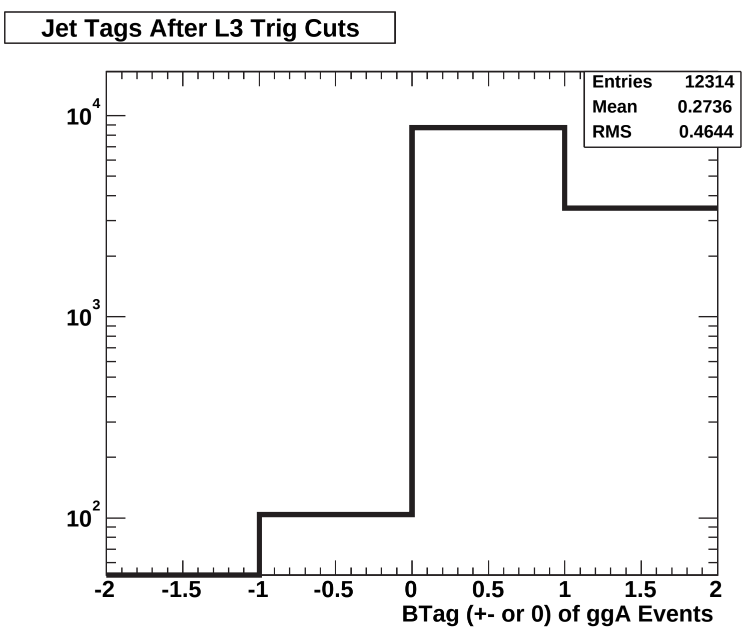
- Haven't used data to measure signal (blinded), but made first estimate of expected signal and background rates

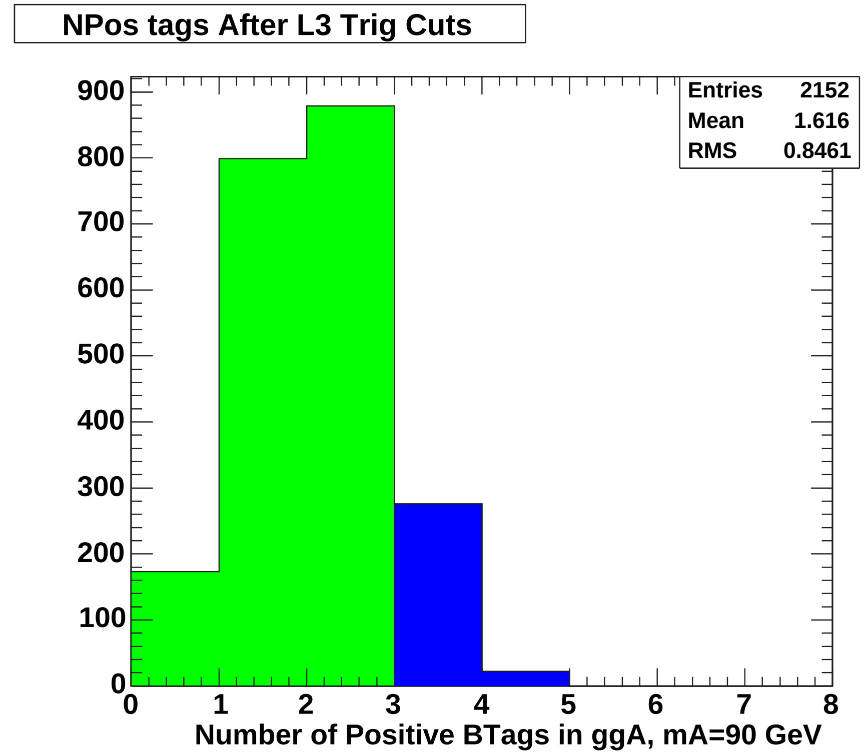
- Comparable to previous study (J. Valls) of expected rates $\Rightarrow$ Use as baseline for expected sensitivity

- Everything is very preliminary

Estimated Efficiencies on Signal

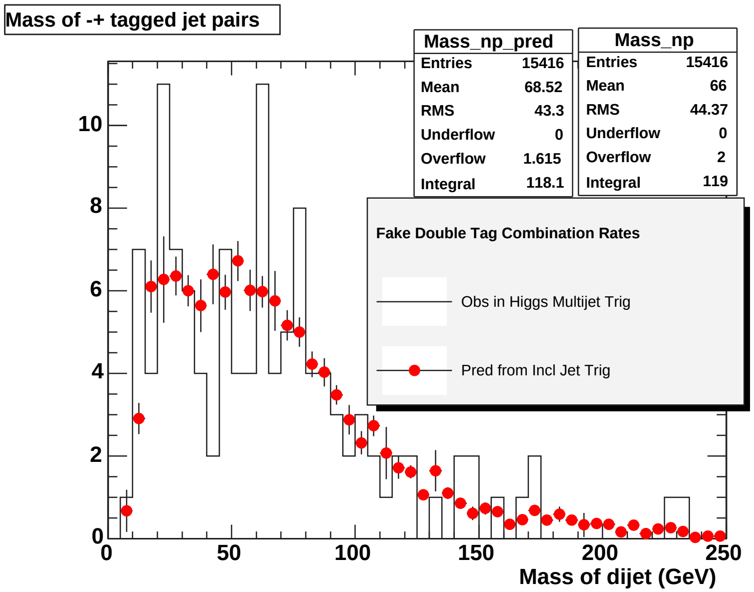


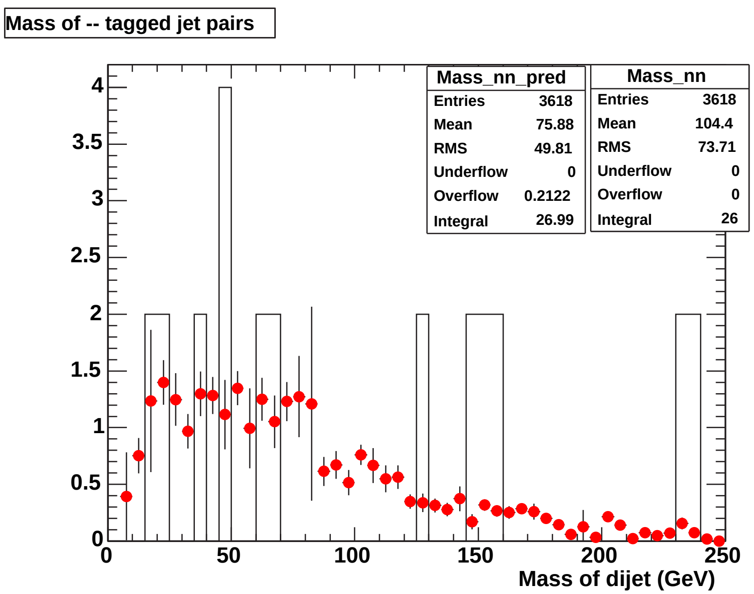




	$m_{\rm A} = 90$ GeV, $\tan\beta = 50$	
Requirement	$gg \to bbA$	$qq \to bbA$
Passes L1&L2&L3	1.5%	37.7%
2+ offline b-tags	32%	47.5%
3+ offline b-tags	9.5%	18.5%
Total eff	0.14%	7.0%
gg+qq eff	0.2%	

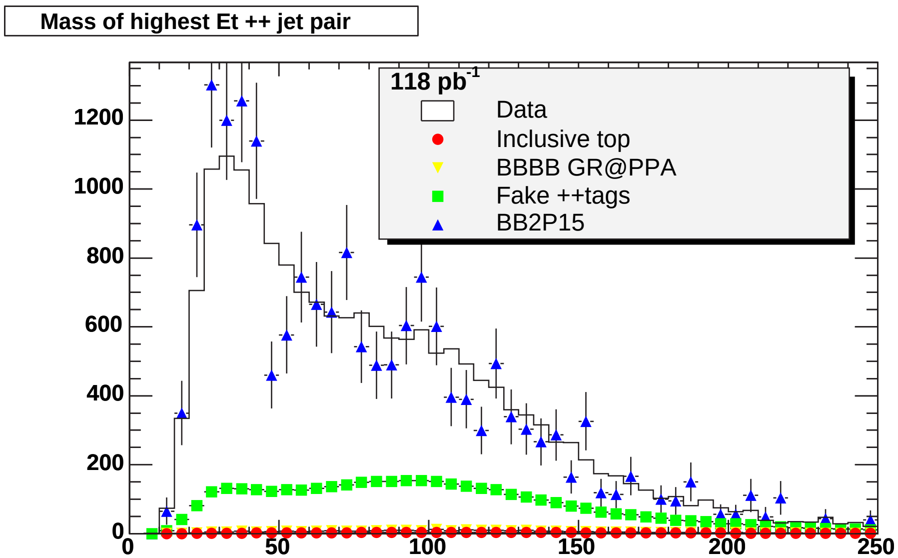
Estimate Fake Tags Like Top Analysis: Fake Matrix

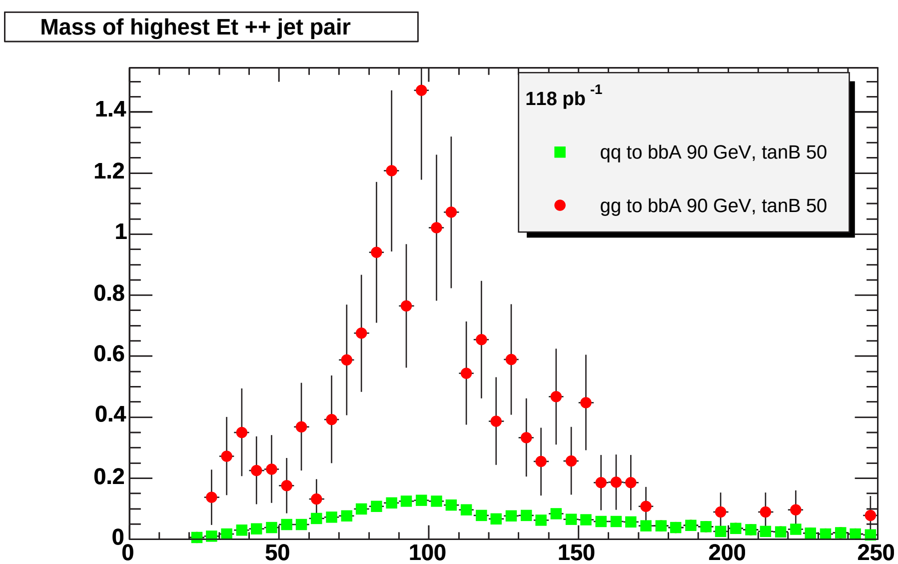




- n_{+-}:
  - Obs 121
  - Pred 119.7 ± 3.6
  - Ratio: 1.01 ± 0.09
- n_{--}:
  - Obs $(26)/2$
  - Pred $(27.2 \pm 1.6)/2$
  - Ratio: 0.96 ± 0.19
- Fake multitag prediction seems to work (for dijet masses above ~ 50 GeV)

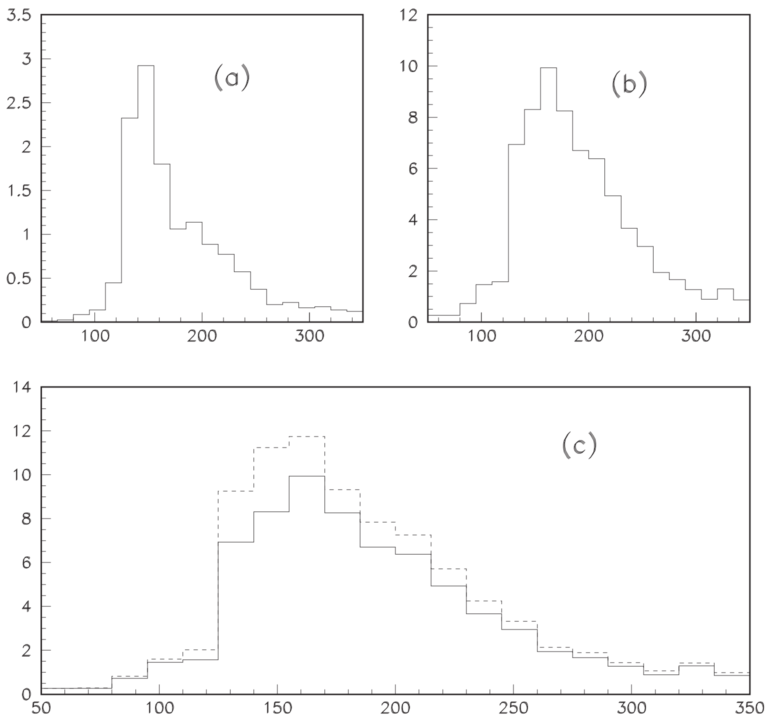
Example of Fitting QCD Bkg from Data





- 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



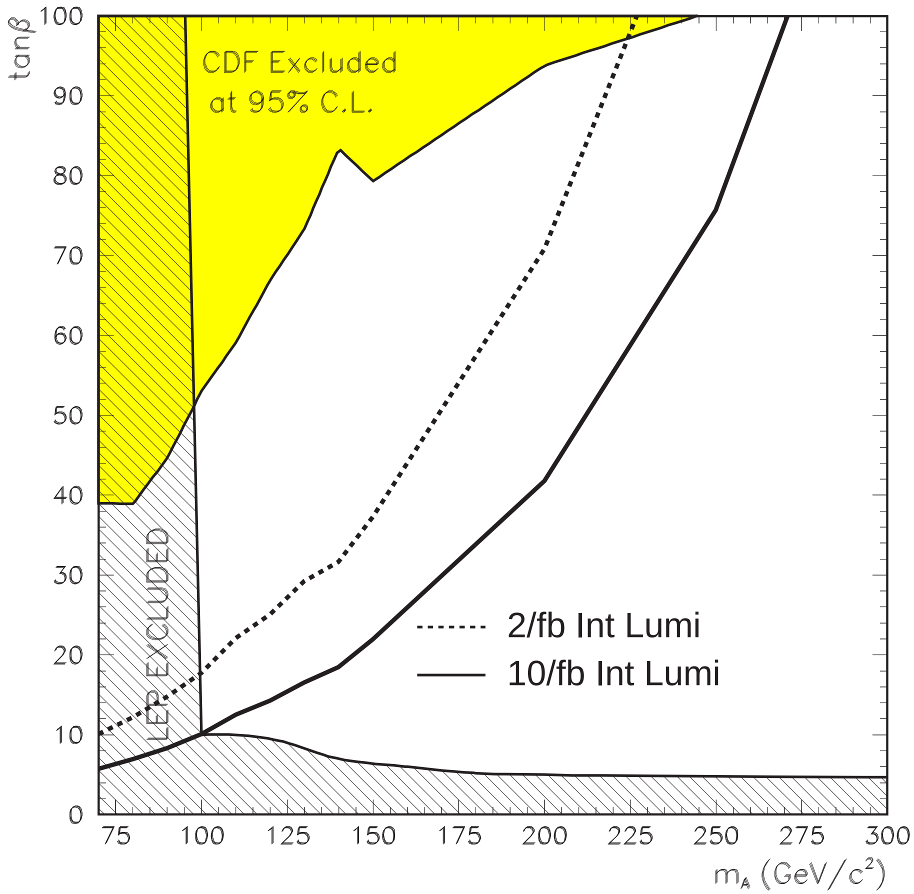
- After the trigger, require triple b-tag
- Reconstruct double-tagged dijet mass: $\sim 15\%$ resolution on signal
- Very little difference between signal (a) and bkg (b) in dijet spectrum, essentially a counting experiment
- (c) signal+bkg for $m_{\mathrm{A}} = 130$, $\tan\beta = 40$ for 1 fb^{-1}

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

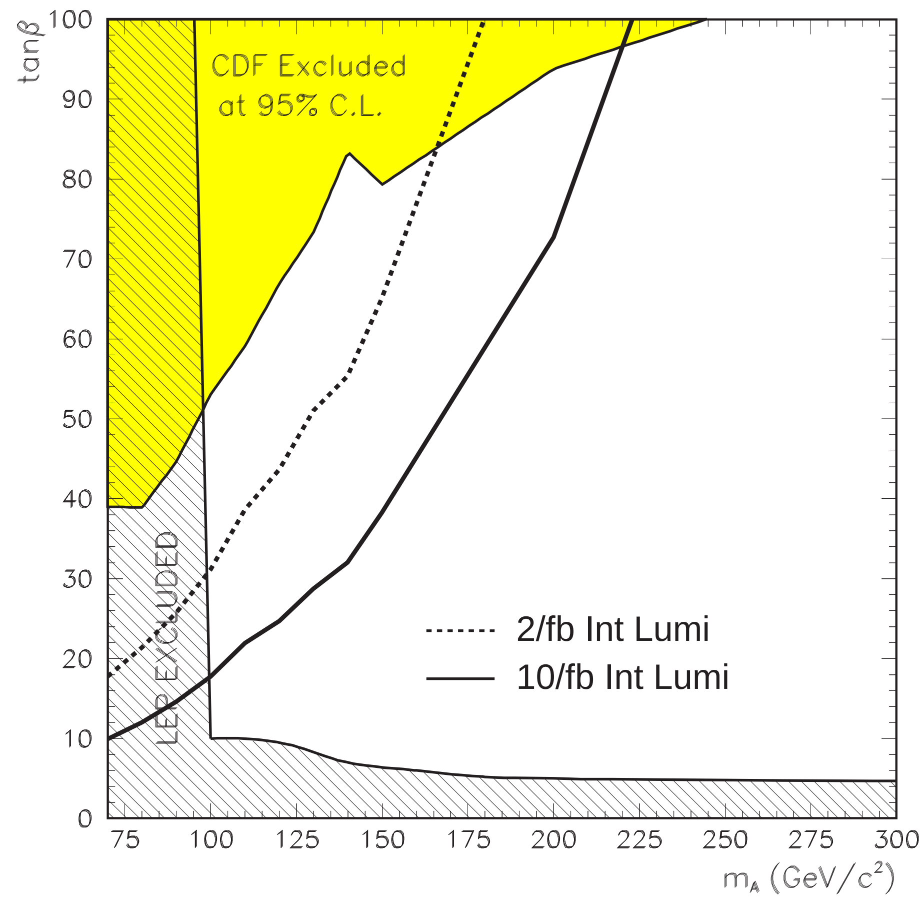
m_{A} GeV	signal at $\tan\beta = 40$	$\mathrm{QCD}_{\mathrm{heavy}}$	$\mathrm{QCD}_{\mathrm{fakes}}$	top	other	total
90	62.4 ± 1.5	56 ± 12	12 ± 10	13.4 ± 3.4	6.6 ± 1.7	88 ± 16
130	13.7 ± 0.5	45 ± 11	7 ± 5	12.2 ± 3.2	3.4 ± 1.4	68 ± 13

Outlook

95% CL Exclusion



5σ Discovery



Summary

- Should be able to exclude SM Higgs to ~ 120 GeV
- Have $\sim 200\ \mathrm{pb}^{-1}$ 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 $m_{\mathrm{A}} = 90$ 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 $\mathrm{gg} \rightarrow \mathrm{b\bar{b}A/h} \rightarrow \mathrm{b\bar{b}b\bar{b}}$

- Implement more efficient trigger

- Combined search
  - Willinbrock predicts $\mathrm{gg} \rightarrow \mathrm{bA} \rightarrow \mathrm{bb\bar{b}}$ is ~ 10 times bigger than 4b final state. Measure similar process $\mathrm{p\bar{p}} \rightarrow Zb$ first.
  - $\mathrm{b\bar{b}}\tau\tau$ 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 sensistivity

- Combine with other SUSY searches, esp $B_s \rightarrow \mu^+\mu^-$ for *global MSSM search*

- MSSM Higgs search seems quite promising

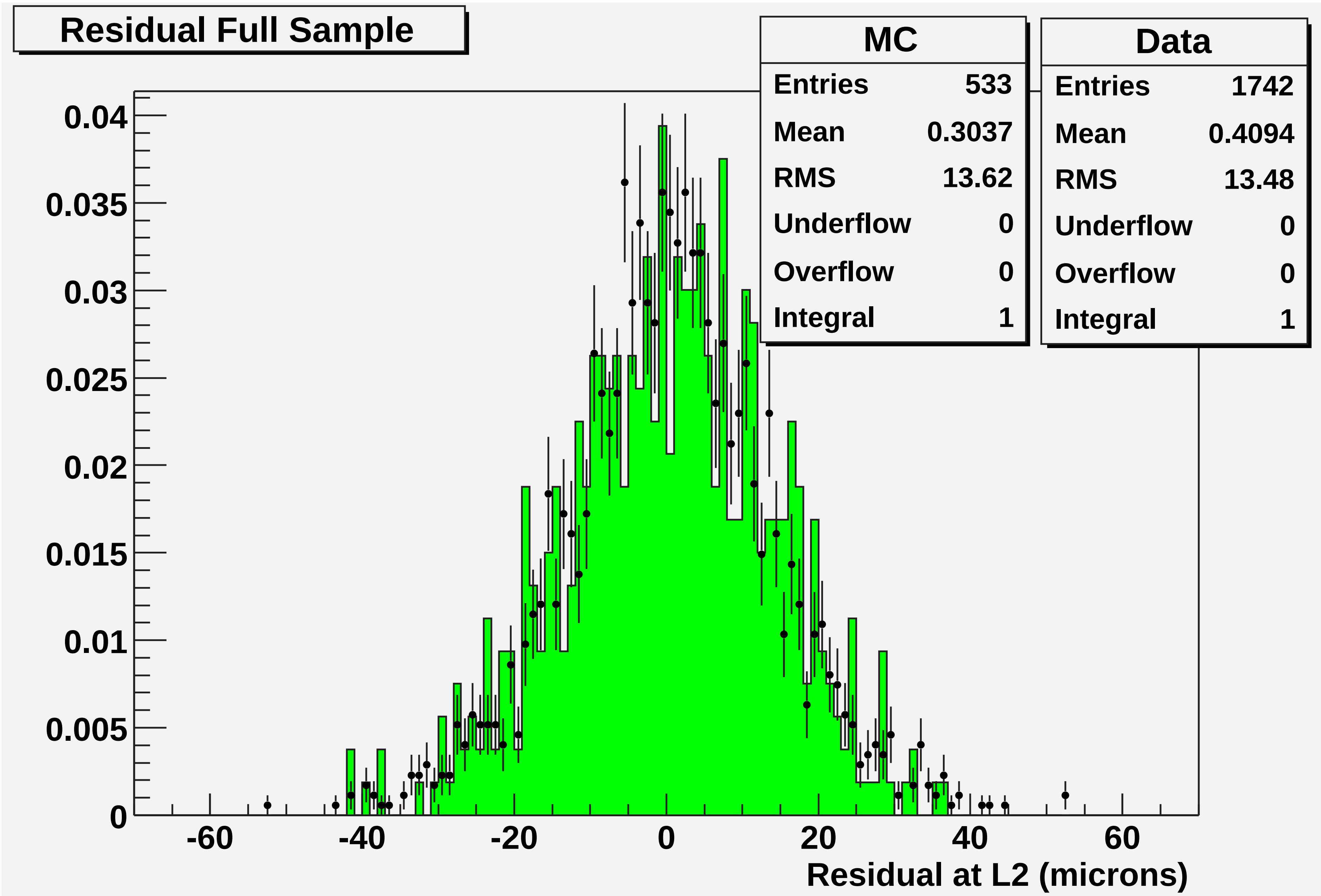
Backup Slides

Higgs Lagrangian

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

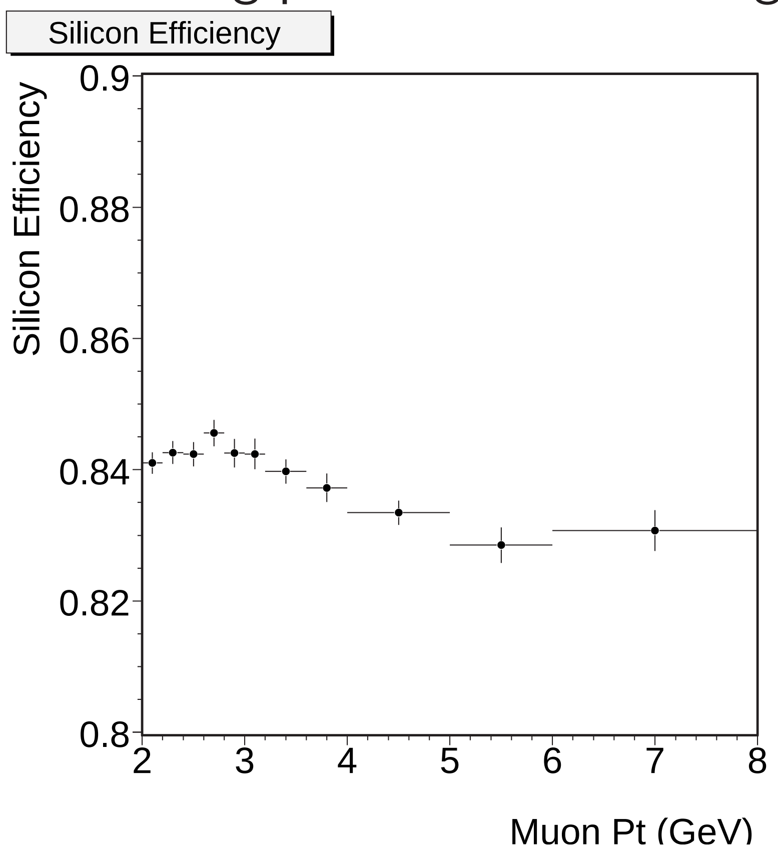
$(D_\mu\phi)^\dagger(D_\mu\phi)$	Gauge-Higgs coupling
$-\,\mu^2(\phi^\dagger\phi) - \lambda(\phi^\dagger\phi)^2$	Mass term and quartic coupling
$+\,k_e(\bar{\ell}_L\phi)e_R + k_e\bar{e}_R(\phi^\dagger\ell_L)$	Lepton-Higgs Yukawa term
$+\begin{array}{l} k_{\mathrm{d}}(\bar{\mathrm{d}}^c_L\phi)\mathrm{d}^c_R + k_{\mathrm{d}}\bar{\mathrm{d}}^c_R(\phi^\dagger\mathrm{d}^c_L)+ \\ k_{\mathrm{u}}(\bar{\mathrm{u}}^c_L\tilde{\phi})\mathrm{u}^c_R + k_{\mathrm{u}}\bar{\mathrm{u}}^c_R(\tilde{\phi}^\dagger\mathrm{u}^c_L)\end{array}$	Quark-Higgs Yukawa terms.

Silicon Tracking Resolution Data vs MC

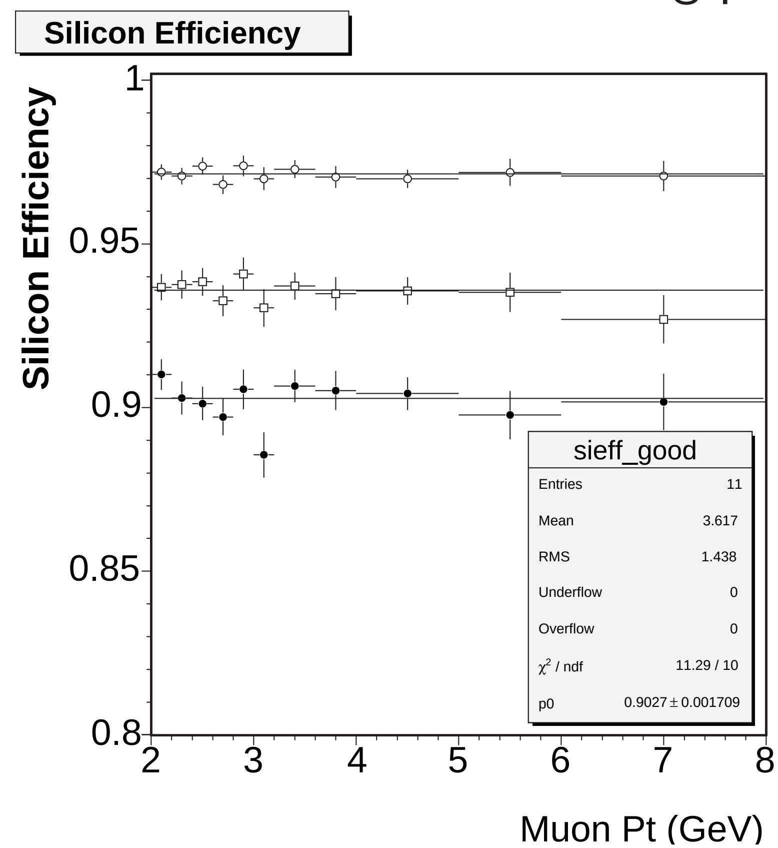


Silicon Tracking Performance

Including pre-stable-data-taking period



After stable-data-taking period

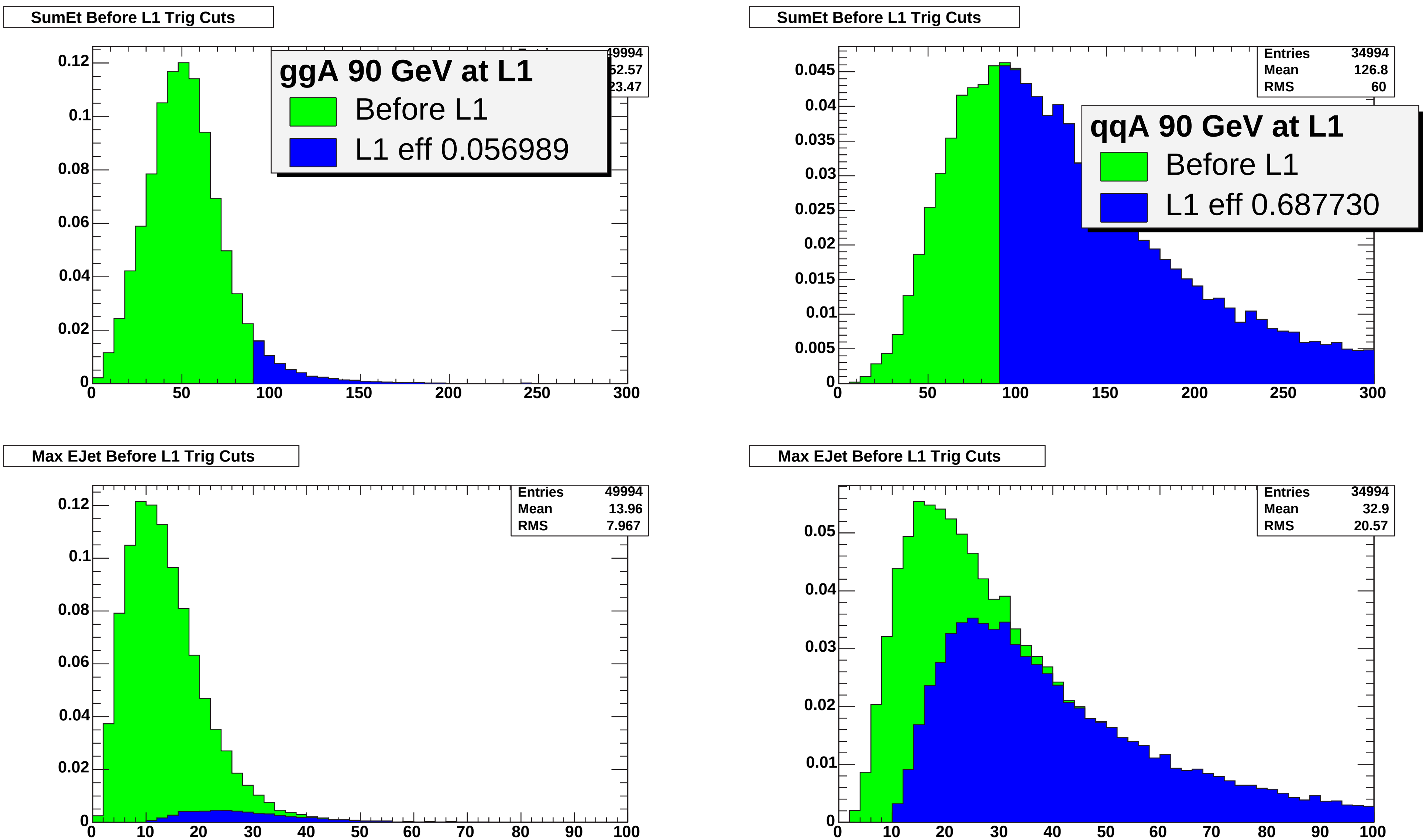


- Eff to attach $\frac{N-1}{N}$ $R\Phi$-Si hits to good COT tracks from $J/\psi \to \mu^+\mu^-$ events
- 5% readout errors (have reduced some)
- 4% bad strips (irreducible)
- 5% dead wedges (have recovered some)
- Have improved tracking/alignment

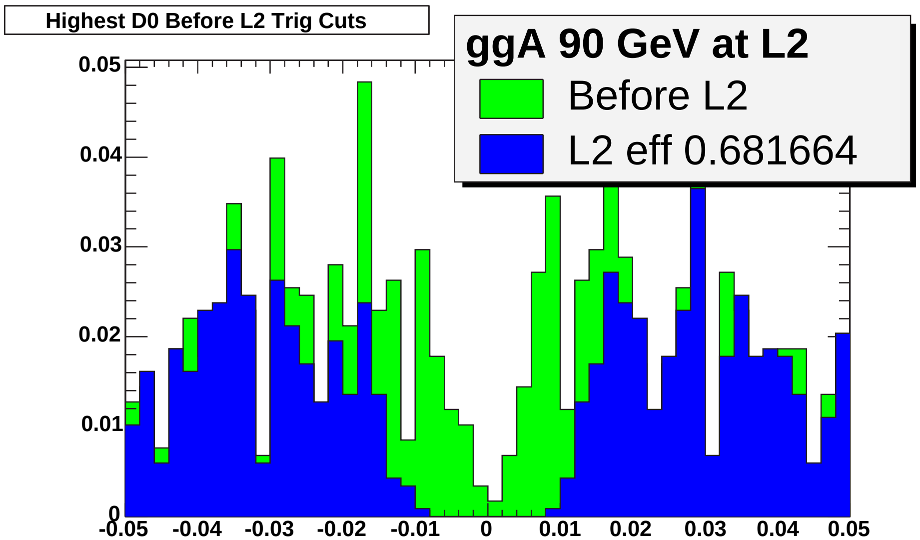
3-Level Higgs Trigger

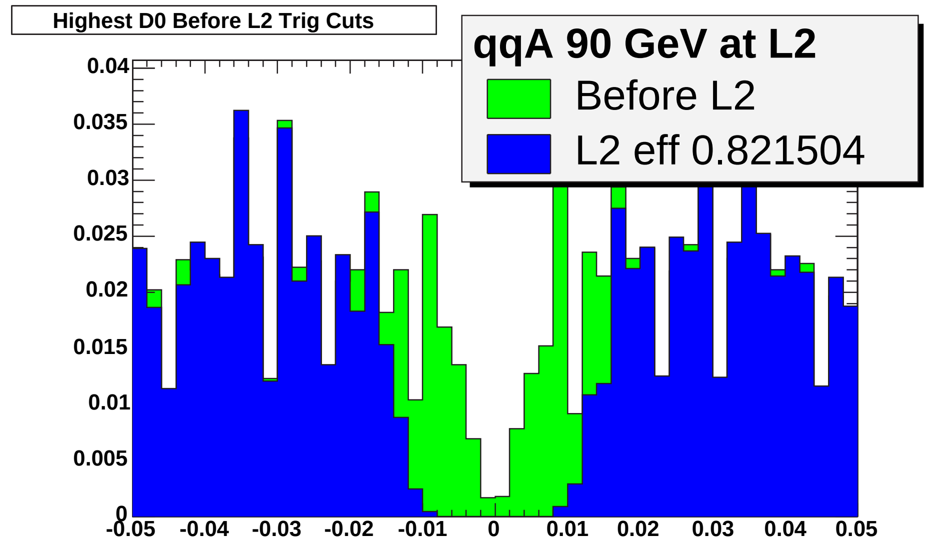
- L1_JET10_&_SUMET90_v-1: Requires one 10 GeV E_T trigger jet from central or plug in coincidence with 90 GeV $\sum E_T$
- L2_TWO_TRK2_D100_L1_JET10_&_SUMET90_v-1: Two tracks each with $100\ \mu\text{m} < d_0 < 1\ \text{mm}$, $\chi^2 < 25$ and $P_t > 2\ \text{GeV}$ from SVT.
- L3_THREE_JET10_SUMET100_TWO_SVT_v-1: 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.
- RunI trigger used for MSSM Higgs was 1.7% efficient on signal

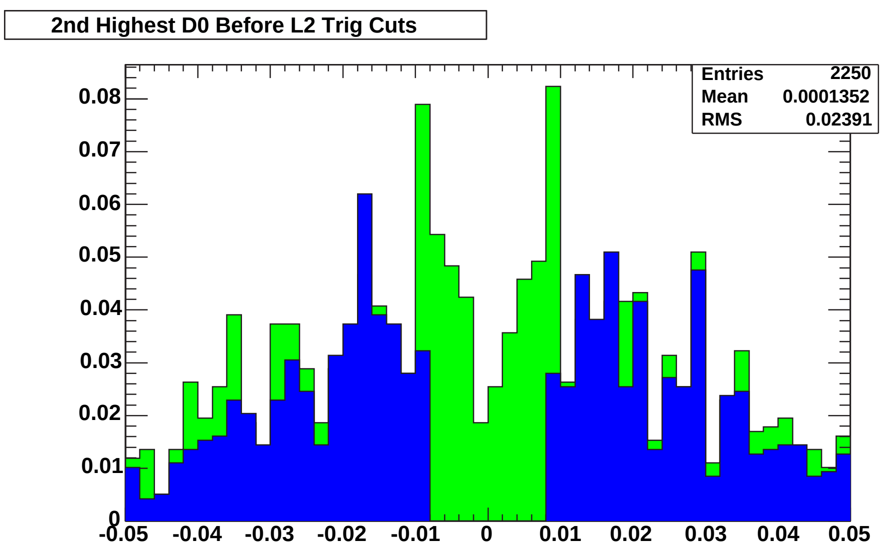
L1 Trigger Efficiency on Signal

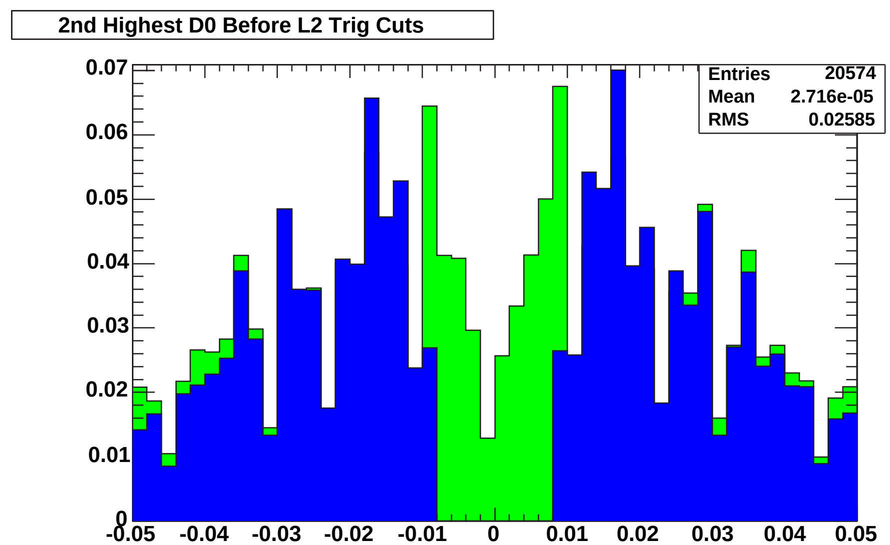


L2 Trigger Efficiency on Signal

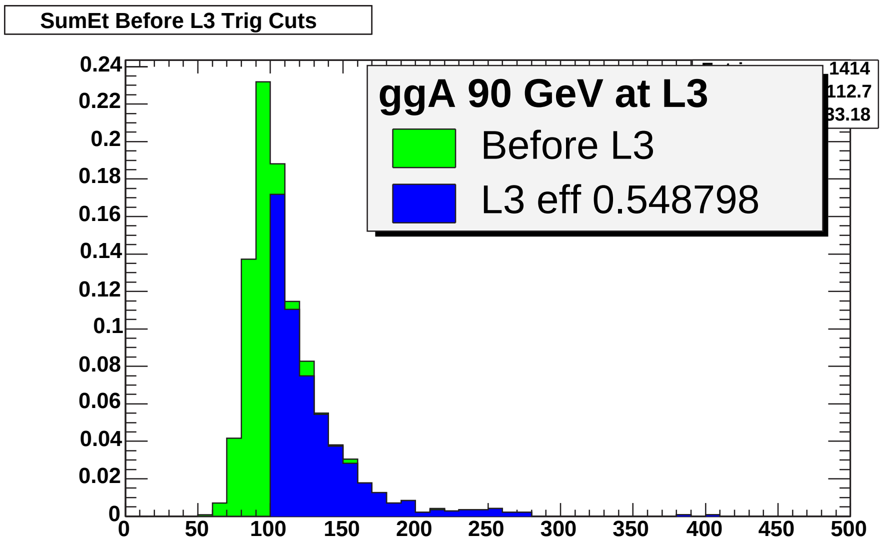


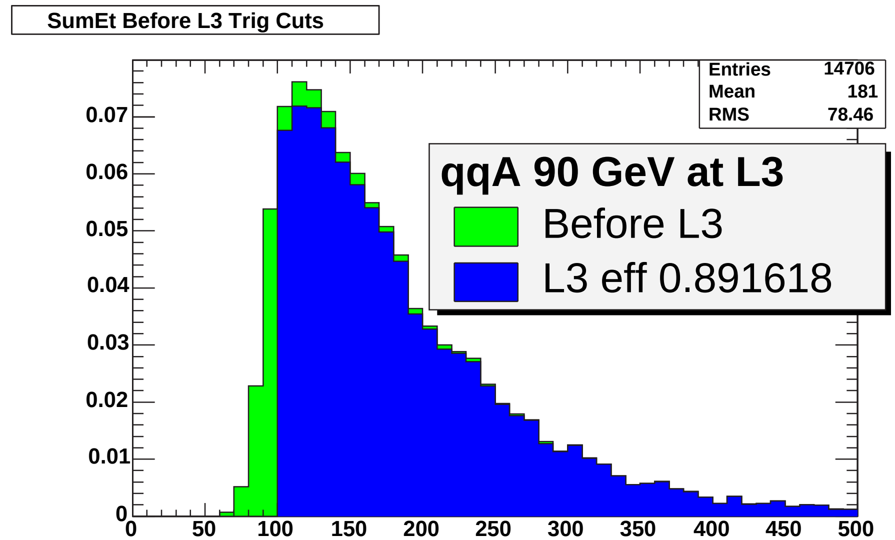


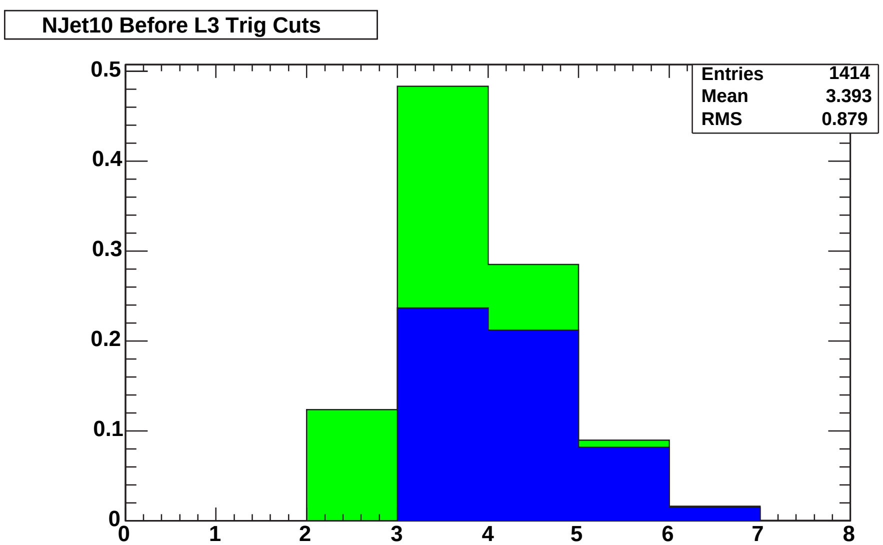


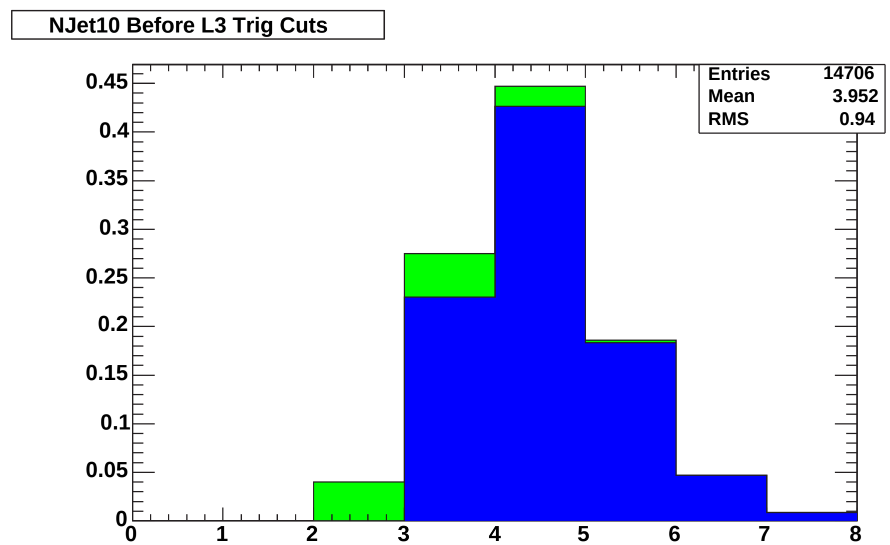


L3 Trigger Efficiency on Signal



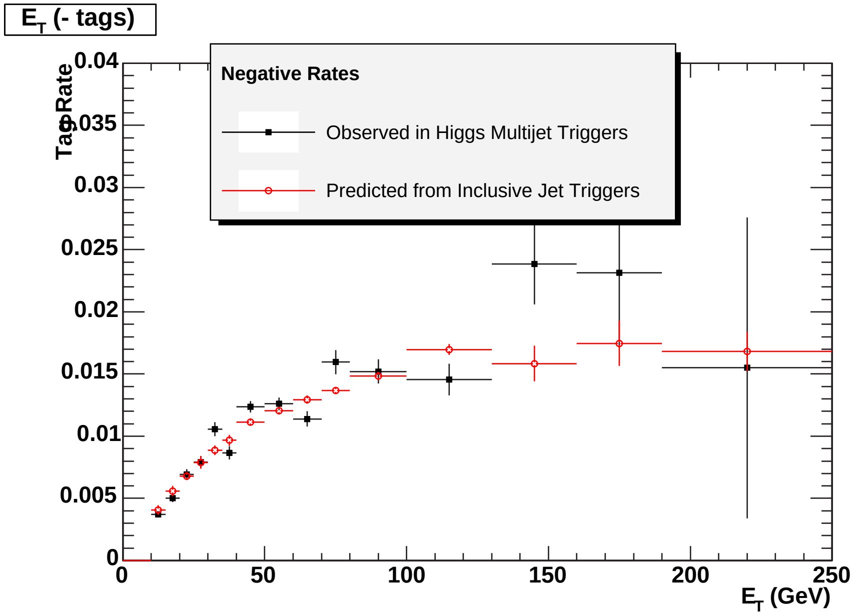


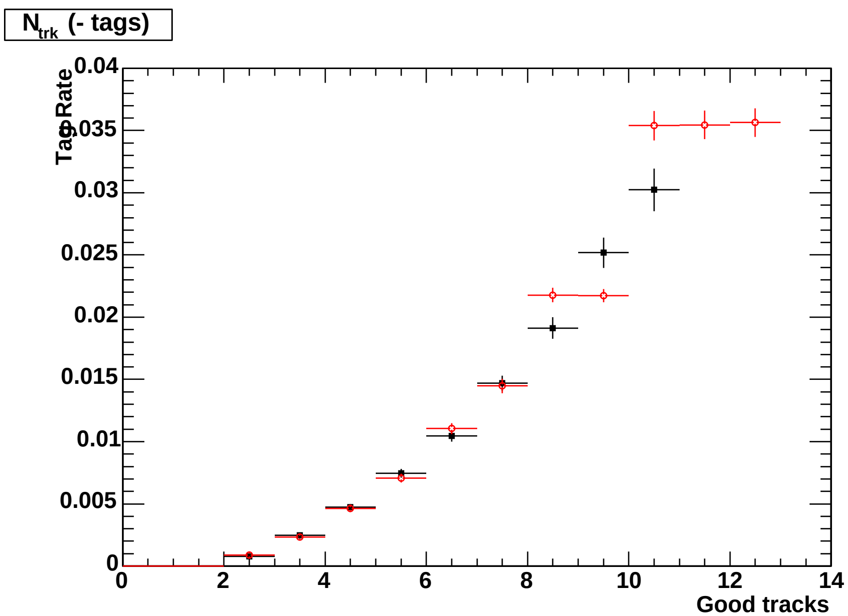




Full trigger $\sim 1.6\%$ eff on 90 GeV signal

Fake Double-Tag Rate Prediction in Data





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

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

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

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

  - Light-heavy $\mathrm{Neg} = \epsilon$, $\mathrm{Pos} = \eta$:

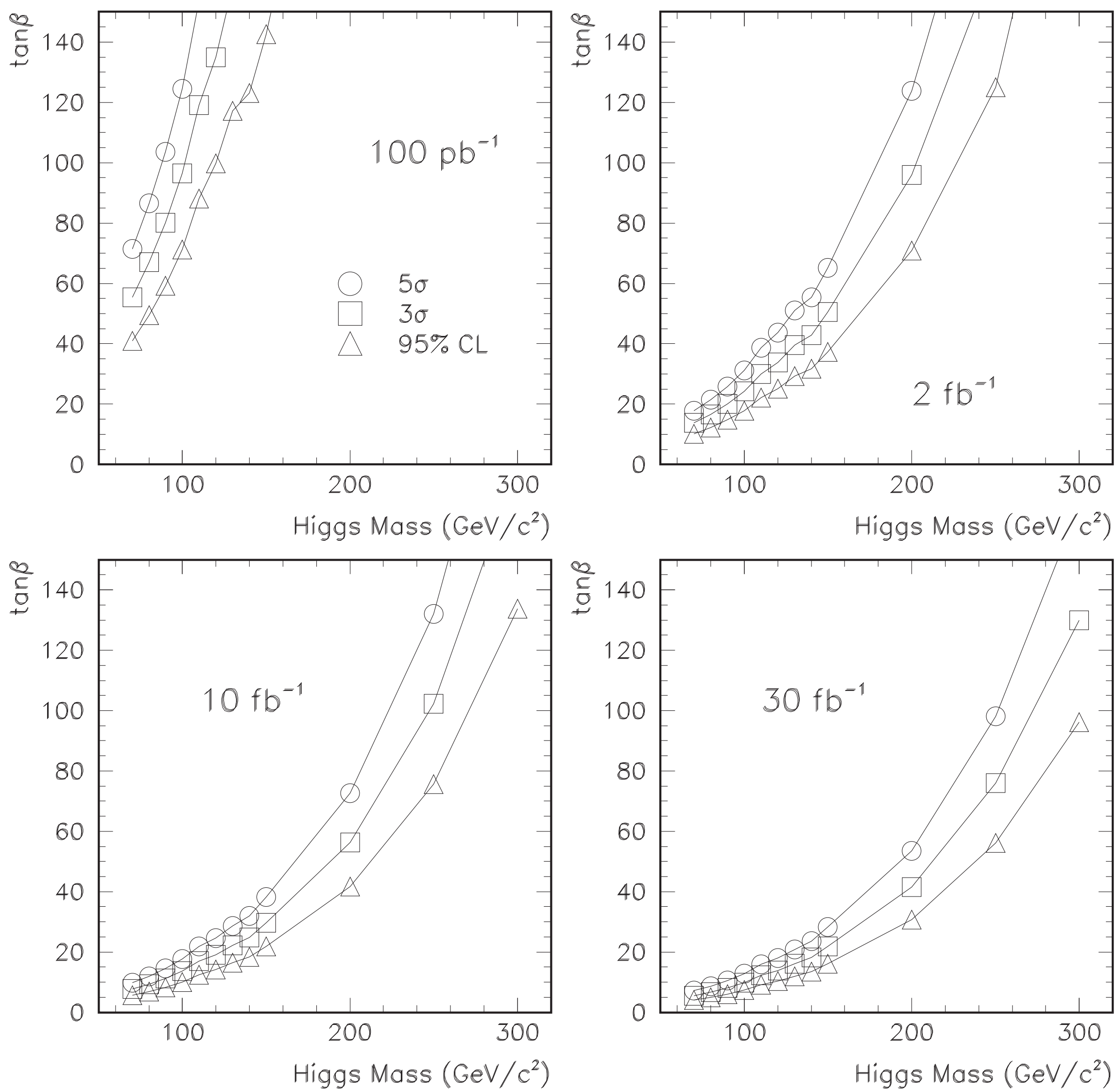
$$P_{--} = \epsilon\eta$$

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

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

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

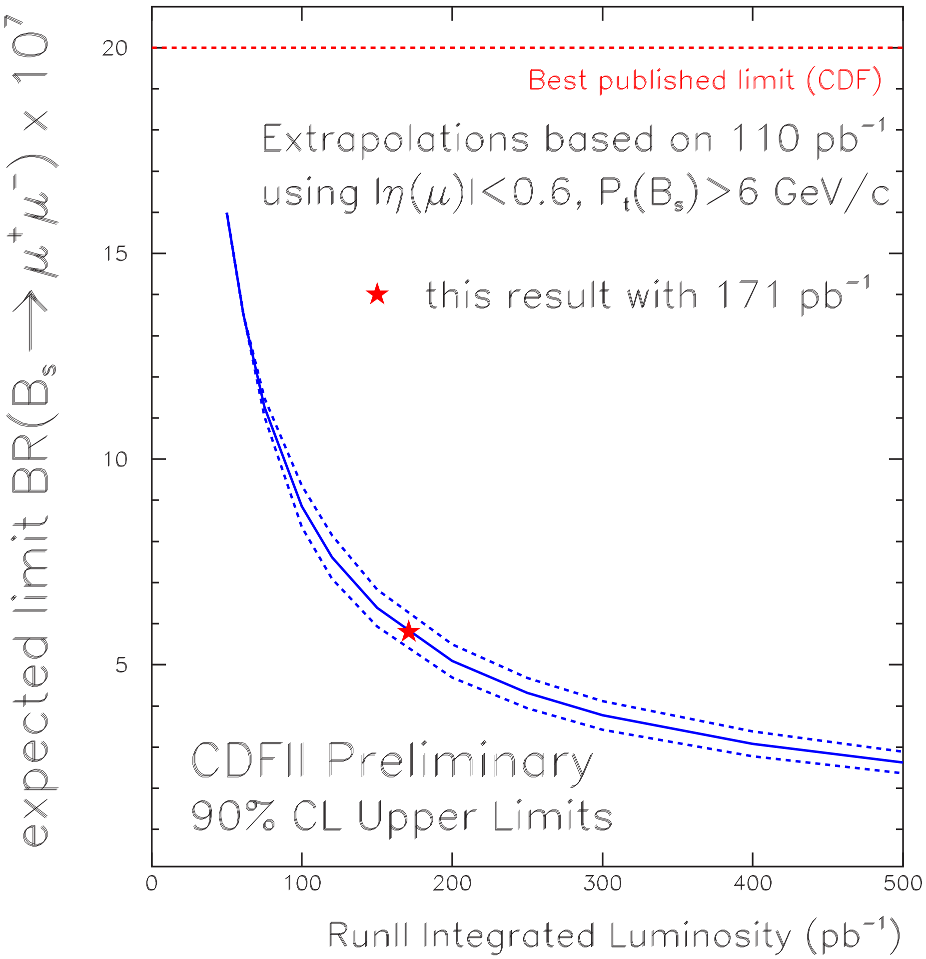
Outlook



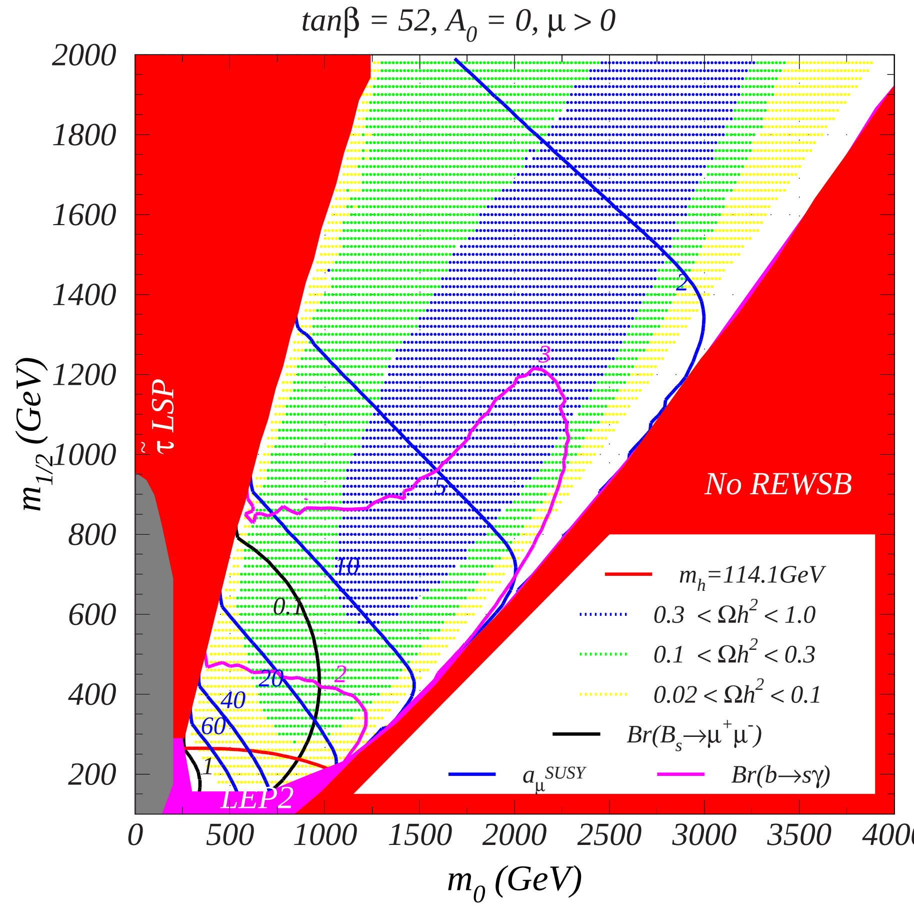
tanβ
Higgs Mass (GeV/c²)
100 pb⁻¹
5σ
3σ
95% CL
2 fb⁻¹
10 fb⁻¹
30 fb⁻¹
0
20
40
60
80
100
120
140
100
200
300

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

From Matt Herndon & Doug Glenziksi



Baer *et al.* **JHEP07** (2002) 050



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