Using Leptons and Bosons to Search for New Physics in Hadron Collisions

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Outline

- Goals of High Energy Physics
- Introduction to the Tevatron and CDF
- Leptons as Probes
- Search for New Heavy Particles in $ZZ \rightarrow eeee$ (submitted to PRD, arXiv: 0801.1129 [hep-ex])
  - Electron Identification Optimization
  - Z and ZZ Candidate Reconstruction
  - Background Estimation
  - Revealing the Search Region
- Muon Optimization
- Other Searches
- Summary

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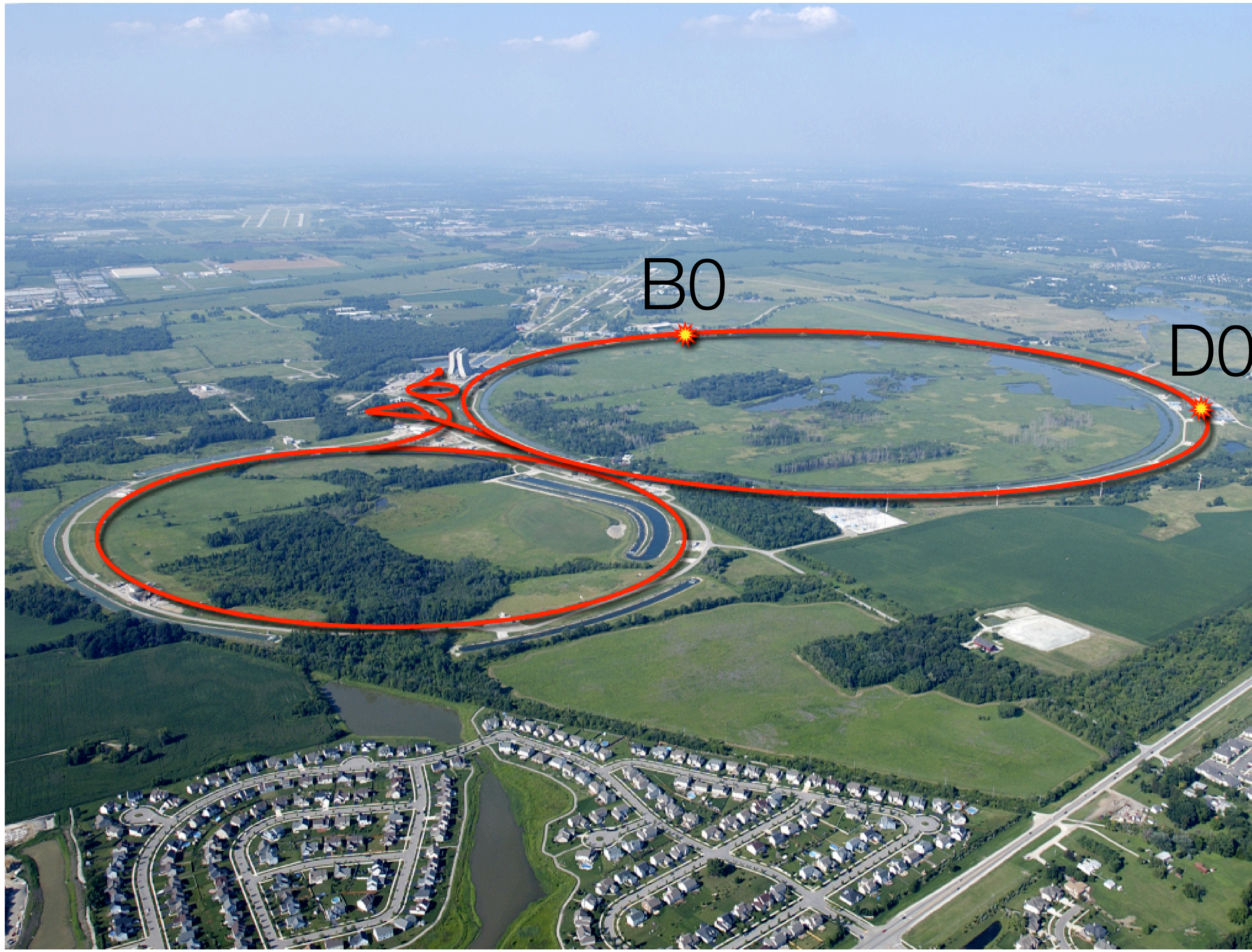
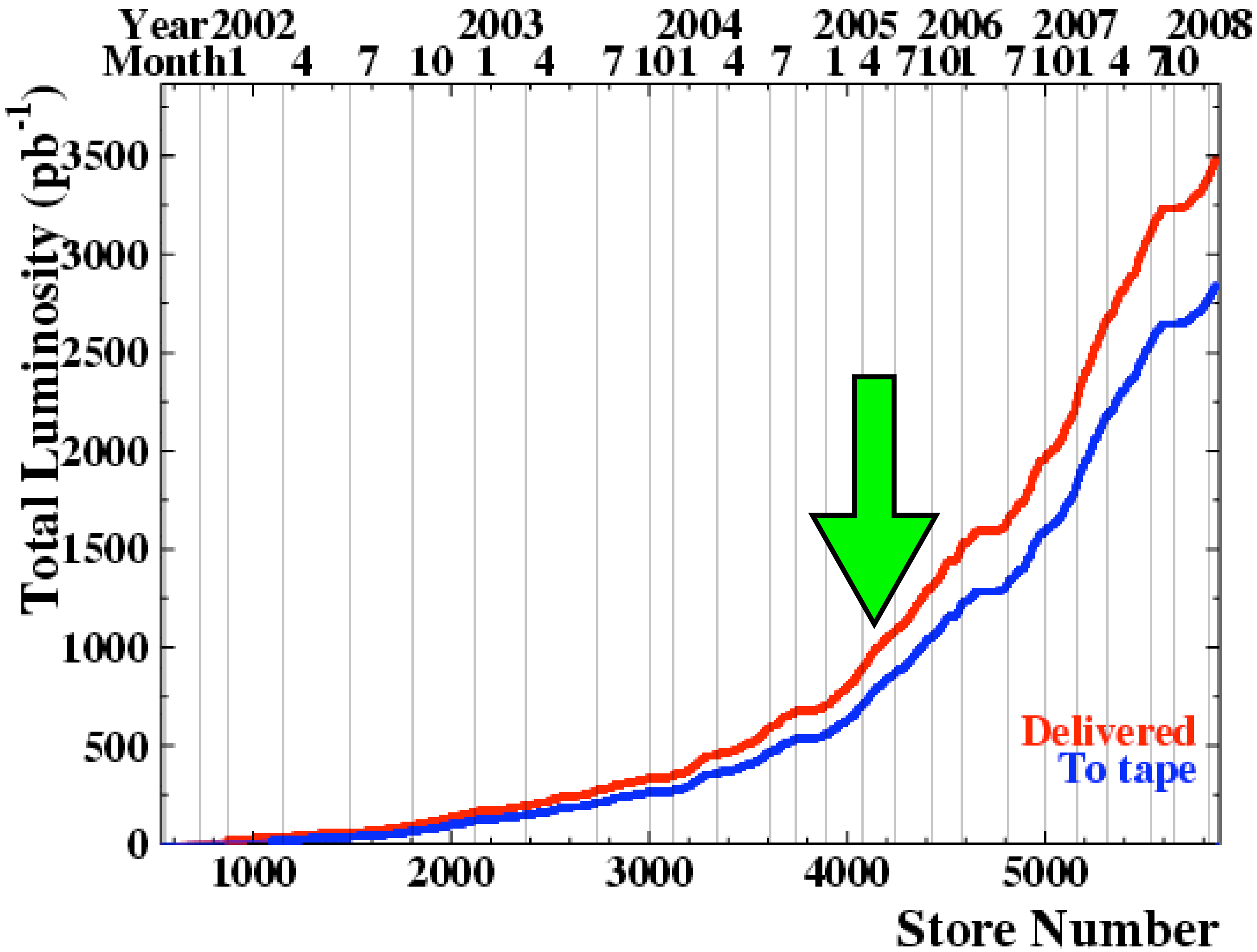
    - Hadron Colliders (Electron Colliders)

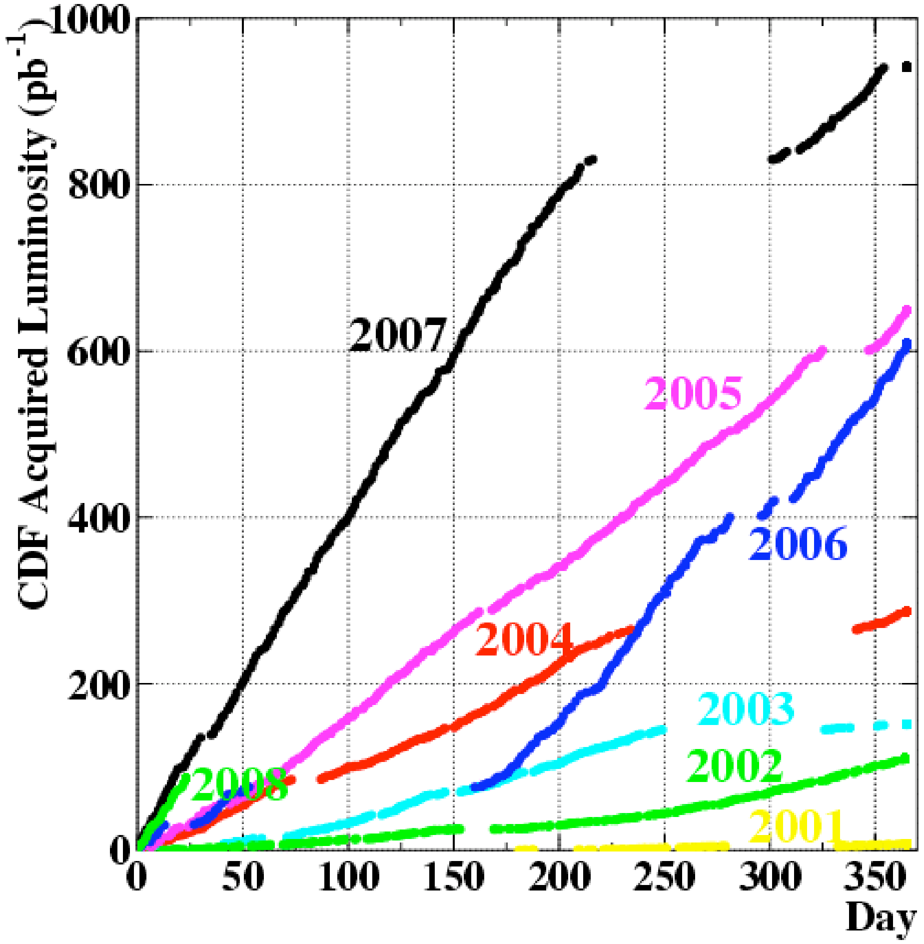
The Tevatron at Fermilab

- Highest E operating pp collider in the world (2 TeV)
- Largest Dataset Ever
  - Many times data of top discovery



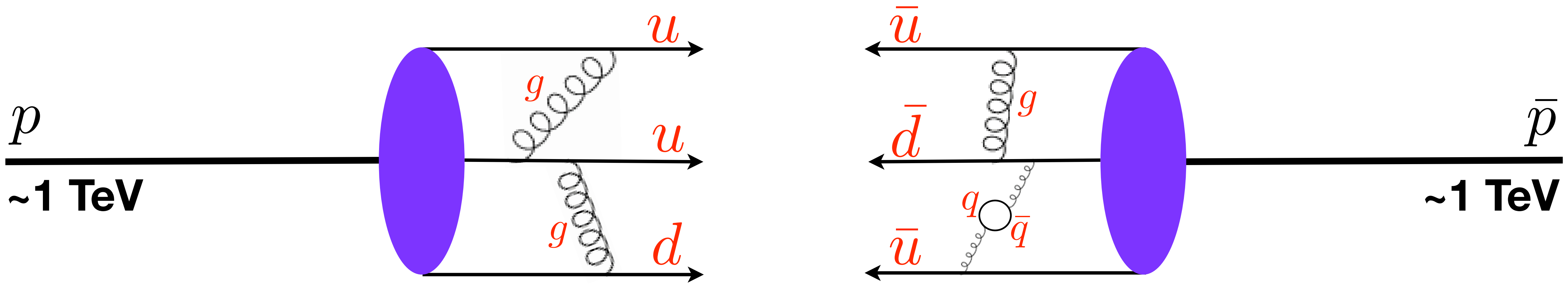
Tevatron Performance



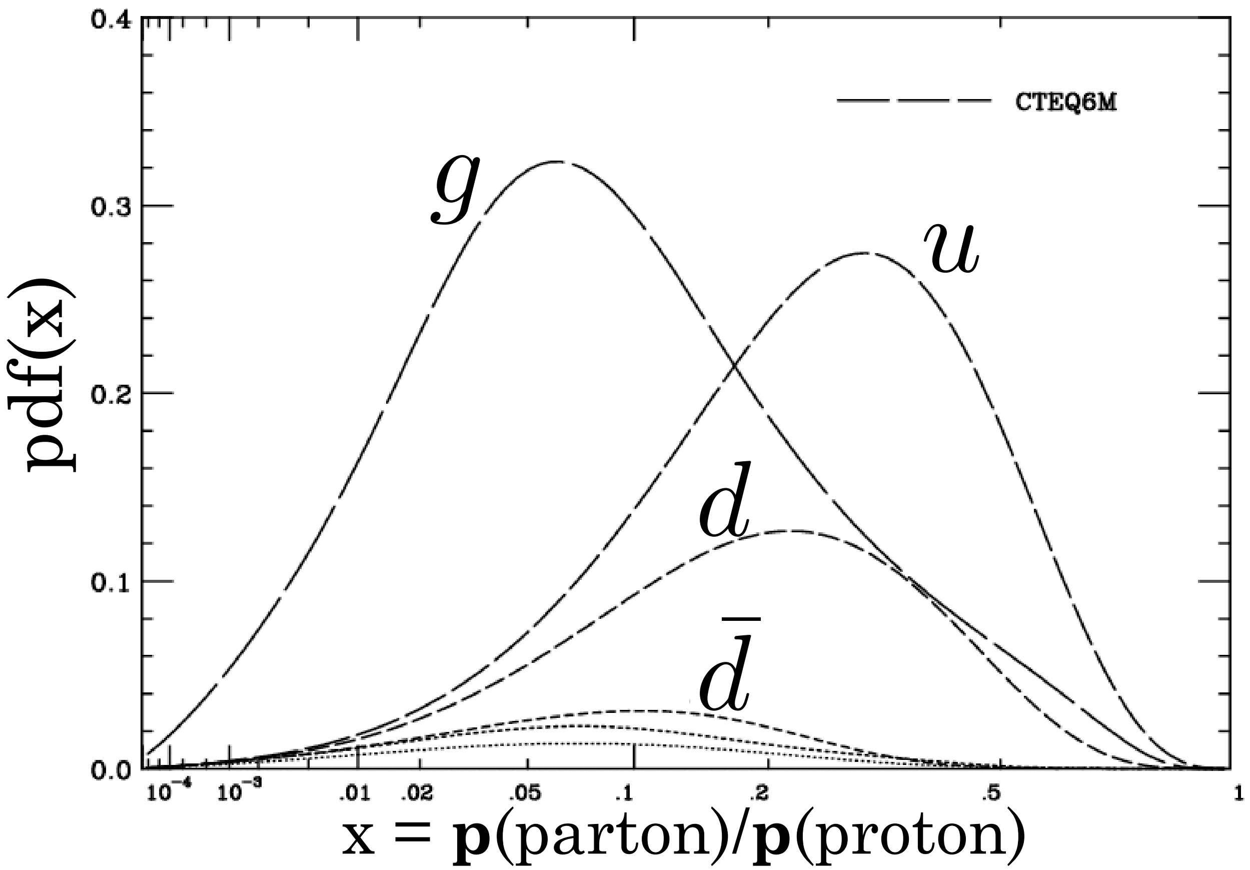


- Record Luminosity: 292.3×10^{30} cm^{-2}s^{-1}
- To Tape Efficiency: 81.6%
- Performance Continues to Improve

$p\bar{p}$ Collisions

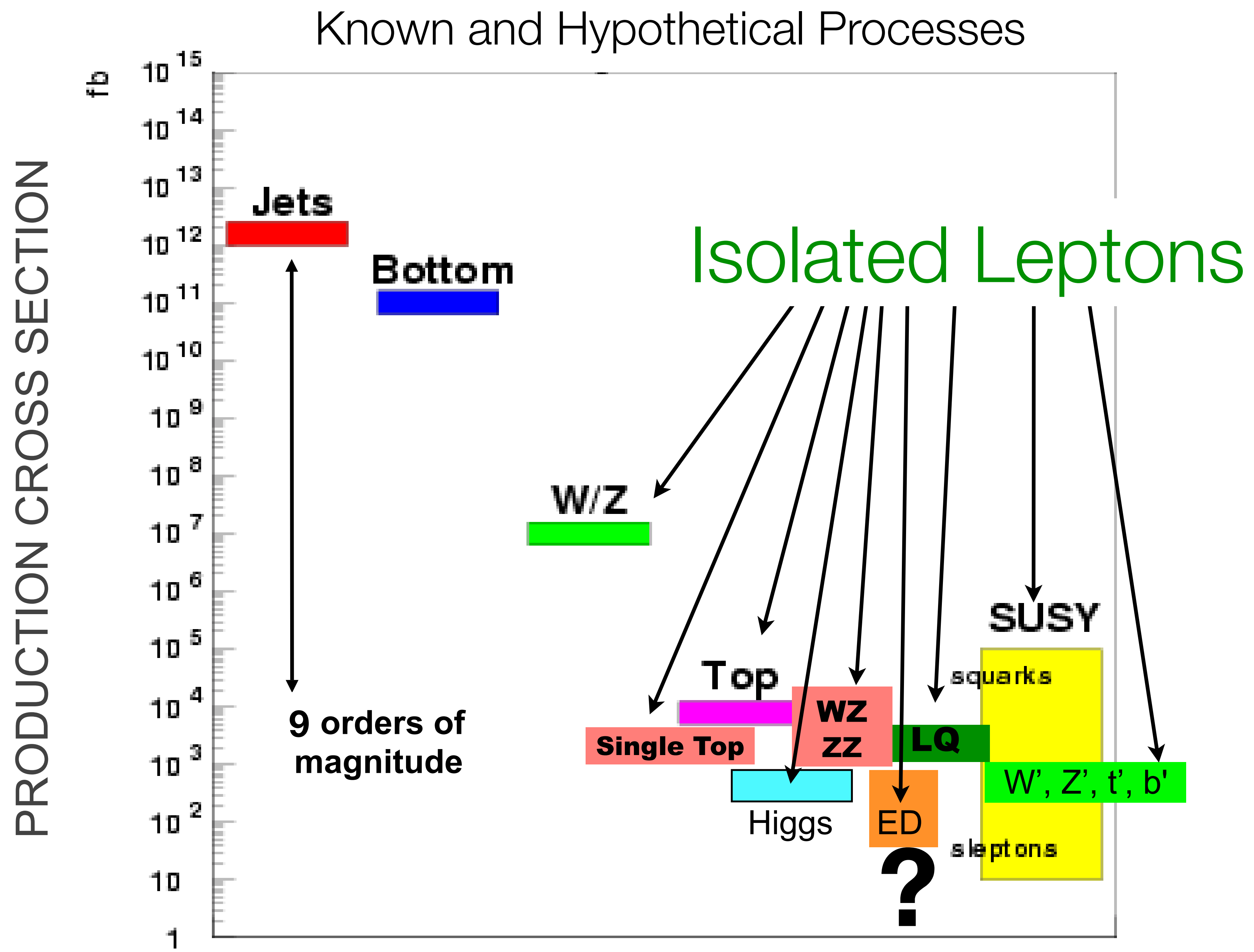


- Are really parton collisions
- Probe higher energy per $ than e^+e^-
- Only a (random) fraction of proton's energy is involved
  - CM is not known
  - Simultaneous probe of many energies
- Contribution from gluon interactions can be significant



What is produced in a $p\bar{p}$ collision?

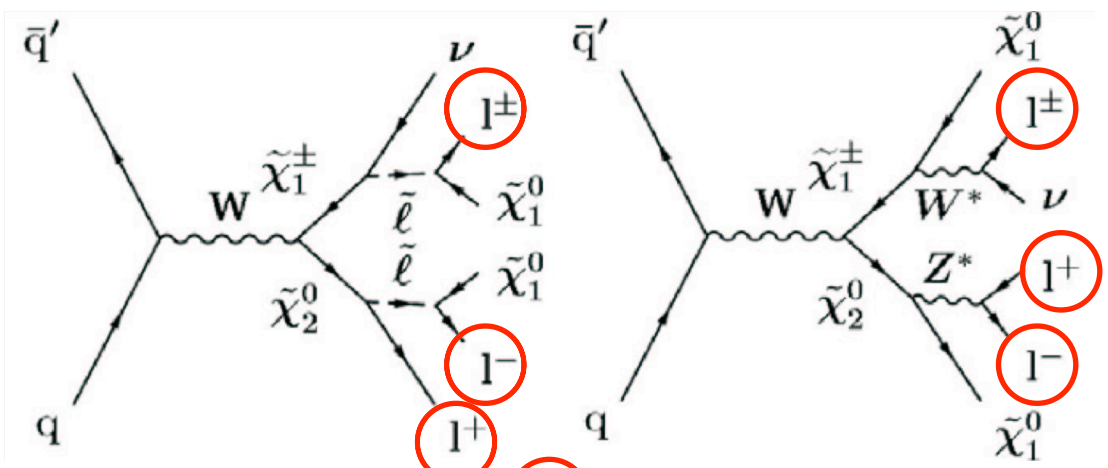
- Light Quark Jets
- b-Quark Jets
- Gauge Bosons W,Z
- Top quark pairs
- Single top quark
- Di-Boson WW, WZ, ZZ
- Boson + Higgs ZH,WH
- Higgs
- SUSY, Technicolor, Leptoquarks, Z',W', excited quarks & leptons...

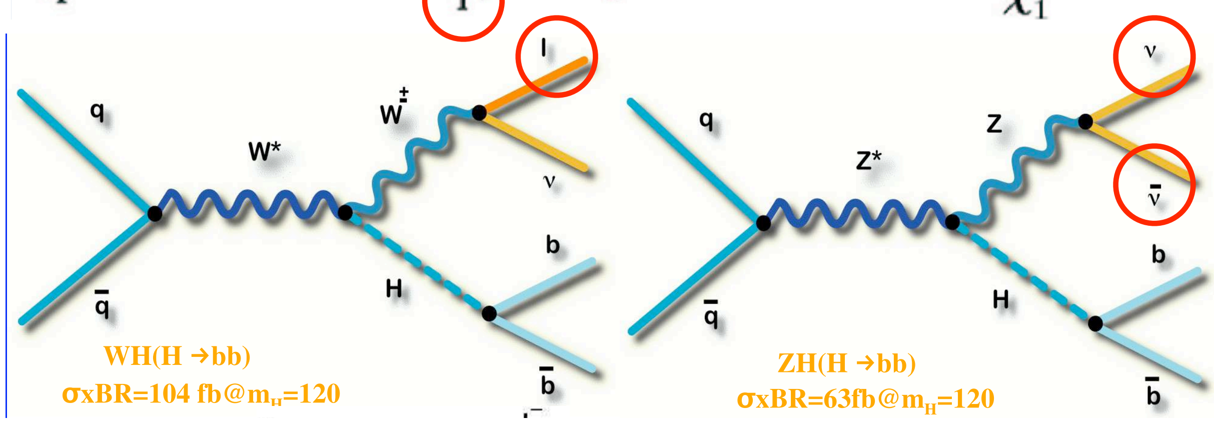


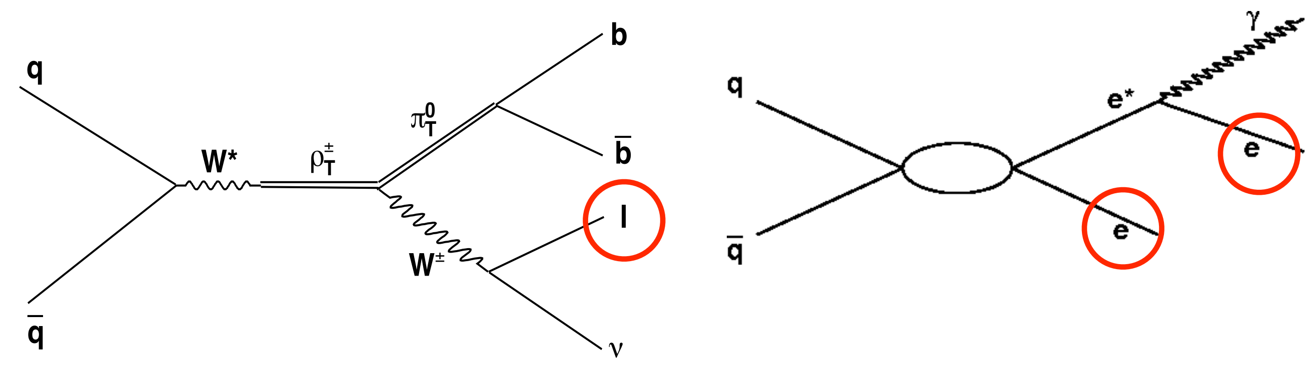
Leptons as Probes of New Physics

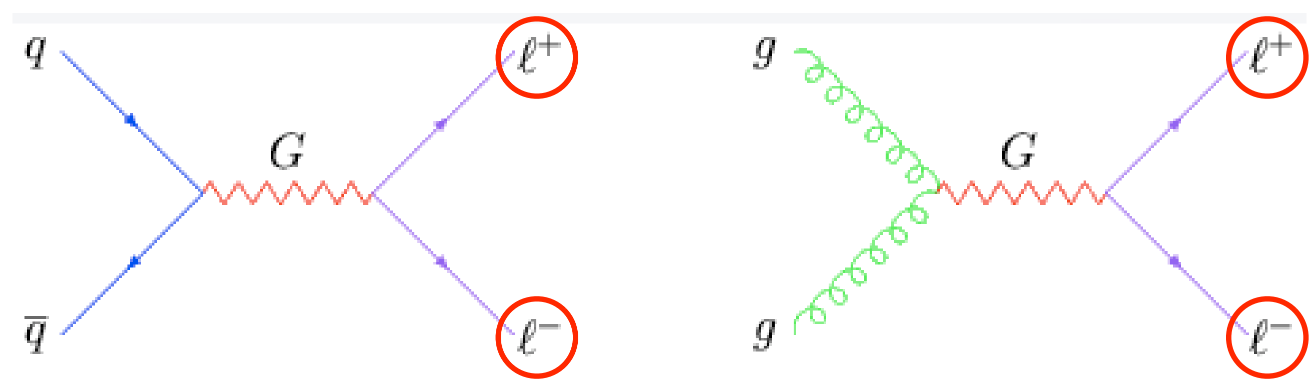
- Many new physics scenarios involve weak interactions → leptons!
- New particles themselves also can couple to leptons (G, W',Z')

Interaction	Type	Spin	Mass	Coupled Fermions
Strong	8 gluons	1	0	q,$\bar{q}$
Electromagnetic	1 photon	1	0	q,$\bar{q}$,l^+,l^-
Weak	W^+, W^-, Z^0	1	82, 91	q,$\bar{q}$,l^+,l^-, ν_l, $n\bar{u}_l$
Gravity	1 graviton	2	0	All matter





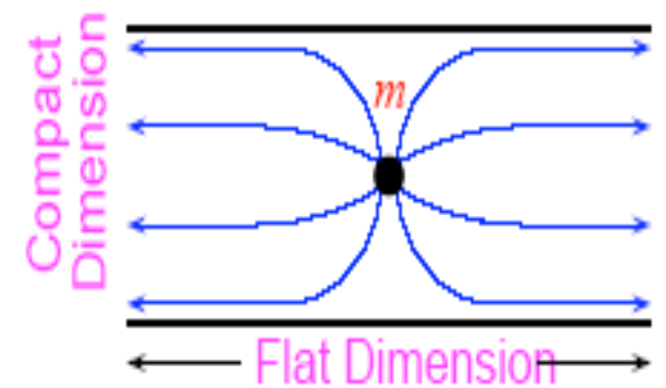


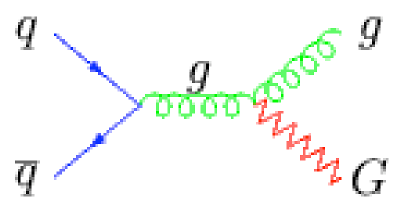


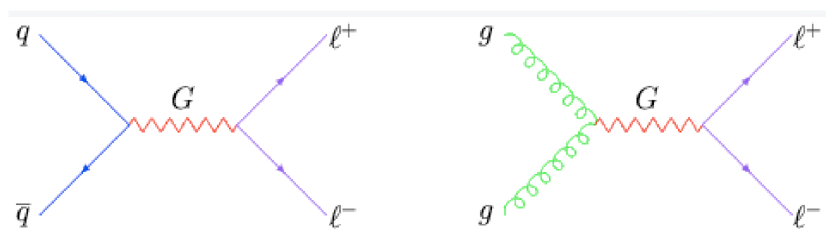
Extra Dimensions

- Provide a solution to the hierarchy problem
- Arkani-Hamed, Dimopoulos, Dvali (ADD)
  - n compact extra dimensions; $M_{Pl}^2 \sim R^n M_D^{2+n}$
  - Standard model confined to a 4-dimensional brane
  - Only gravity lives in full 4+n dimensional bulk

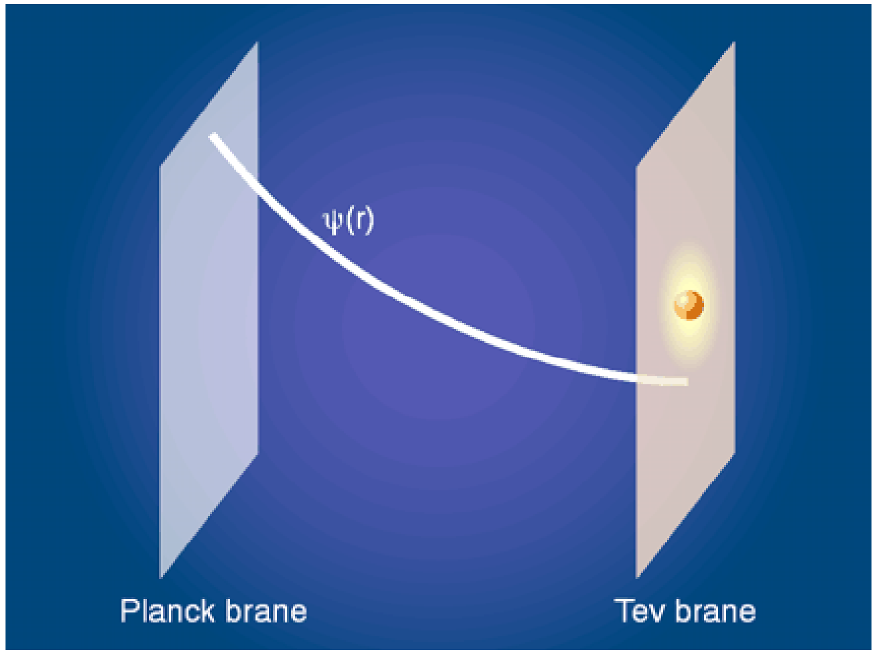
– Weakness of gravity due to being diluted by volume of extra dimensions





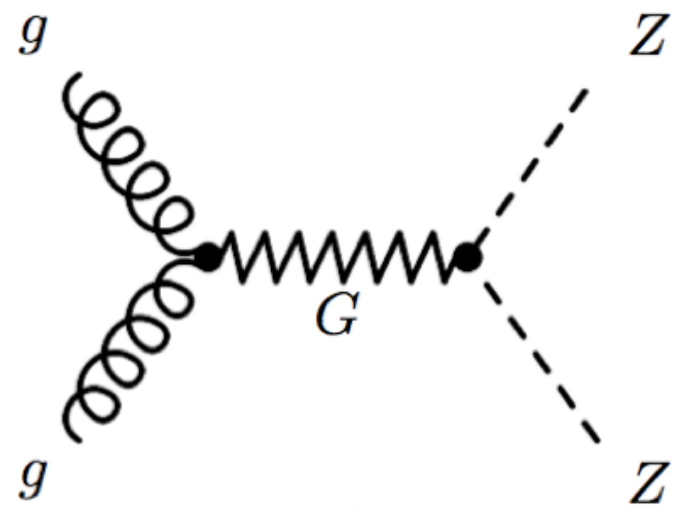


- Randall-Sundrum I (RS)
  - Warped extra dimension(s), exponential warp factor solves hierarchy problem
  - Two branes, TeV and Planck. Gravitons live everywhere, SM localized at TeV brane.
  - Signature: High-Mass Graviton Resonances
    - pp → G_n, $m_n \sim x_n\, k/M_{Pl}$
    - Decays to qq, ll, γγ, WW, ZZ



Search for New Massive Particle X→ZZ→eeee

- Signature-Based Search for heavy particle X → ZZ → eeee
  - Sensitive to production of any massive particle decaying to ZZ
  - First search for this at Tevatron!
- For a Randall-Sundrum graviton model (RS1):
  - Predicts graviton masses at ~TeV scale
  - $\sigma(pp \to G \to ZZ)$ ~290 fb for m_G = 500 GeV, k/M_{Pl} = 0.1



- Backgrounds
  - Standard model ZZ production
  - Mis-identified e's can be understood data sidebands
- Expect 0.33 events /fb^{-1} per G→ZZ→llll (m_G = 500 GeV, k/M_{Pl} = 0.1)

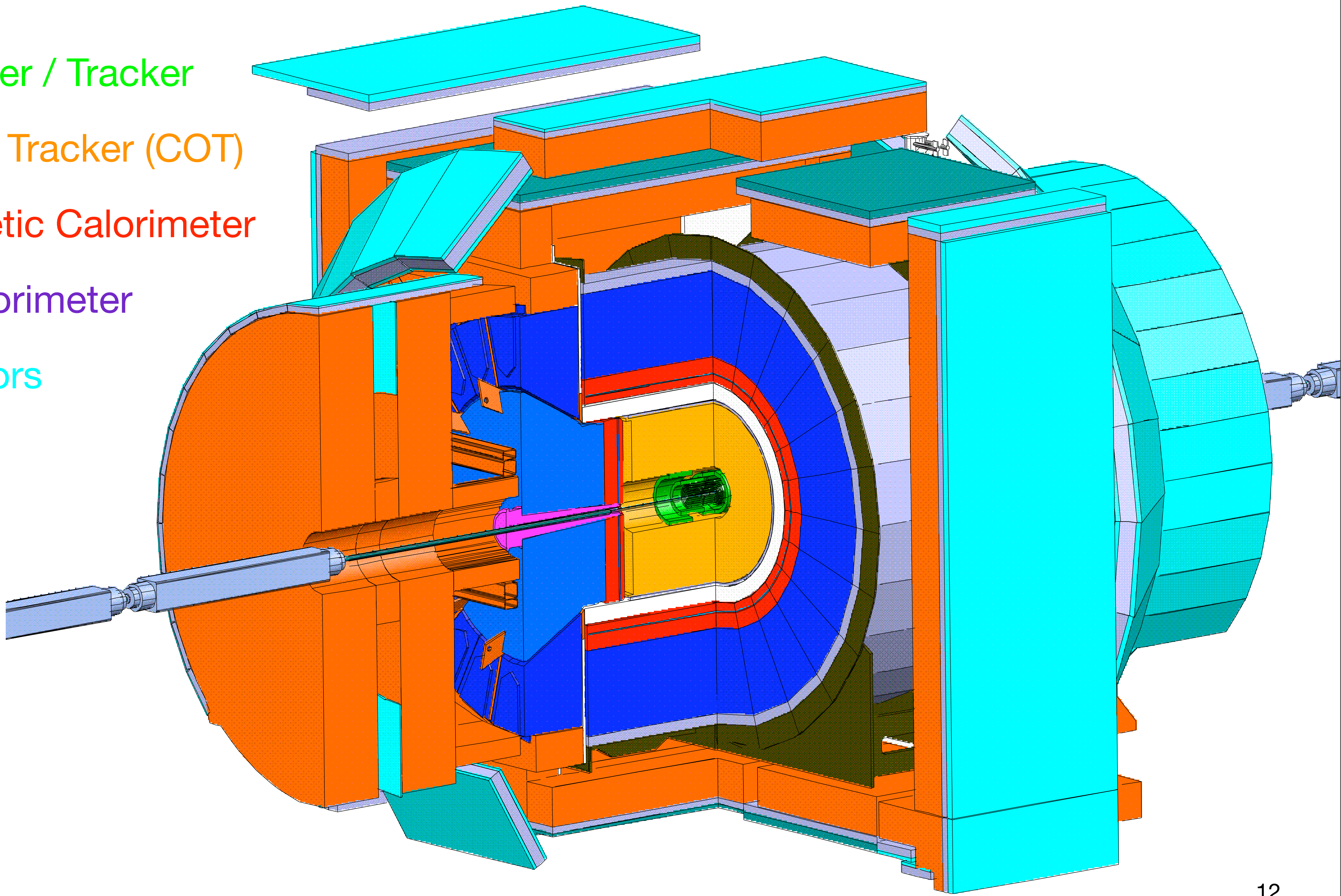
➡Total 11 events produced in 8 fb^{-1} in all lepton modes

Analysis Steps

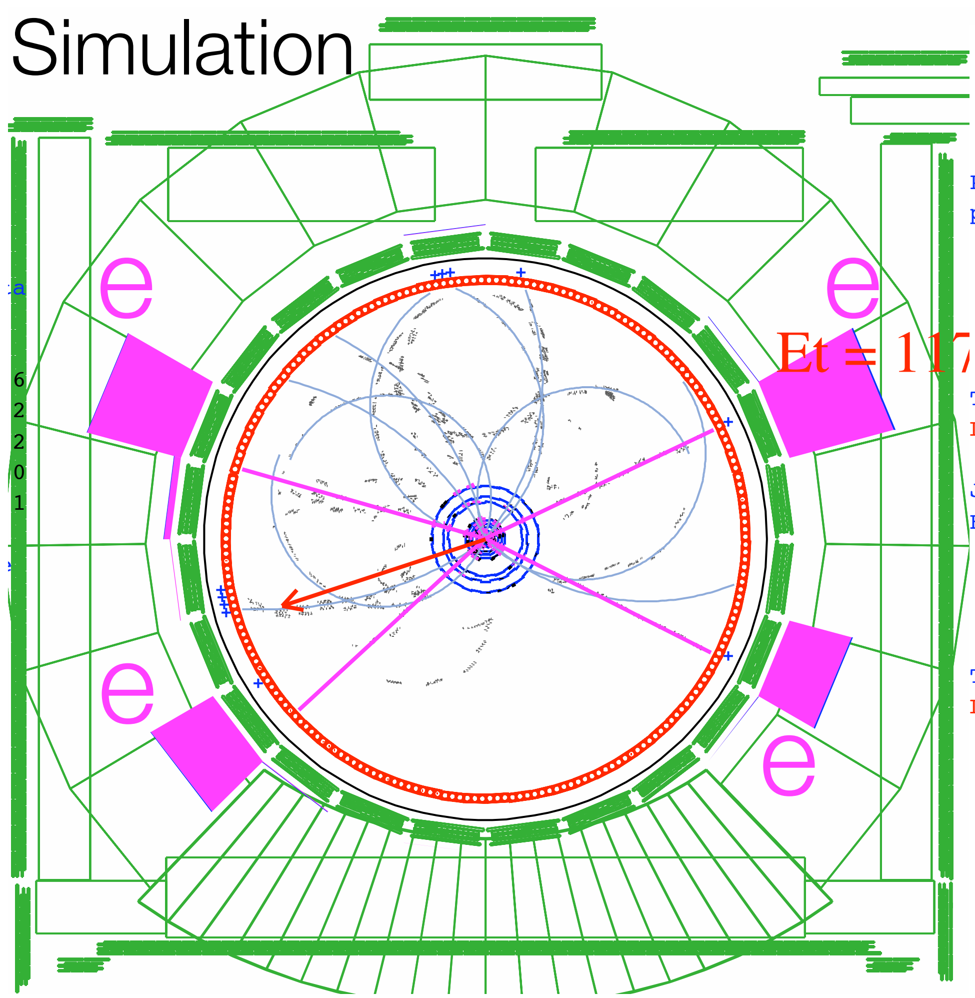
- Know the detector
- Study simulated signal
- Trigger on electrons
- Study data
- Efficiently identify energetic electrons in collision events
- Form Z candidates from pairs of e's
- In events with two or more Z candidates, find best pairings to form two Z's
- Estimate backgrounds
- Look in signal region
- Discovery / Limits

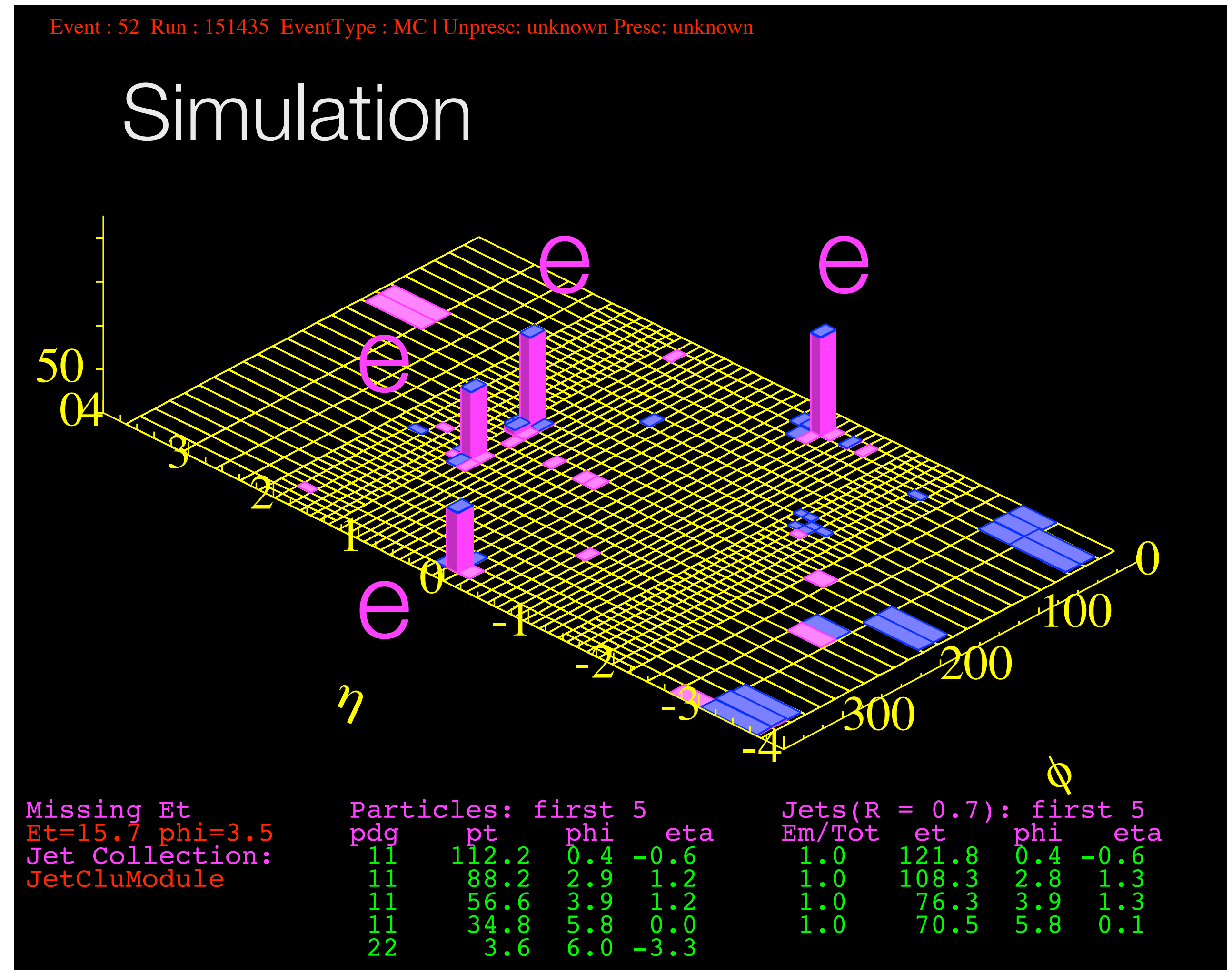
Collider Detector at Fermilab (CDF)

- Silicon Vertexer / Tracker
- Central Outer Tracker (COT)
- Electromagnetic Calorimeter
- Hadronic Calorimeter
- Muon Detectors



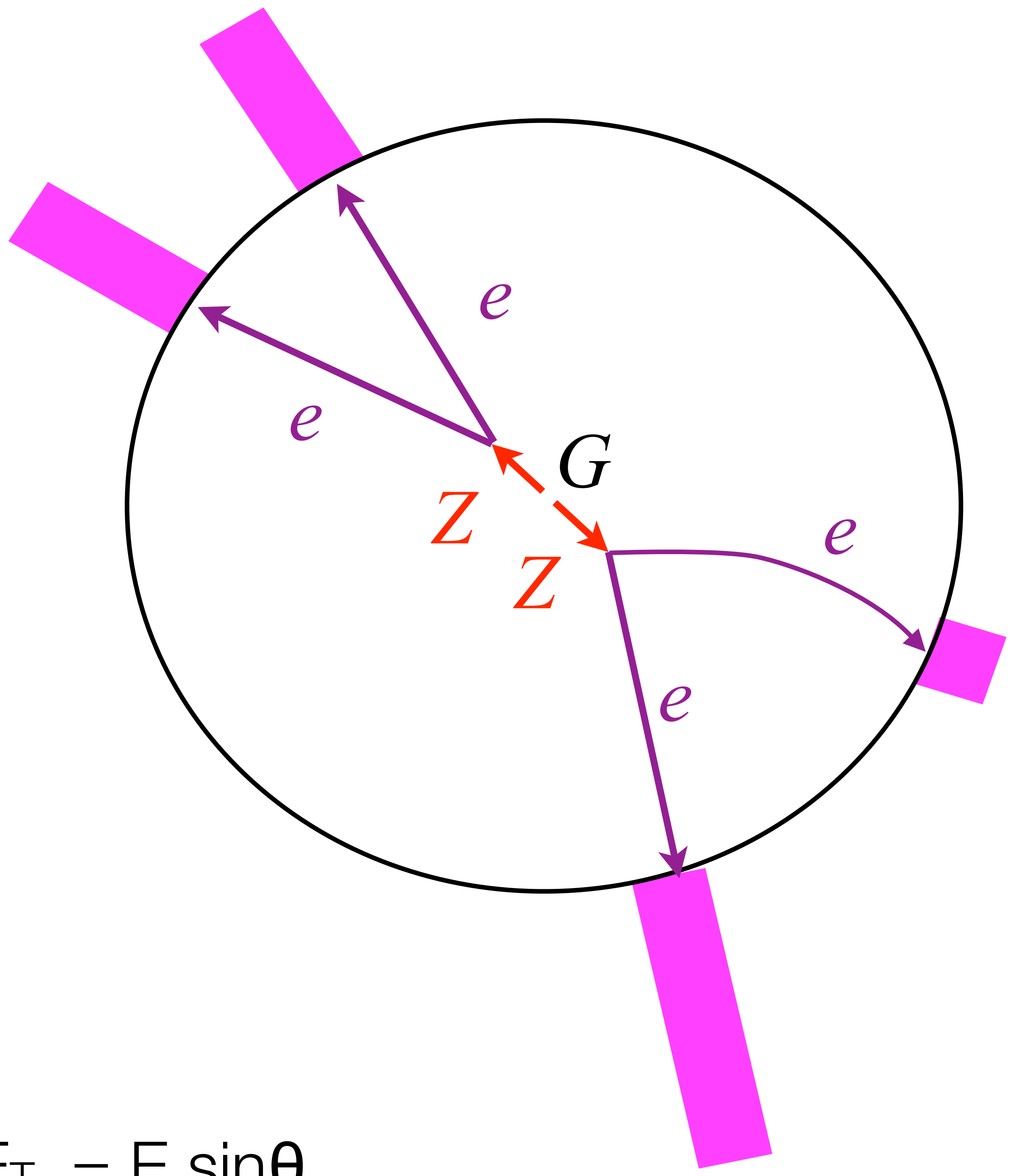
Signal Characteristics

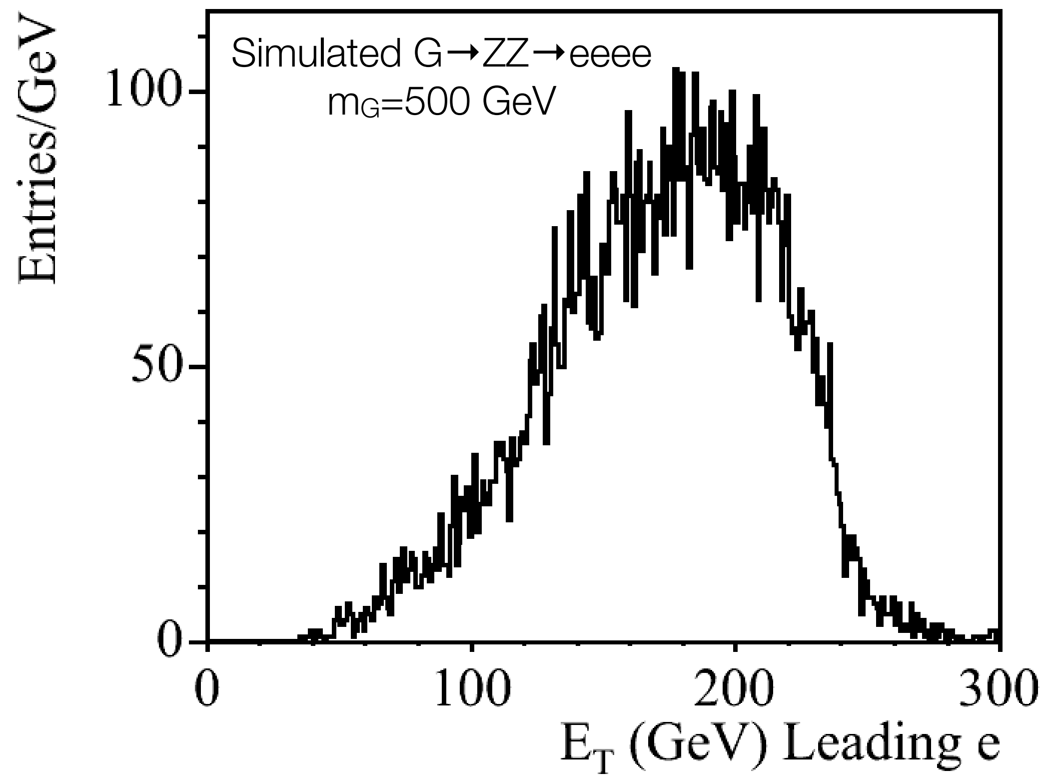


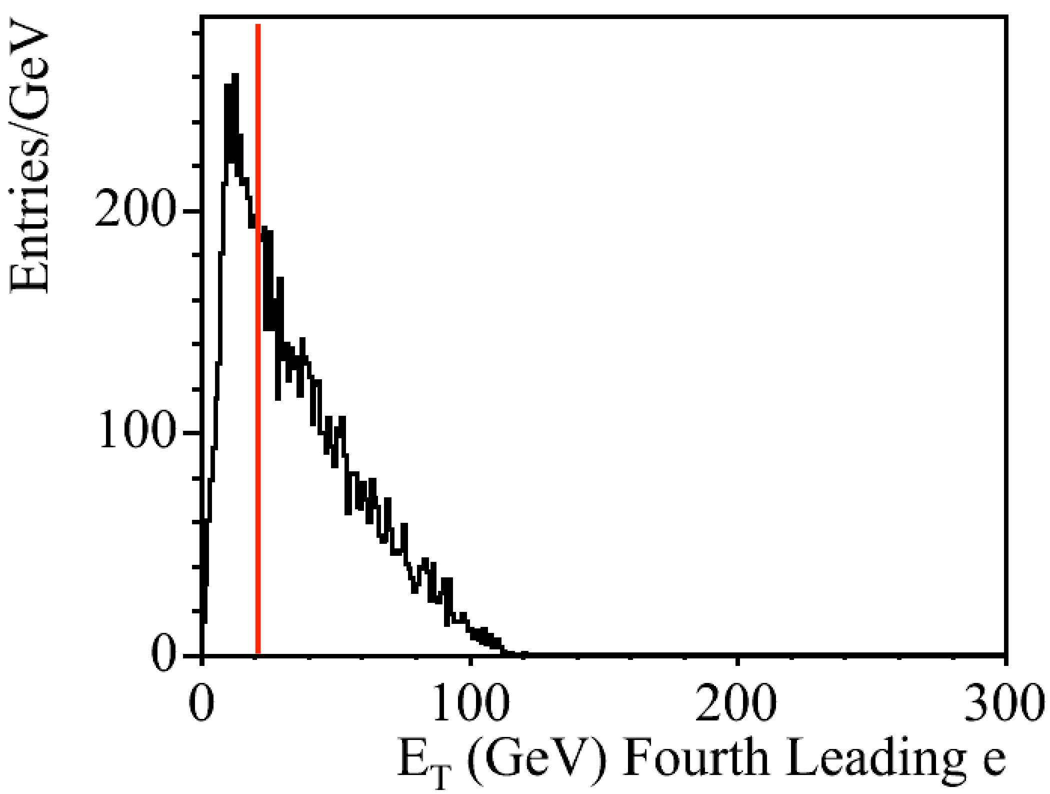


- Signature: Two high-p_T Z bosons
  - Four electrons (can be at both very high p_T and very low p_T): must be very efficient to find all four
- Three invariant masses (two m_{ee}, one m_{eeee}) provide powerful handles to reject backgrounds

Electron momentum: high p_T Zs have both high and low E_T e's







$E_T = E \sin\theta$

$p_T = p \sin\theta$

Baseline Electron Identification at CDF

Baseline High-Pt Electron Selection Criteria and Efficiencies: Gen5 and Gen6

Efficiencies and Scale Factors: Blessing Talk and CDF note 7950 measured by Teresa Spreitzer and Corrinne Mills

All users should get electron variables from the StdCEM and StdPEM classes in ElectronUser

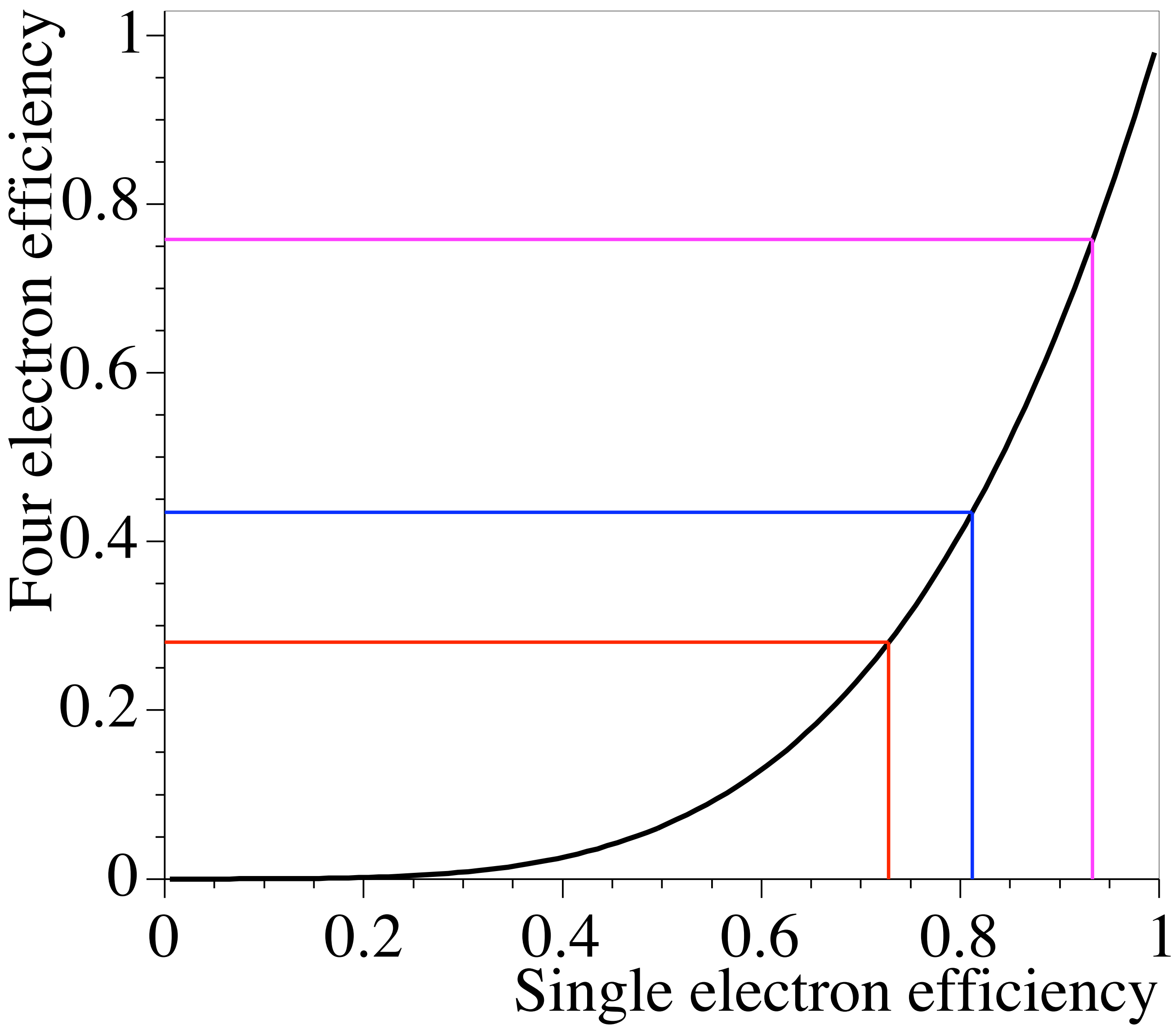
- Gen5 refers to the data taken up to September 2004 (run < 190000) and processed with 5.3.1
- Gen6 refers to the data taken betwee December 2004 and September 2005 (190000 < run < 203800) and processed with 6.1.0
- MC is 5.3.3 with the extended run range up to 203799 and no extra interactions.

1. **Central Electrons**
   - **StdCEM Definitions**
     - E = two-tower EM energy with CEMCOR corrections
     - Et = E * sin(theta_track)
     - P and Pt have curvature corrections for data
     - Isolation has leakage corrections
     - CES clusters are track-based
     - CES chi-2 has been scaled with E
   - **Central Tight Electrons**
     - Cuts
       - Region = 0 (CEM)
       - Fiducial = CES fiducial equal to 1
       - Et >= 20 GeV
       - |Track Z0| =< 60 cm
       - Track Pt >= 10 GeV/c
       - COT
         - 3 Axial SLs with 5 hits / SL
         - 2 Stereo SLs with 5 hits / SL
       - Conversion - not equal to 1
       - Iso(R=0.4)/Et =< 0.1
       - E_Had / E_EM (3 tower) =< 0.055 + (0.00045 * E)
       - Lshr (3 tower, track) =< 0.2
       - E/p =< 2 unless track Pt >= 50 GeV/c
       - |CES delta-Z| < 3 cm
       - Signed CES delta-X: -3.0 =< Q * delta-X =< 1.5 cm
       - CES Strip chi-2 =< 10
     - Efficiencies and Scale Factor combining all the data (> 700 /pb)
       - **Data Efficiency = 0.799 +- 0.002**
       - **MC Efficiency = 0.814 +- 0.001**
       - **Scale Factor = 0.981 +- 0.003 (stat.) +- 0.004 (syst.)**
     - Efficiencies and Scale Factor without Isolation cut combining all the data (> 700 /pb)
       - **Data Efficiency = 0.823 +- 0.002**
       - **MC Efficiency = 0.831 +- 0.001**
       - **Scale Factor = 0.990 +- 0.003(stat) +- 0.003(syst)**
   - **Central Loose Electrons**
     - Central Tight Electrons without E/p, Signed CES delta-X, and CES Strip chi-2 cuts (red colors in Tight selections above)
     - Efficiencies and Scale Factor combining all the data (> 700 /pb)
       - **Data Efficiency = 0.923 +- 0.001**
       - **MC Efficiency = 0.926 +- 0.001**
       - **Scale Factor = 0.996 +- 0.002(stat) +- 0.004(syst)**
2. **Plug Electrons**
   - **StdPEM Definitions**
     - PEM2x2 Energy with PEMCOR corrections
     - Add Leaker Correction
   - **Plug Tight Electrons**
     - Et >= 20 GeV
     - PES 2D Eta: 1.2 =< |eta| =< 2.8
     - E_Had / E_EM =< 0.05
     - PEM 3x3 chi2 =< 10
     - PES 5x9 U => 0.65
     - PES 5x9 V => 0.65
     - Iso(R=0.4) / Et &<= 0.1
     - Delta R (between PES centroid and PEM centroid) =< 3.0 cm
     - Efficiencies and Scale Factor combining all the data (> 700 /pb):
       - **Data Efficiency = 0.837 +- 0.003**
       - **MC Efficiency = 0.897 +- 0.001**
       - **Scale Factor = 0.933 +- 0.005(stat) +- 0.012(syst)**
   - **Plug Tight Phoenix Electrons**
     - Plug Tight Electron Cuts (see above)
     - PhxMatch = TRUE
     - Number of Silicon Hits >= 3
     - |Z(Phoenix)| =< 60 cm
     - Efficiencies and Scale Factor combining all the data (> 700 /pb):
       - **Data Efficiency = 0.658 +- 0.004**
       - **MC Efficiency = 0.691 +- 0.001**
       - **Scale Factor = 0.952 +- 0.006(stat) +- 0.012(syst)**
     - note that the efficiency depends strongly on eta but the scale factor is rather independent of eta
   - **Plug Tight Phoenix Electrons with |eta|< 2.0**
     - Plug Tight Phoenix Cuts (see above)
     - PES 2D Eta: |eta| =< 2.0
     - Efficiencies and Scale Factor combining all the data (> 700 /pb):
       - **Data Efficiency = 0.730 +- 0.004**
       - **MC Efficiency = 0.775 +- 0.001**
       - **Scale Factor = 0.942 +- 0.005(stat) +- 0.012(syst)**

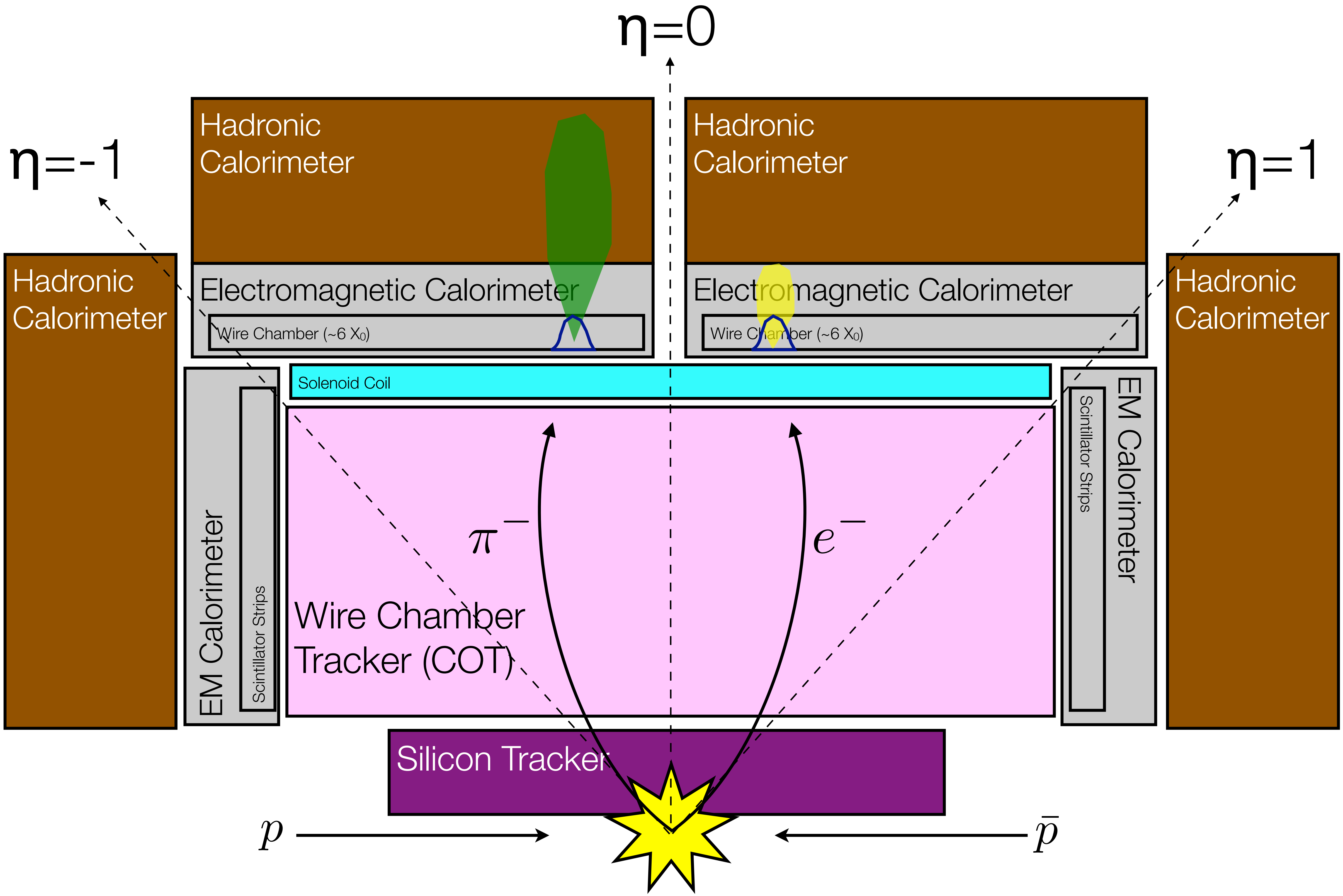
- Very Low Backgrounds.
- Good for W, Z, ttbar
- Inefficient for multilepton events

Electron ID Efficiency and Acceptance

- Four Electrons:
  - Yield looses like $(A\times\varepsilon)^4$
- Ten identification criteria, each 97% efficient:
  - Single electron: 73%
  - Four electrons: 30%
- Acceptance has similar effect
  - Calorimeter Coverage: missing ~18% of solid angle from gaps in Central Calorimeter
- ZZ Signal MC: 15% total

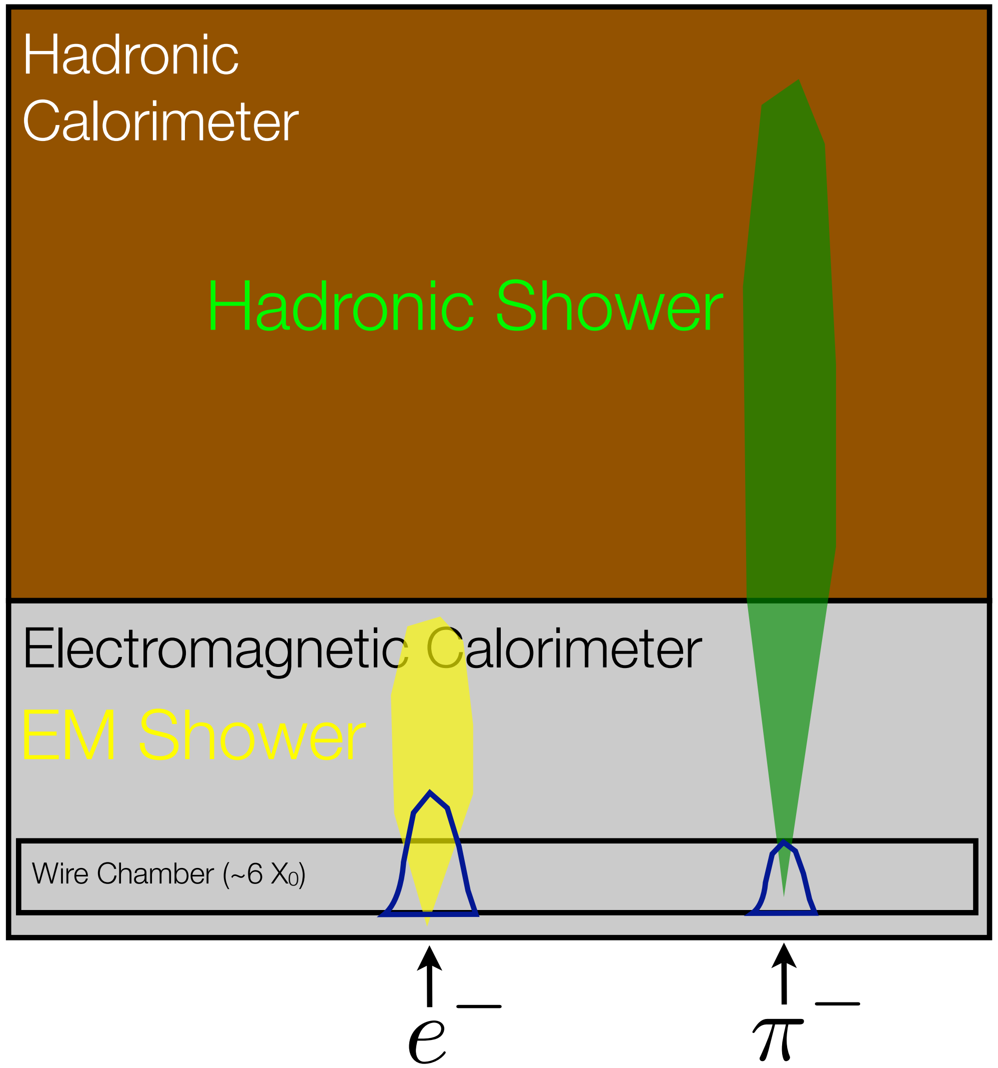


Electron Identification at CDF



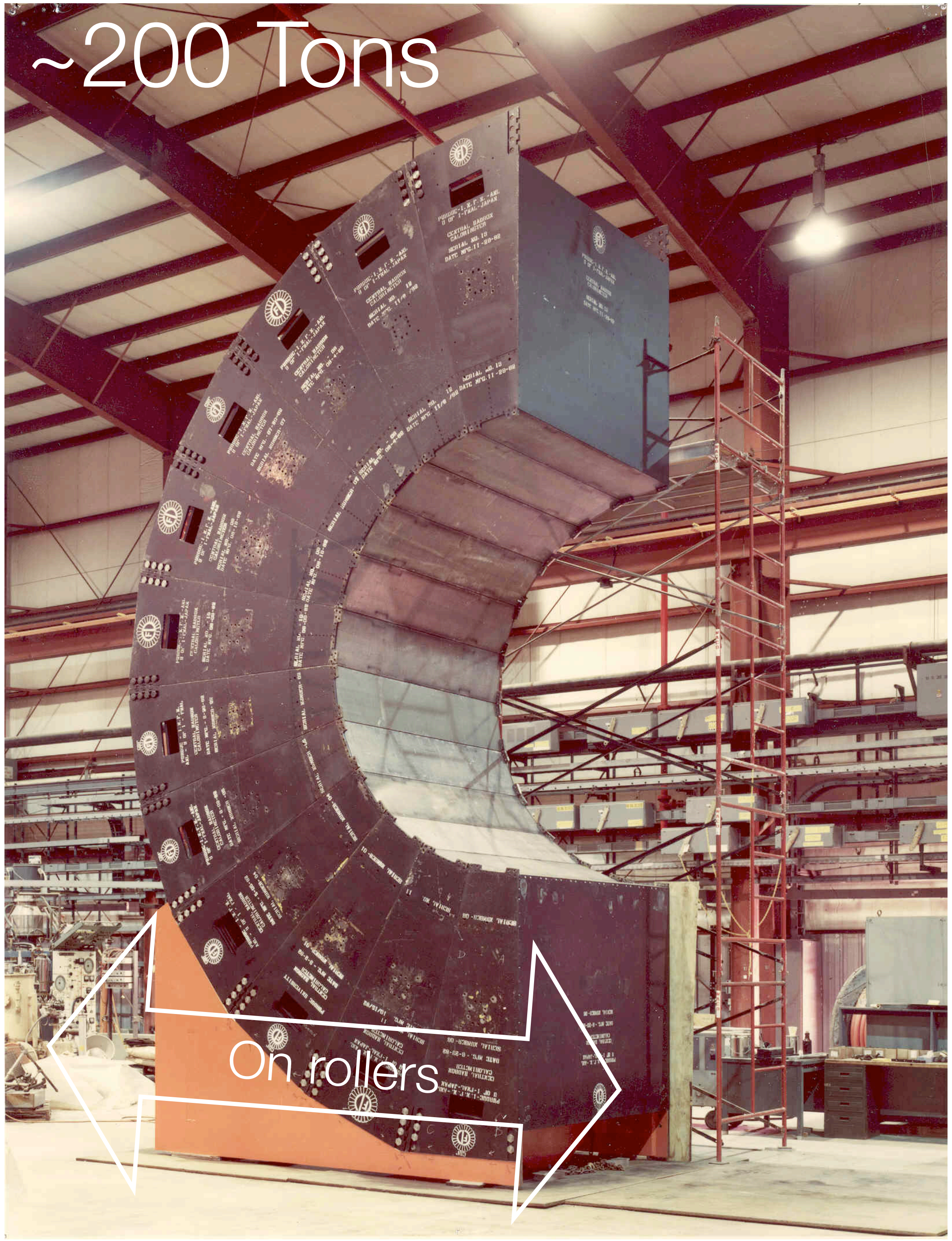
CDF's Calorimeters

- Electrons and photons interact mainly with EM field of nucleus
  - Bremsstrahlung, Compton scattering, pair-production, photoelectric effect
  - Relevant scale is radiation length, X_0
- Hadrons interact mainly with nuclei
  - Relevant scale is nuclear interaction length, λ
- Electromagnetic Calorimeter ~fully contains EM shower
- Hadronic Calorimeter measures penetrating hadronic shower



Calorimeter	EM Depth	HAD Depth	X_0/λ
EM (Pb/Scintillator)	$18\ X_0$	0.6λ	30.5
HAD (Fe/Scintillator)	$46.4\ X_0$	$5.2\ \lambda$	8.9

CDF Central Calorimeter



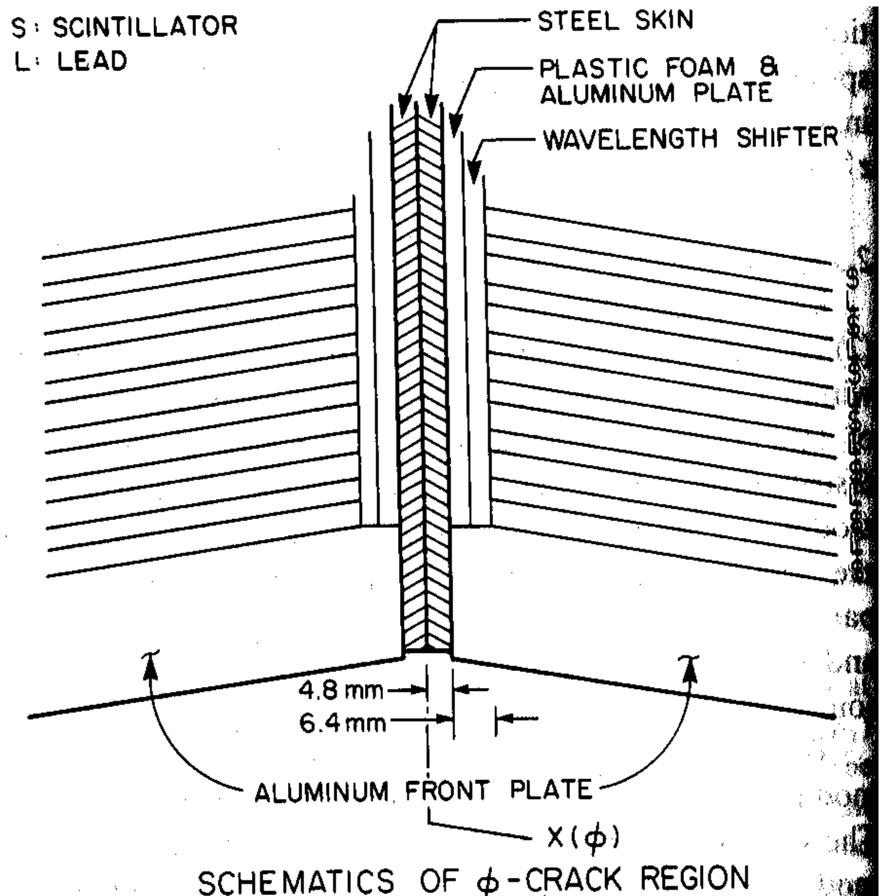
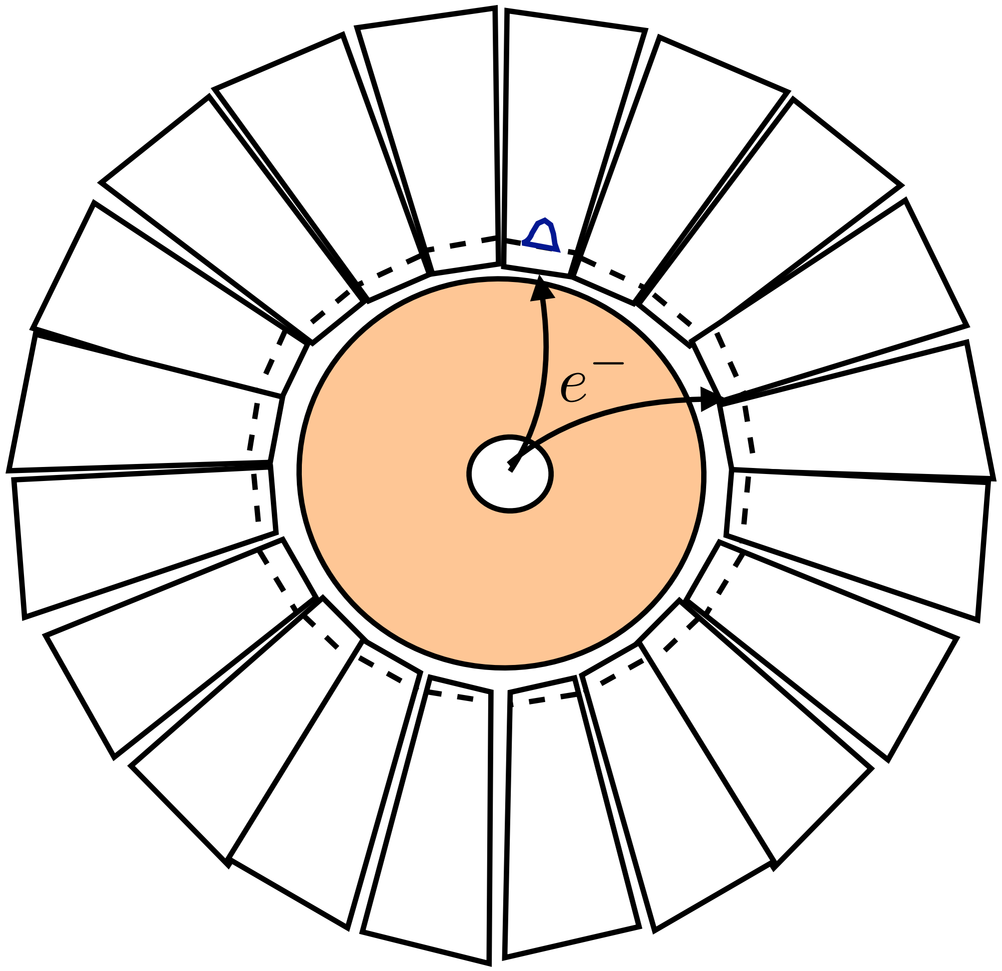
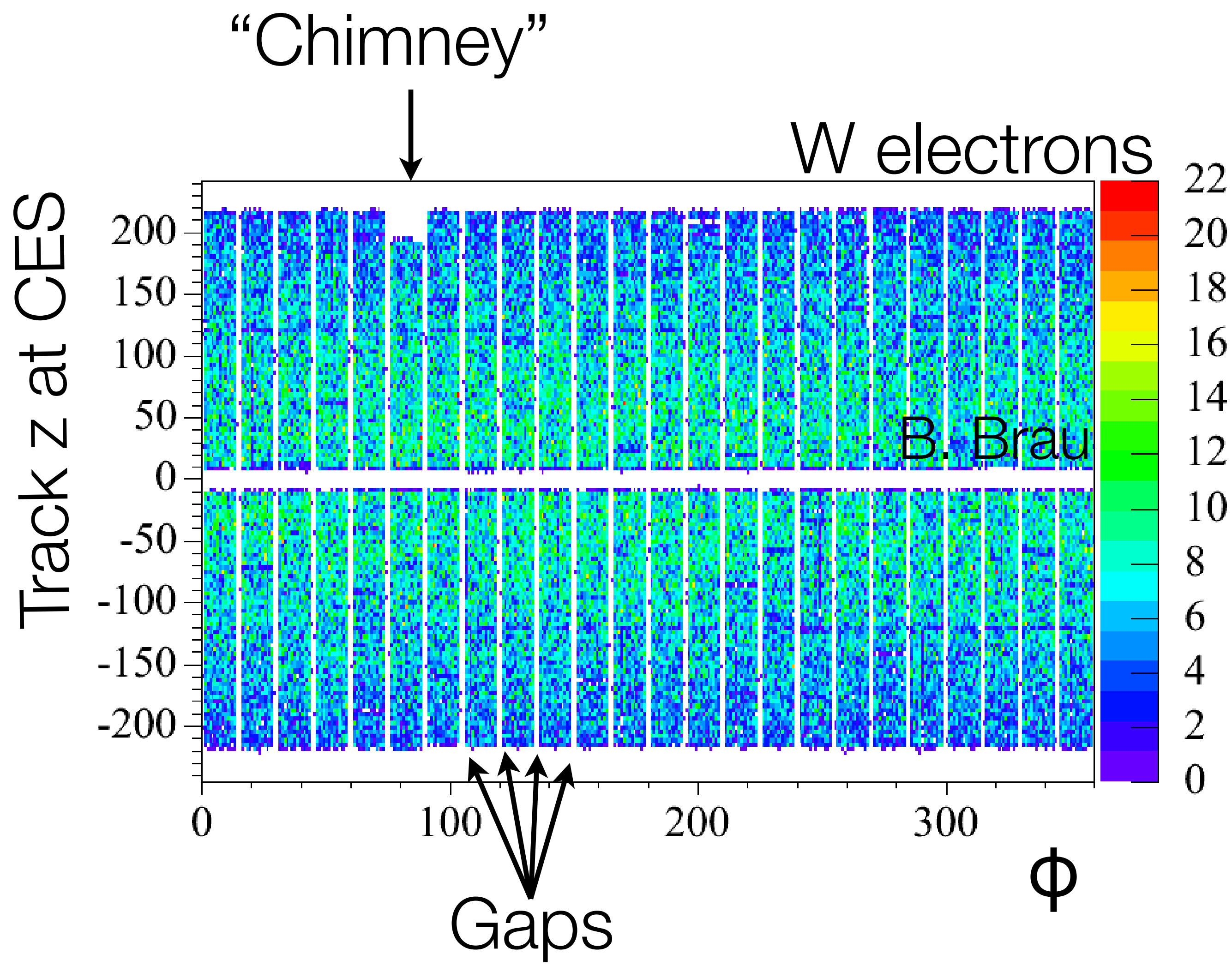


Fig. 6. Schematics of ϕ-cracks region.

- Wedge geometry
  - Has gaps between wedges
- Each of four arches on rollers

Central Calorimeter Coverage

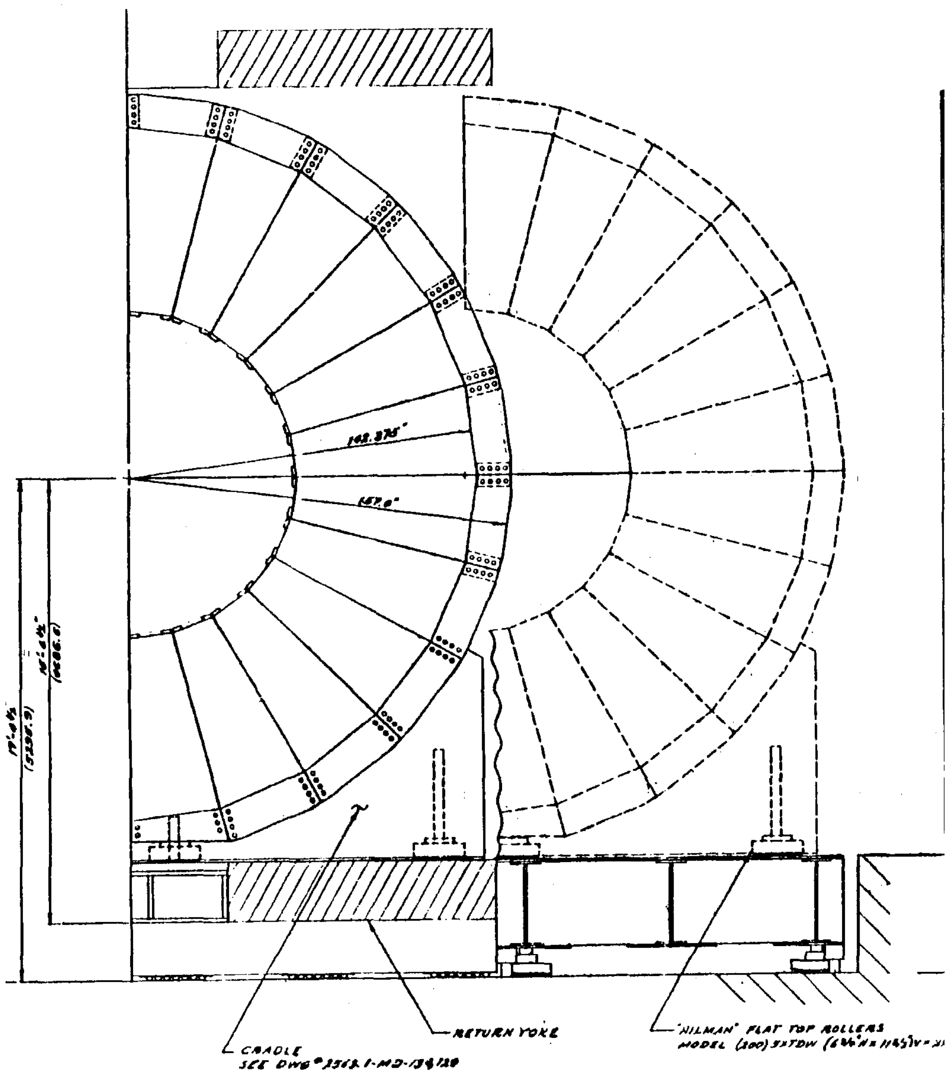


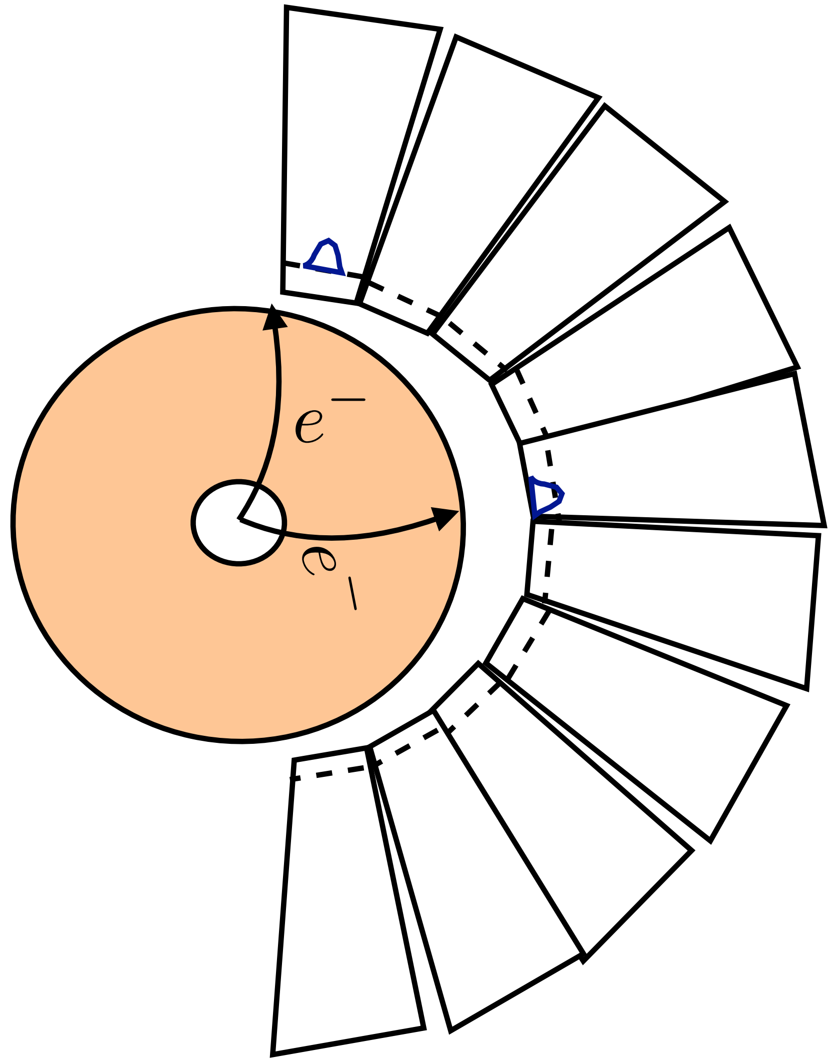


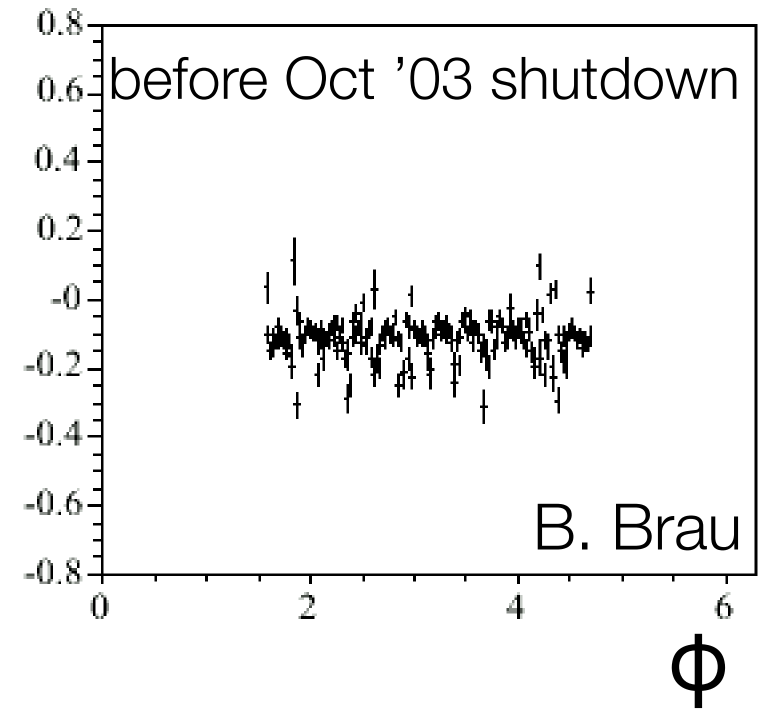
- Electrons are required to be Fiducial
  - Ensures E well-measured
- Gaps in coverage:
  - Chimney

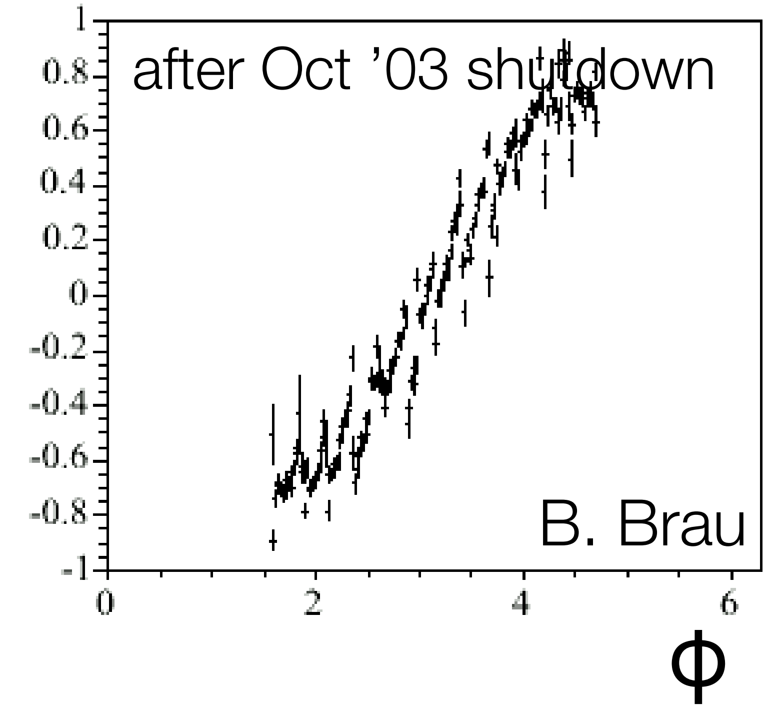
- 18cm between arches at z=0
- Each wedge loses 2/15 in ϕ
- Total: 18% of acceptance for $|\eta| < 1$ missing

Displaced Calorimeter Arches









- Δz_{CES}, $\Delta x_{CES} \cdot q$ used to identify electrons
- Position resolution ~few mm
- Found two of the central calorimeter arches weren’t quite put back after a shutdown

Optimized Electron Selection

- One Central "Seed" Electron (satisfying trigger requirements):
  - High-momentum track pointing at calorimeter
  - Fiducial (energy well-measured)
  - Isolated from other energy deposits
  - $E_T > 20$ GeV
  - E_{HAD}/E_{EM} consistent with an Electromagnetic Shower
  - Shower profile consistent with a Electromagnetic Shower
- Central and Forward Optimized electrons:
  - Medium-momentum track pointing at Central calorimeter
  - Fiducial (energy well-measured)
  - Isolated from other energy deposits
  - $E_T > 5$
  - E_{HAD}/E_{EM} consistent with an Electromagnetic Shower
  - Pseudorapidity < 2.5
- Isolated track electrons:
  - Well-measured high-momentum isolated track pointing at gaps in calorimeter coverage

Z→ee Yields

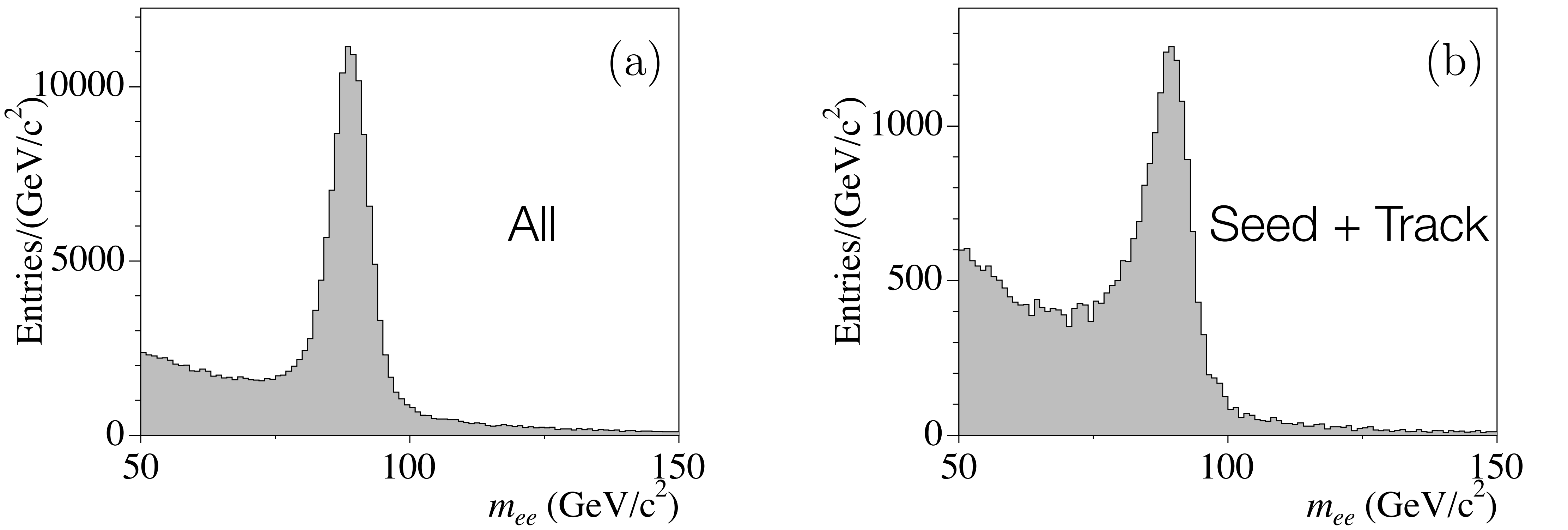


Figure 1: Distribution of m_{ee} for Z^0 candidates formed from a "seed" electron candidate together with a second electron candidate in data (a), and the subset of Z^0 candidates formed from a "seed" electron candidate and an isolated track (b).

- Approximately 100,000 Z candidates in 1.1 fb^{-1}
- Approximately 10,000 Z candidates from CEM + isolated track

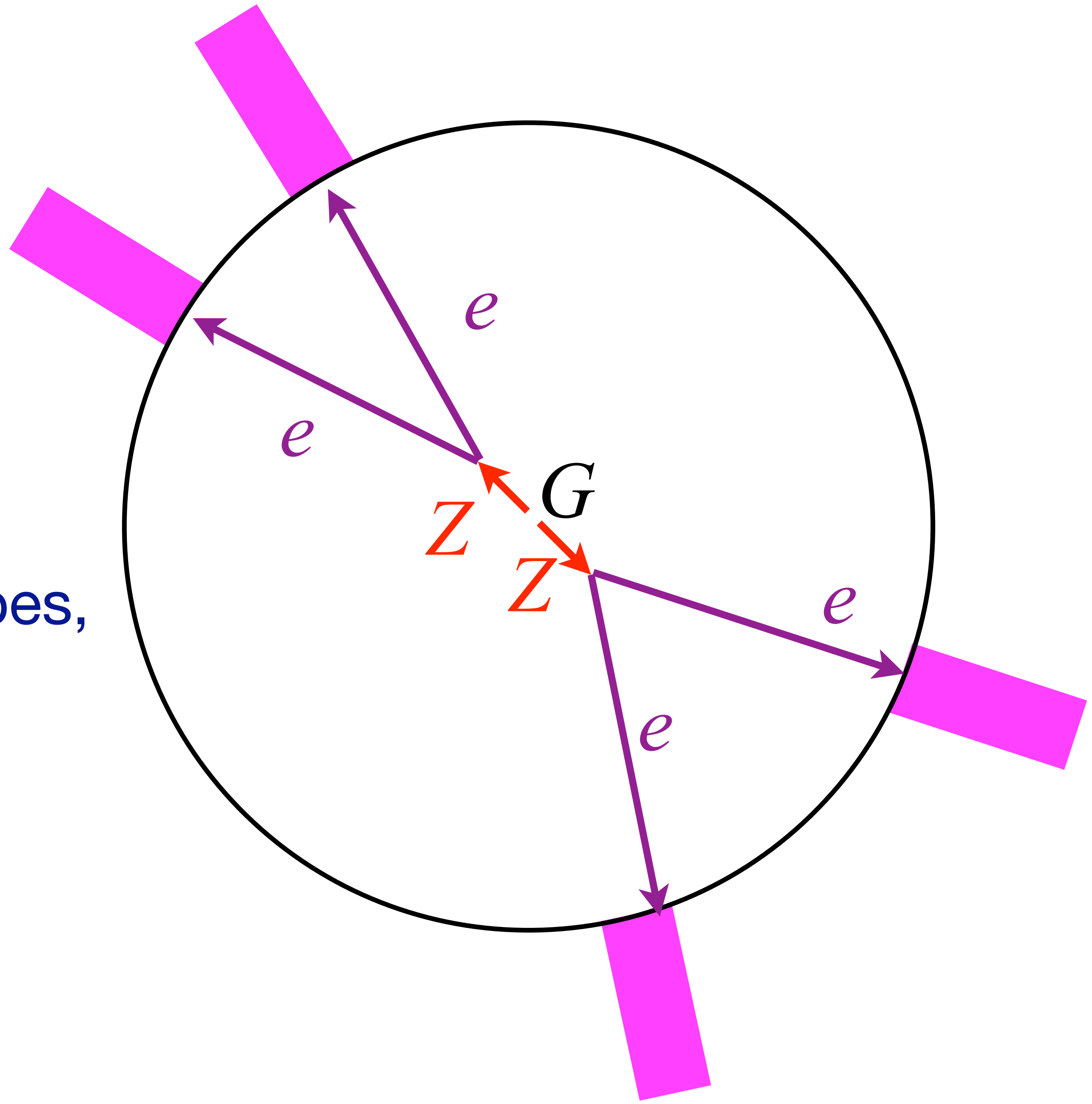
X→ZZ→eeee Signal Reconstruction: m_{eeee}, χ^2

- Look for events with ≥ 4 electrons
- For each ZZ combination, compute

$$\chi^2 = \sum \left(\frac{m_{ee} - m_{Z^0}}{\sigma} \right)^2$$

- σ ~2.5-4.5 GeV, depends on electron types, E_T
- Keep one combination with smallest χ^2 value
- Require $\chi^2 < 50$ (ε~93% in signal MC).
- Hidden signal region:

  $m_{eeee} > 500$ GeV, $\chi^2 < 50$



RS1 Signal MC

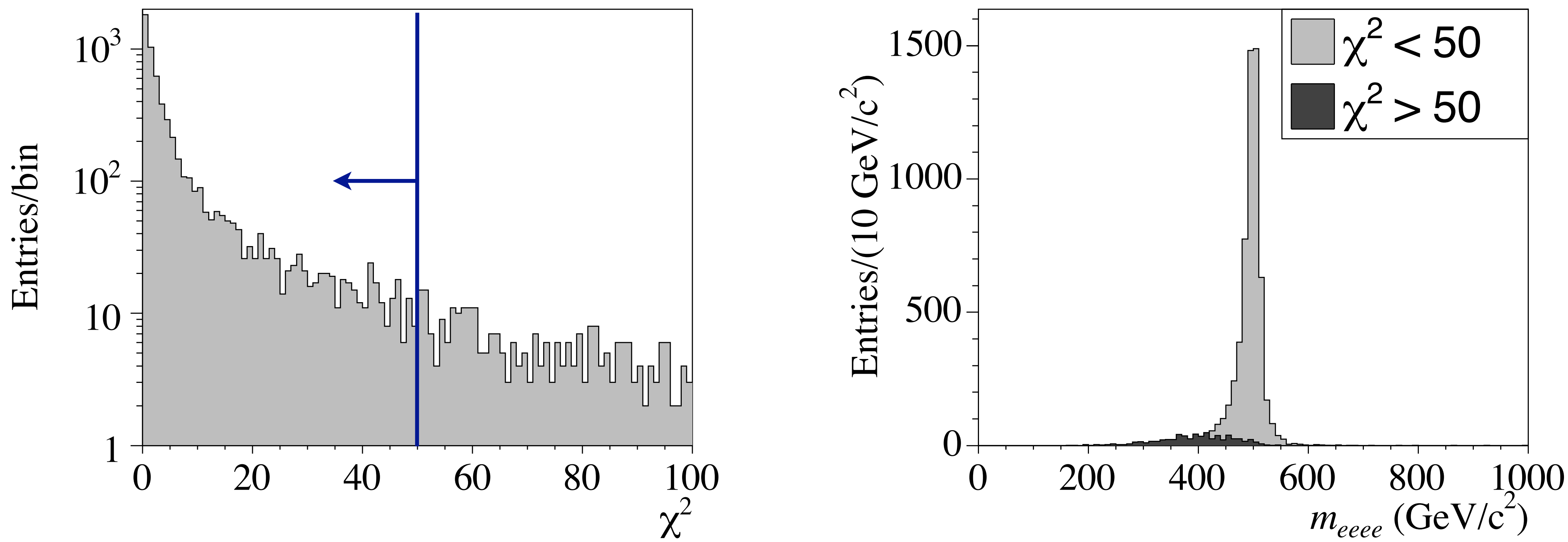
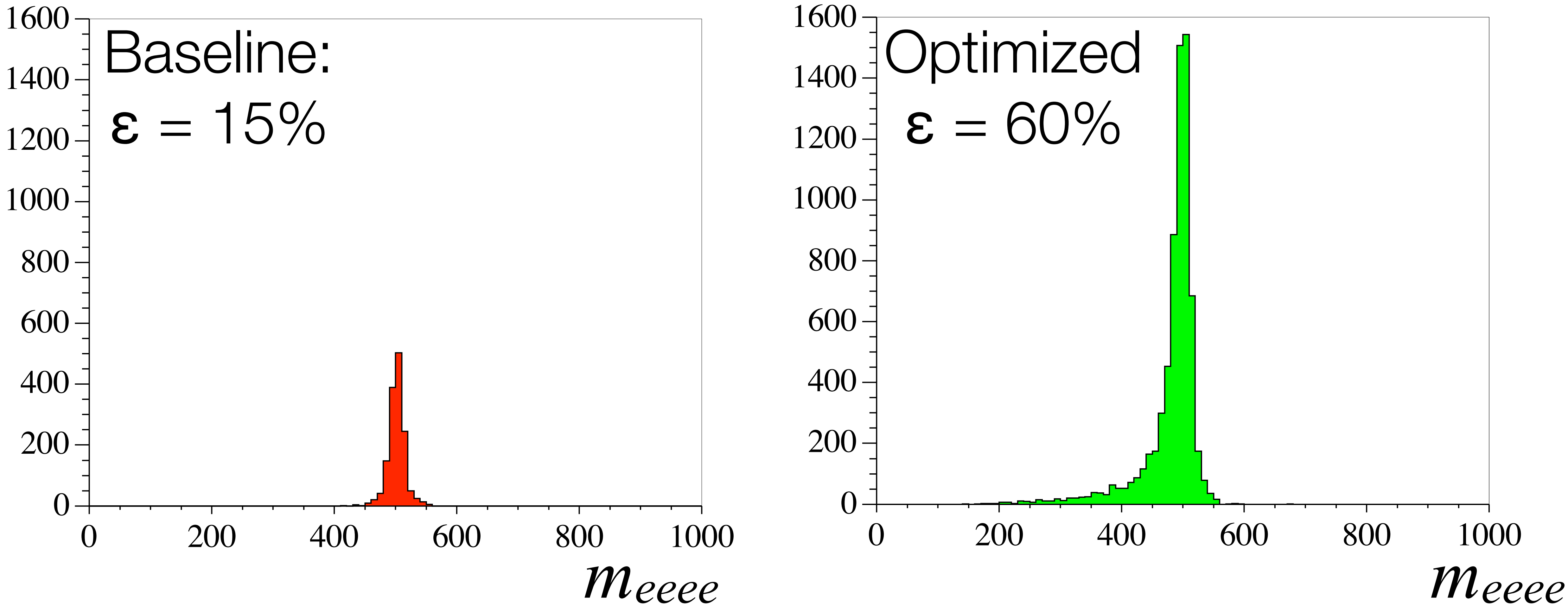


Figure 2: Distribution of χ^2 for simulated Randall-Sundrum signal scenario (m_G = 500 GeV/c^2) (top). Four-electron invariant mass distribution for events satisfying $\chi^2 <$ 50 (gray) and for events which fail this requirement (black) (bottom).

- Requiring $\chi^2 < 50$ is efficient for ZZ signal
- Acceptance times efficiency ~50-60%, depending on mass

Graviton Yield in Simulated Events



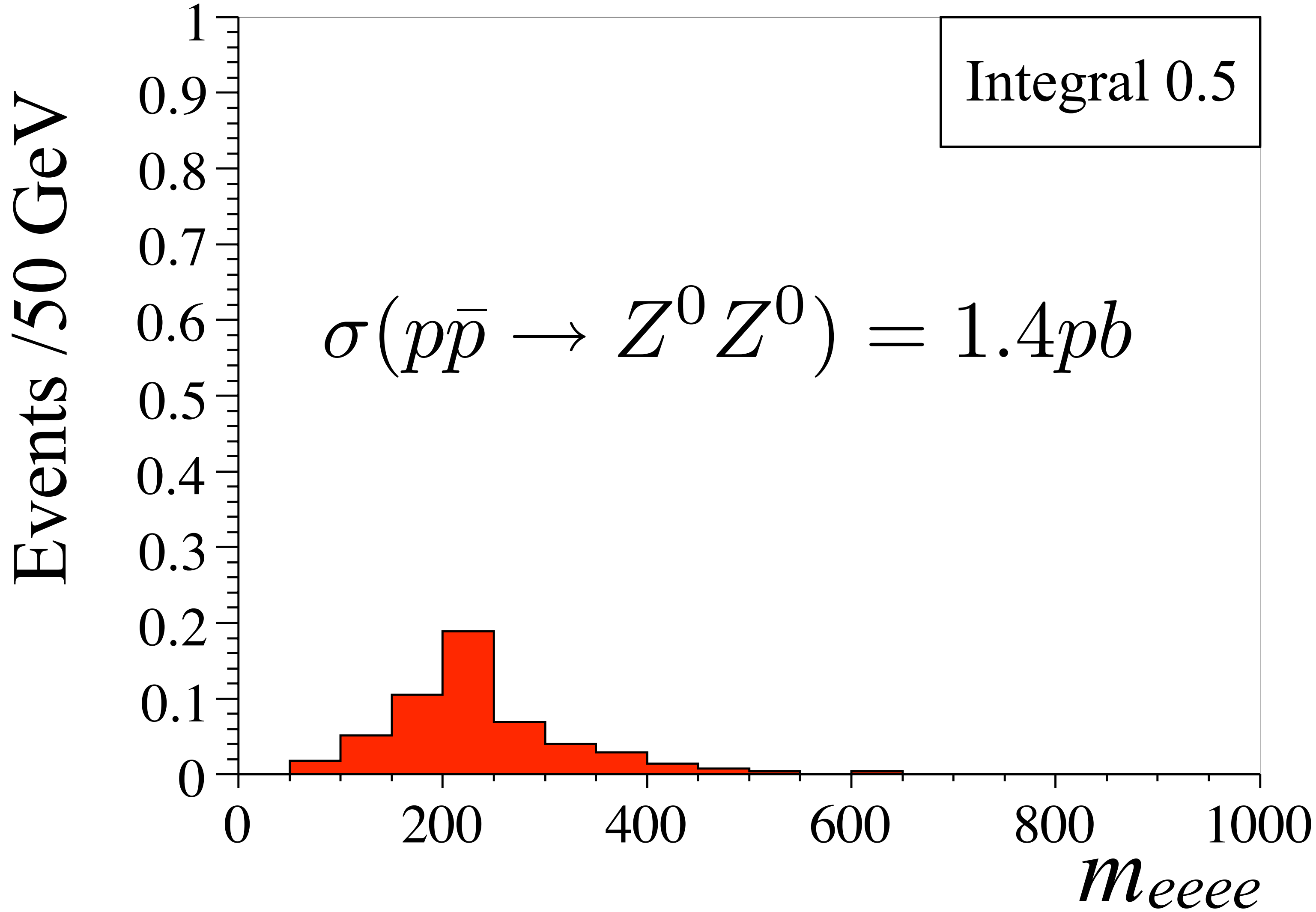
- Optimized selection has approximately four times acceptance times efficiency than standard selection for this four-electron signature

G→ZZ→eeee Backgrounds

- Tiny, but must quantify to establish significance of signal or set limits
- Four real electrons
  - Standard model ZZ production
  - Pythia MC prediction: 0.008 ± 0.006 events in search window ($\chi^2 < 50$, $m_{eeee} > 500$ GeV)
- Events where one or more hadrons (from jets) is misidentified as an electron
  - Z + jets, W + jets
  - QCD multijet

  ➡ Estimate with data

Standard model ZZ background

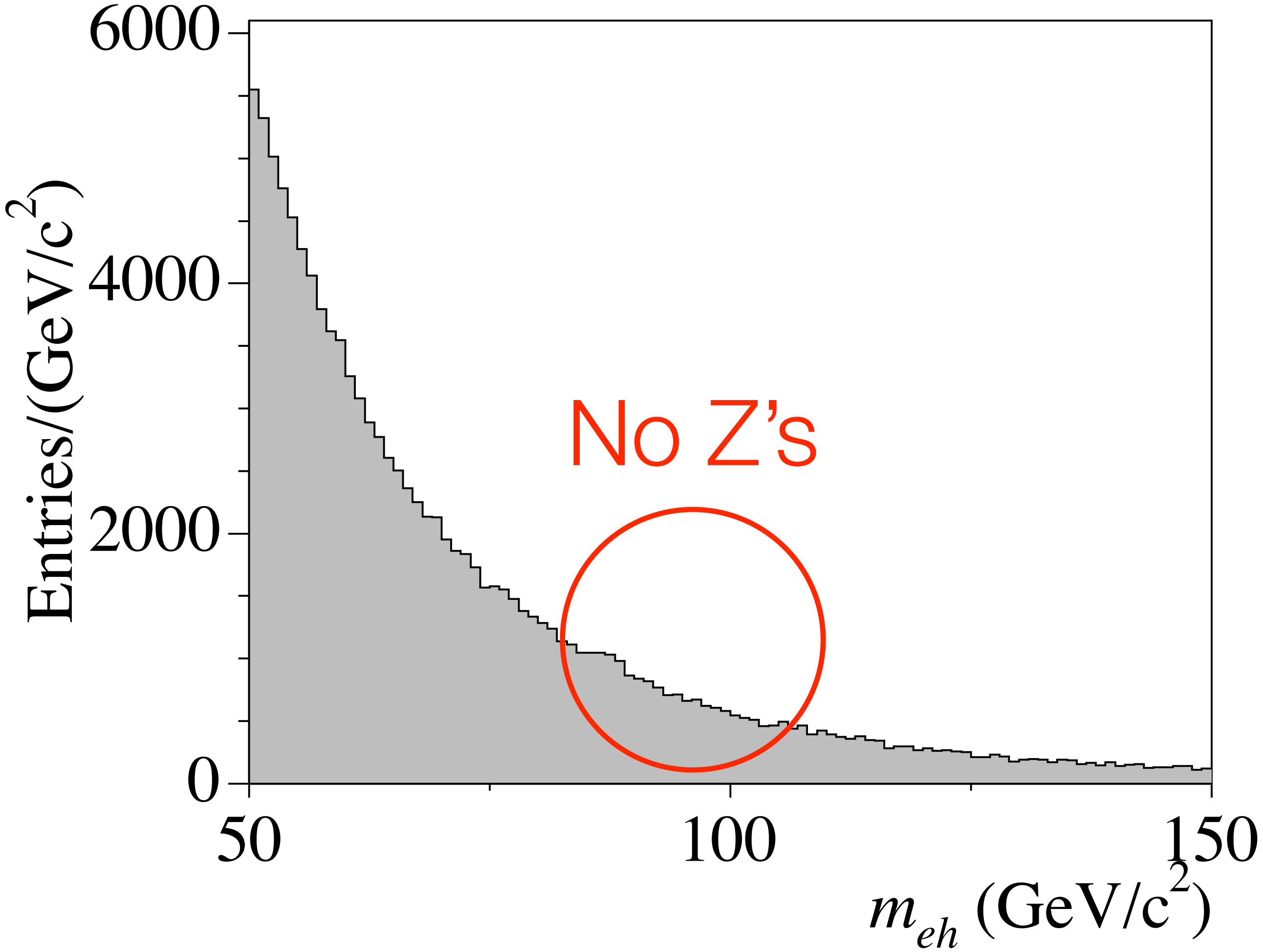


- Standard model ZZ production has four electrons
- Is non-resonant

- Use Pythia MC:
  - Expect 0.008 standard model ZZ events total for $m_{eeee} > 500$ GeV in 1.1/fb

Misidentified Electrons: Control Samples

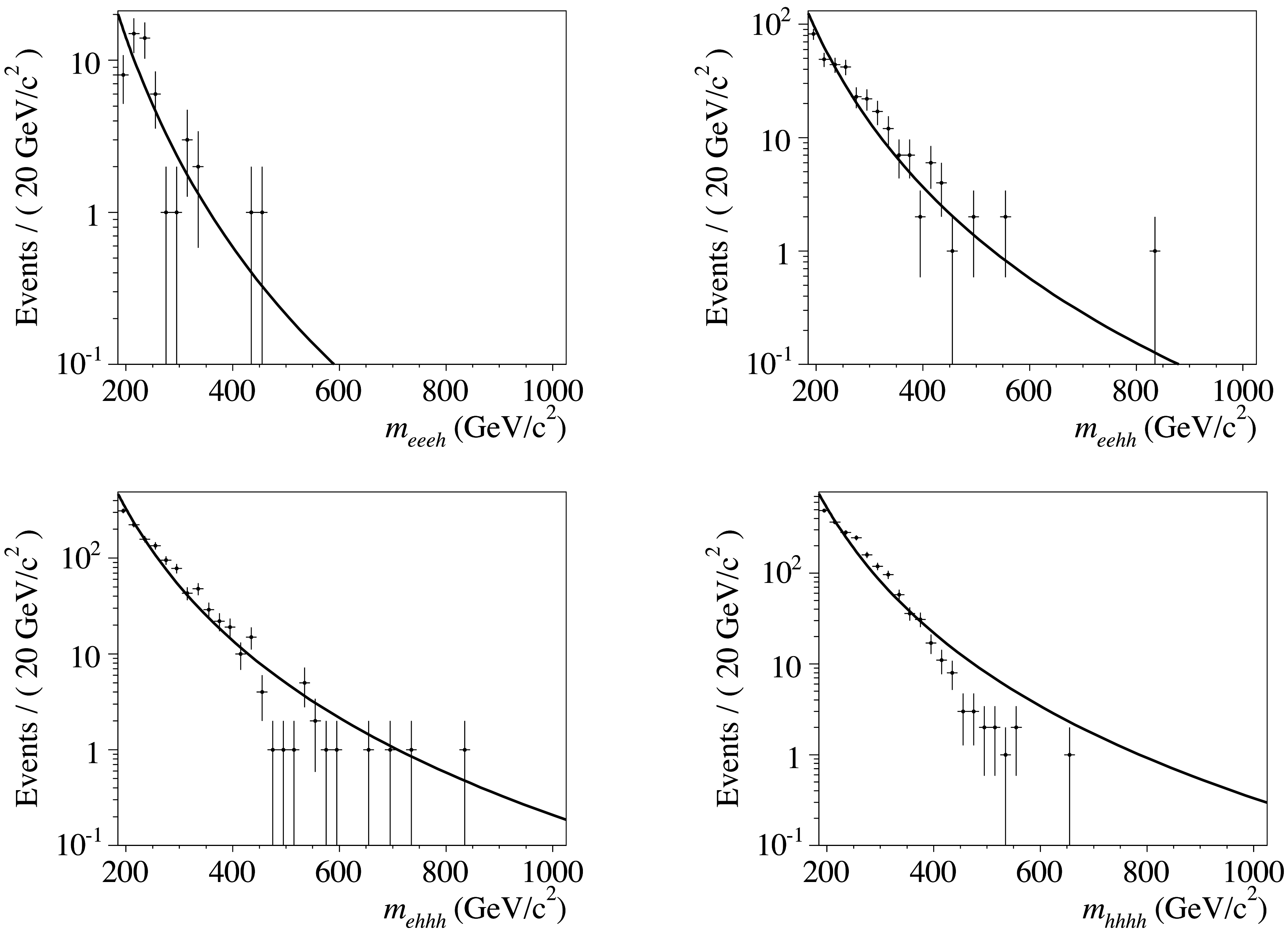
- Use control samples in data to estimate shape and normalization of backgrounds from hadrons misidentified electrons and conversions
- Select ‘hadron’ candidates by inverting & dropping electron selection criteria
- Form ‘fake’ ZZ combinations by using one or more hadron candidates with electron candidates in the event
- Invariant mass of of one seed and one hadron shows no Z peak: few real electrons in the hadron control sample.
- Fit fake ZZ combinations (eeeh, eehh, ehhh, hhhh) invariant mass to extract shape.



Fit to Obtain Background Shape

- Fit to obtain empirical description of background at high m_{eeee}
- Shape is independent of number of hadrons used in combination.
- Normalization fixed by low-mass four-electron sample
- Estimate 0.020±0.009±0.007 events in search region above 500 GeV

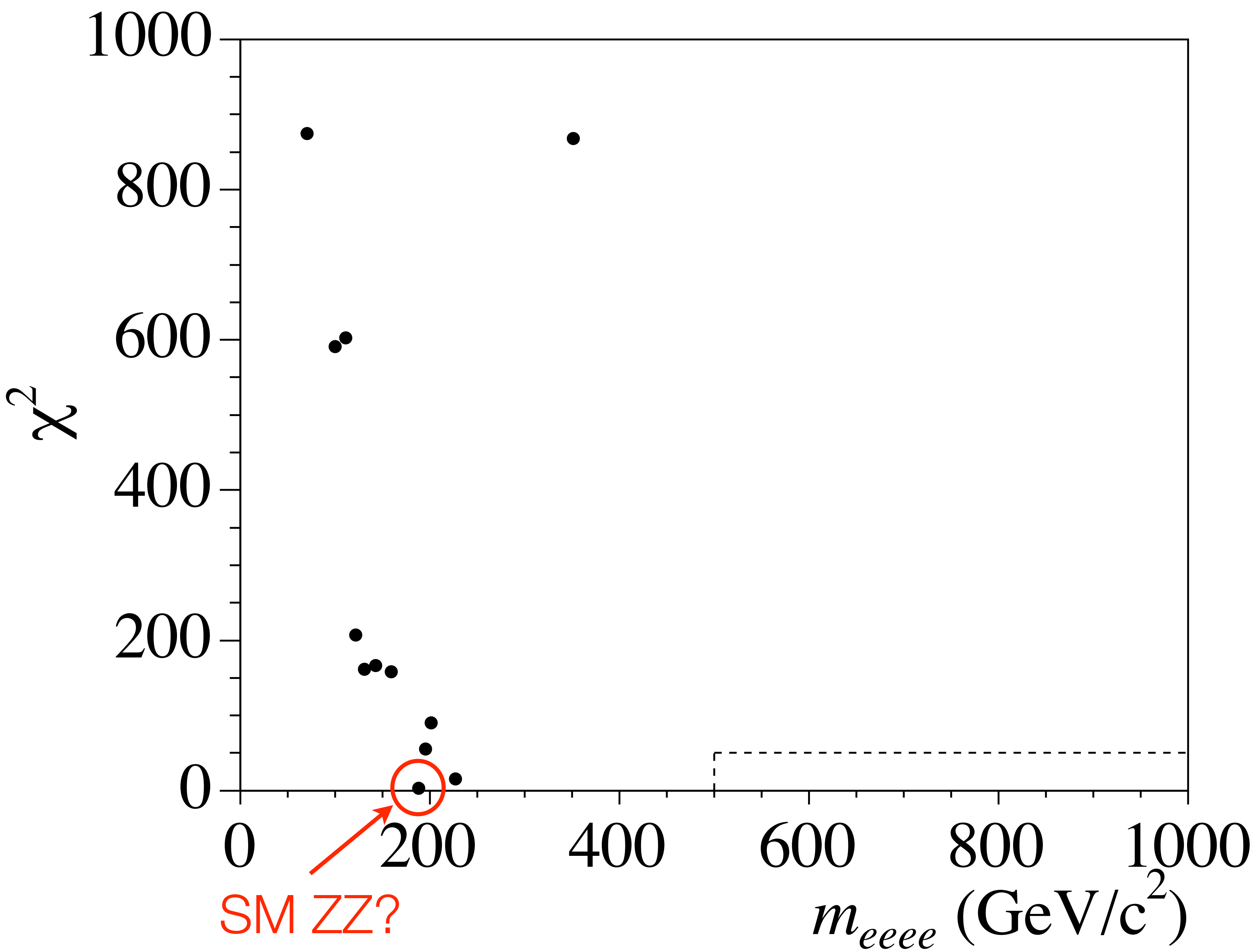
$$f(\chi^2, m_{eeee}) = C m_{eeee}^{\gamma} e^{\chi^2 \tau},$$



Data in the Search Region

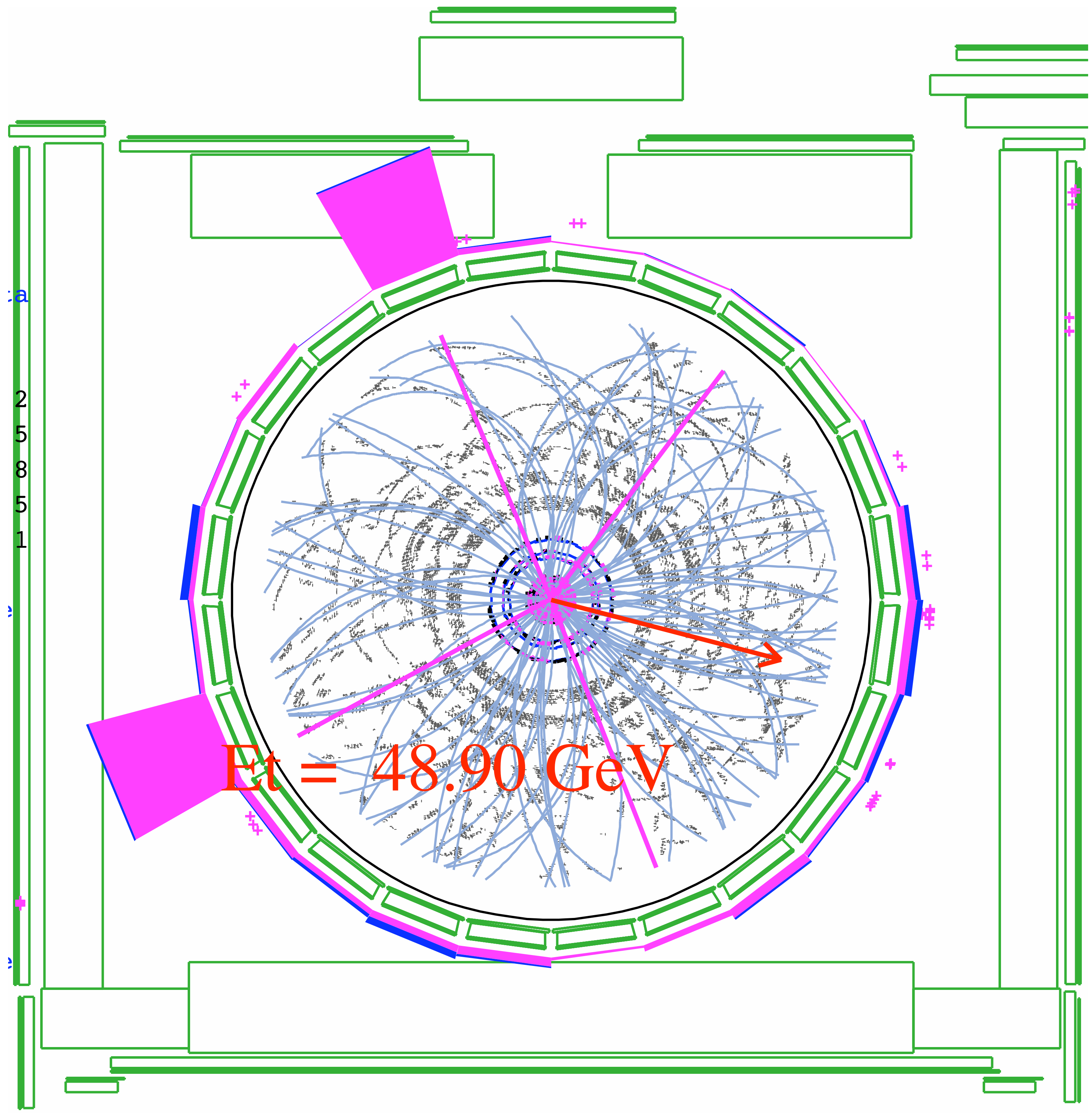
- Total Background events expected in search region:

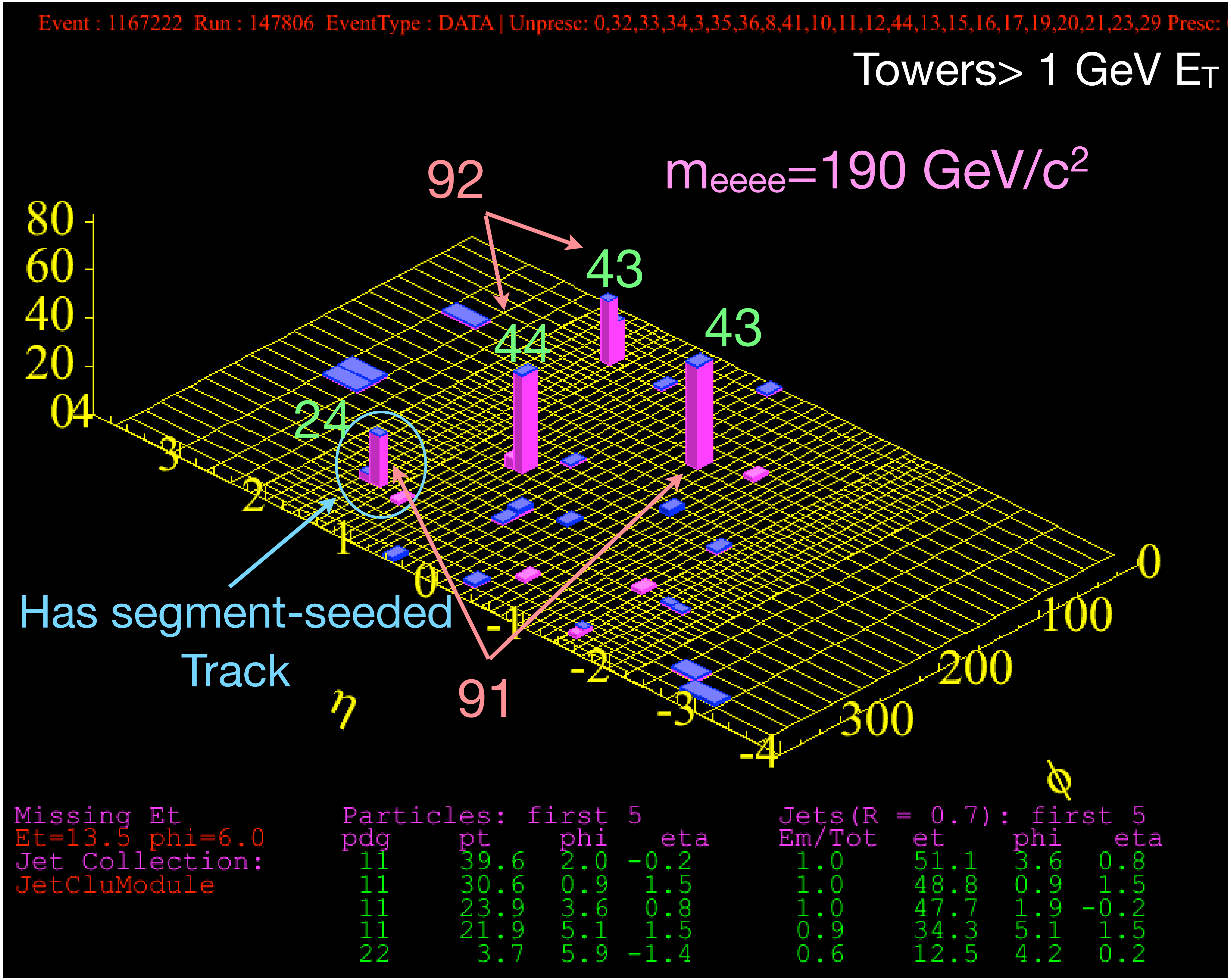
  0.028 ± 0.009 ± 0.011
- Observe none
- One event consistent with SM ZZ production (χ^2=0.29)
- Second lowest event has χ^2=12
  - Passes very loose cut
  - Looks like background upon inspection
- Set limits



Event Displays

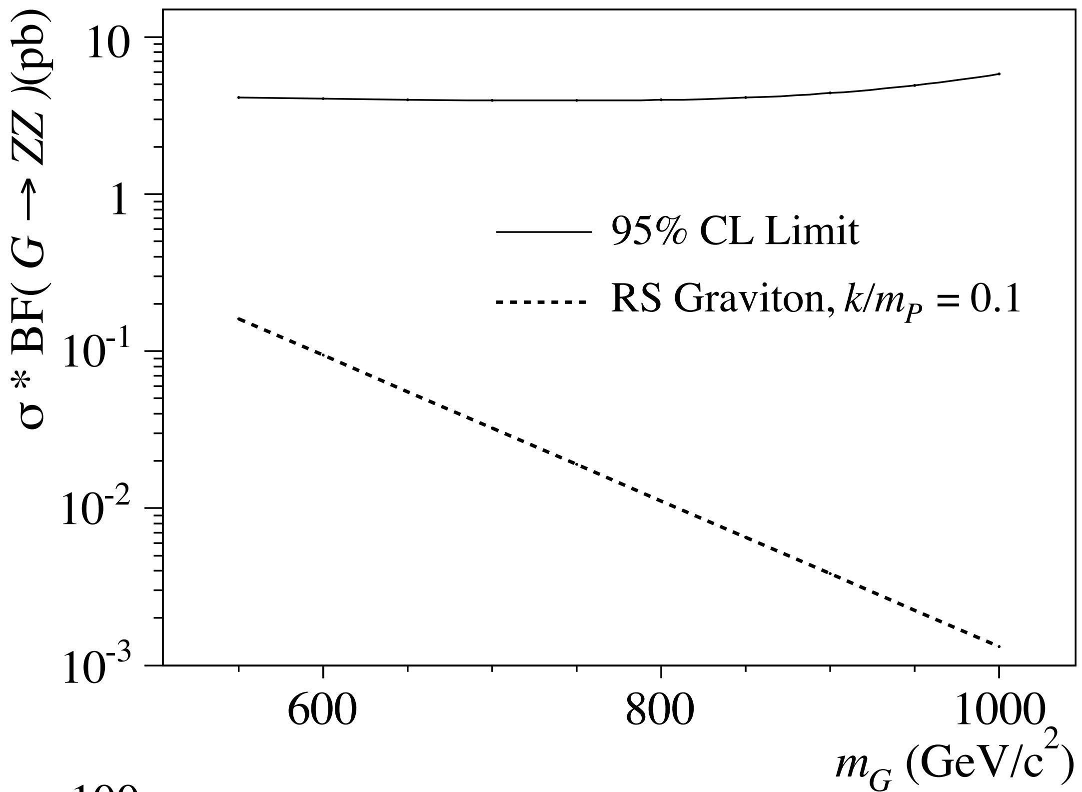
- Two Central e's
- Two Forward e's
  - Have calorimeter-seeded silicon tracks (Phoenix)
- Charge assignment for best pairing is consistent
- Lots of low-p_T activity
- July 6, 2002

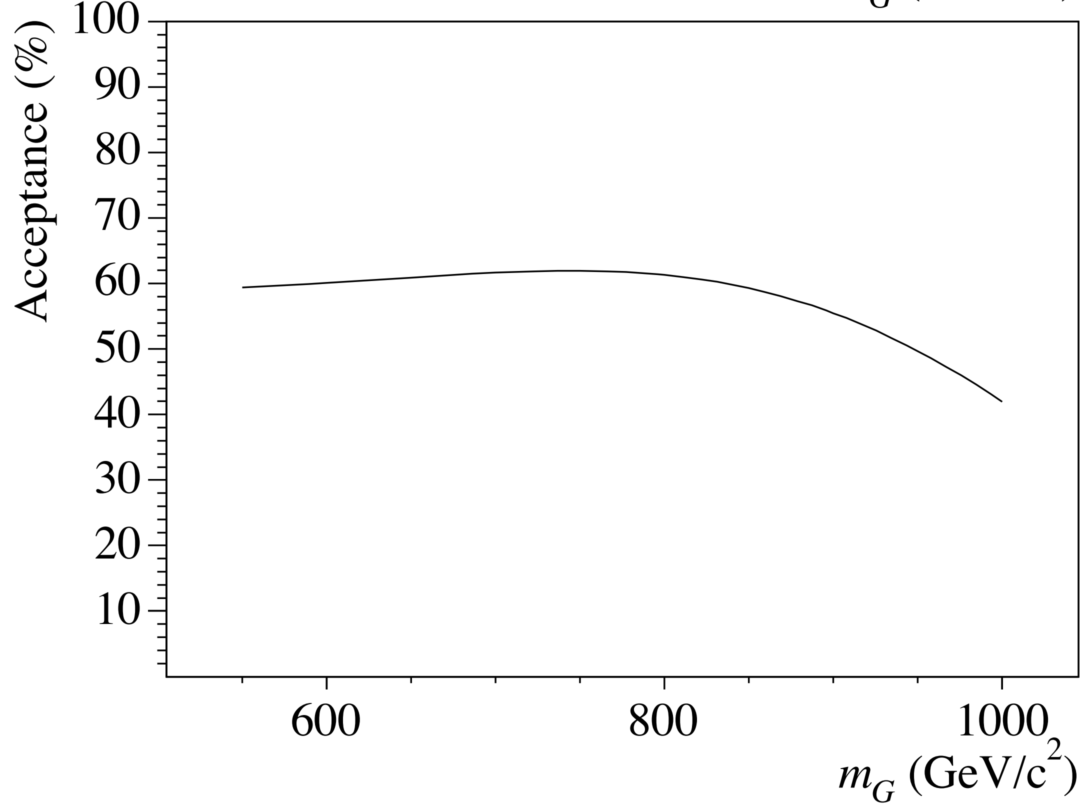



Event : 1167222 Run : 147806 EventType : DATA | Unpresc: 0,32,33,34,3,35,36,8,41,10,11,12,44,13,15,16,17,19,20,21,23,29 Presc:
Towers> 1 GeV ET
meeee=190 GeV/c2
92
43
43
44
24
Has segment-seeded Track
91
η
φ
80
60
40
20
0
3
2
1
0
-1
-2
-3
-4
0
100
200
300
Missing Et
Et=13.5 phi=6.0
Jet Collection:
JetCluModule
Particles: first 5
pdg pt phi eta
11 39.6 2.0 -0.2
11 30.6 0.9 1.5
11 23.9 3.6 0.8
11 21.9 5.1 1.5
22 3.7 5.9 -1.4
Jets(R = 0.7): first 5
Em/Tot et phi eta
1.0 51.1 3.6 0.8
1.0 48.8 0.9 1.5
1.0 47.7 1.9 -0.2
0.9 34.3 5.1 1.5
0.6 12.5 4.2 0.2

Limits on σ × BF(G→ZZ)

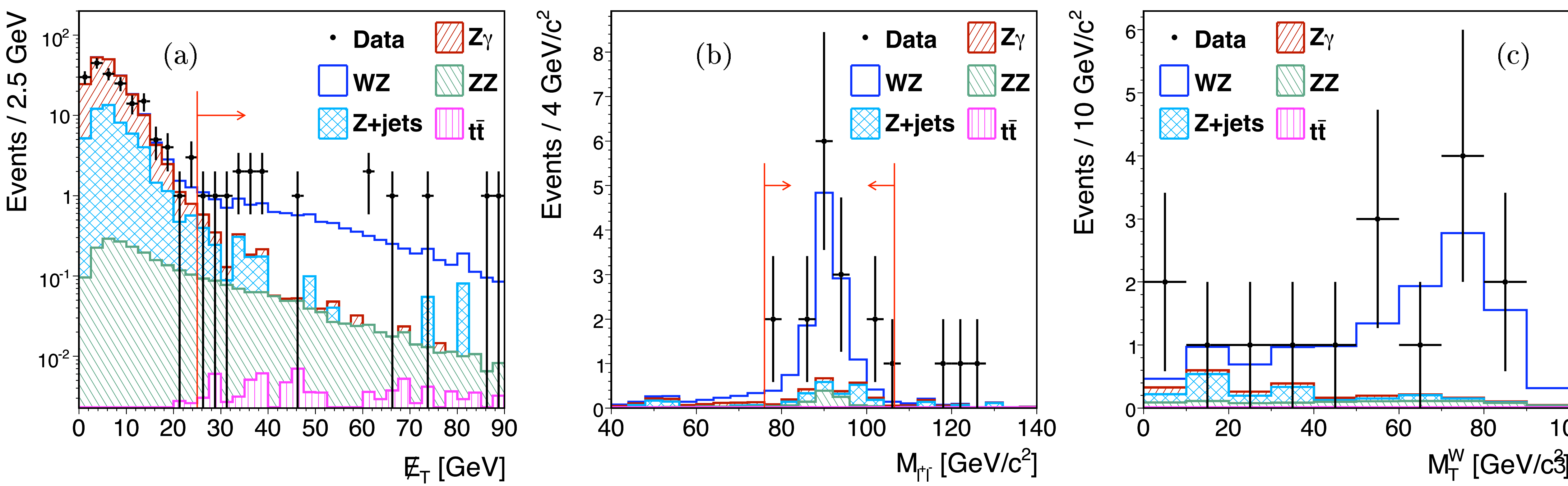
- Limits set in context of RS1 Graviton scenario
- Bayesian binned maximum likelihood method in 100 GeV wide windows
- Systematics included in limit calculation:
  - Luminosity (5.9%)
  - PDF Uncertainties (0.4%)
  - MC Statistics (1.3%)
  - ISR (1.0%)
  - Electron ID (1.0% per electron)
- Limits 4-6 pb, depending on mass.





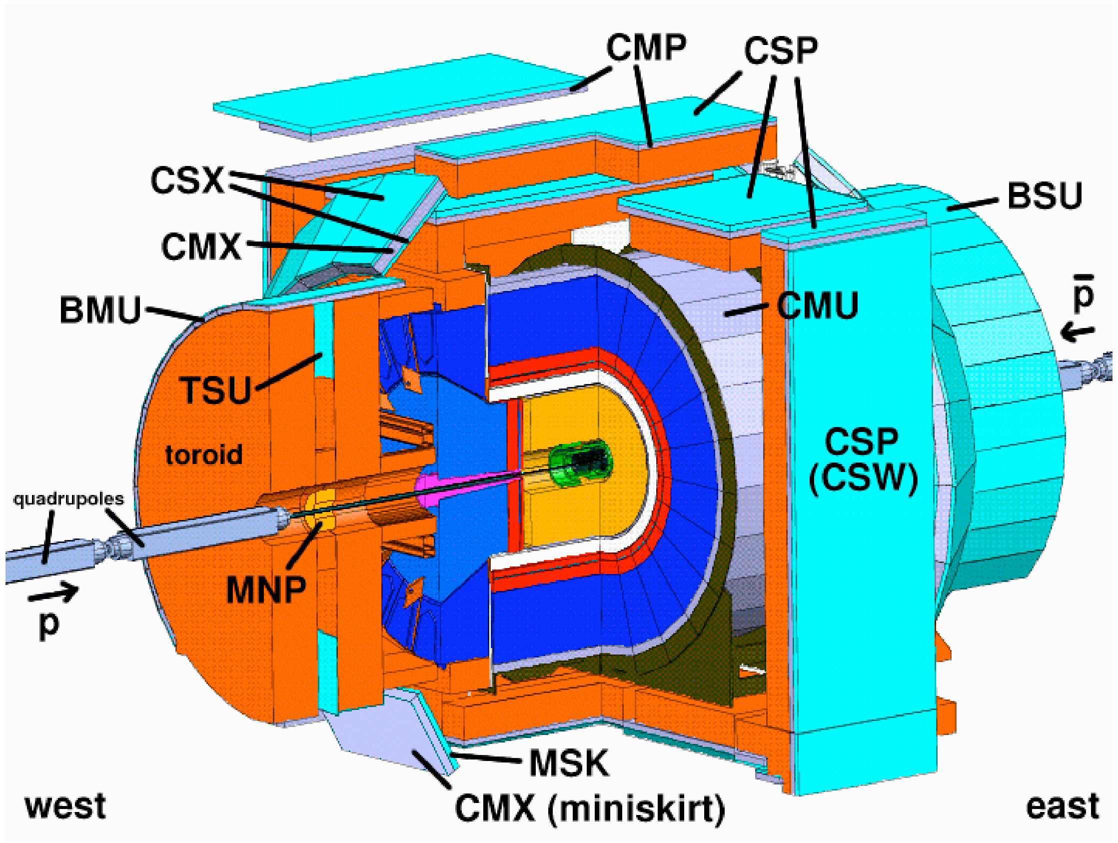
Observation of WZ produciton at CDF

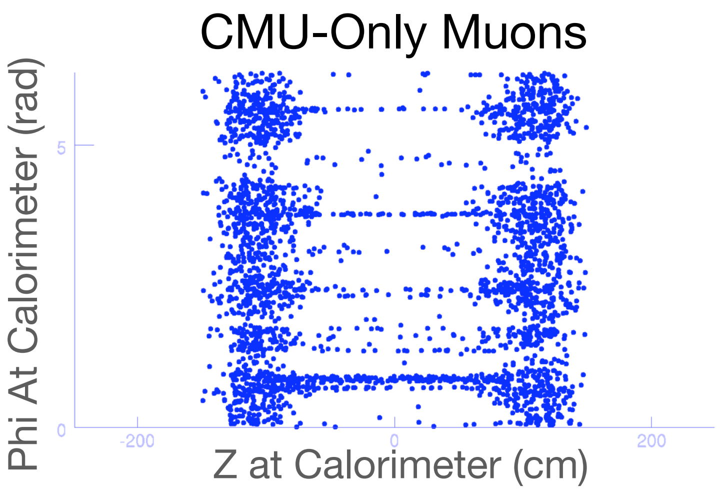
- Other analyses at CDF have employed these techniques to increase lepton acceptance
- Standard model WZ production was observed with 1.1 fb^{-1} with electrons and muons
- Literary member of WZ publicatioin review committee
- Phys. Rev. Lett. **98**, 161801 (2007)

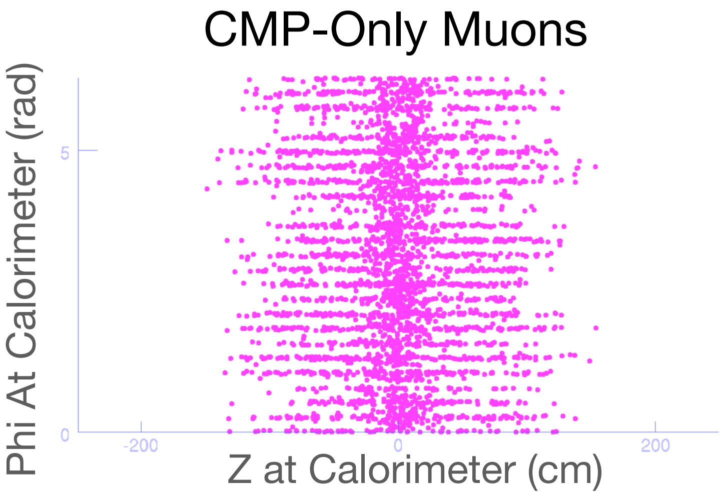


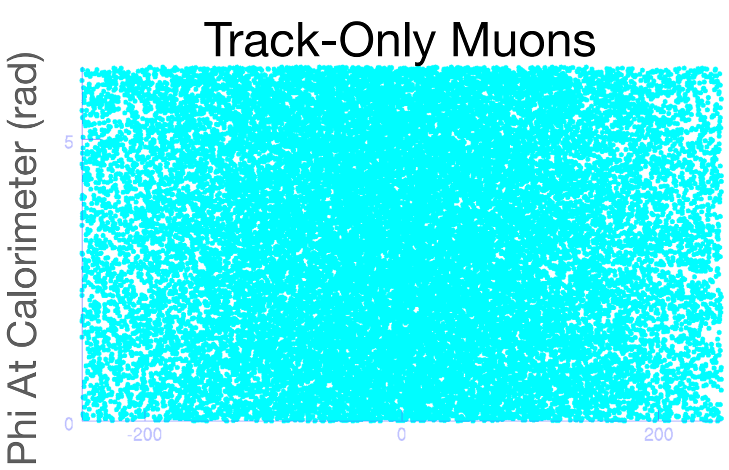
What about Muons?

- Expect 0.33 events /fb^{-1} per $G \rightarrow ZZ \rightarrow llll$ (m_G = 500 GeV, k/M_{Pl} = 0.1)
- Add muons: factor of 4 in acceptance (eeee, eeμμ, μμee, μμμμ)
    - Not quite:
    - Baseline muon selection has worse acceptance than Baseline electron selection:
      Increase Muon Coverage
- Different Background Estimate









Adding Muons

- Momentum measured with track
  - Identified as a muon in muon detectors (stub) or calorimeter (MIP)
  - Resolution becomes important

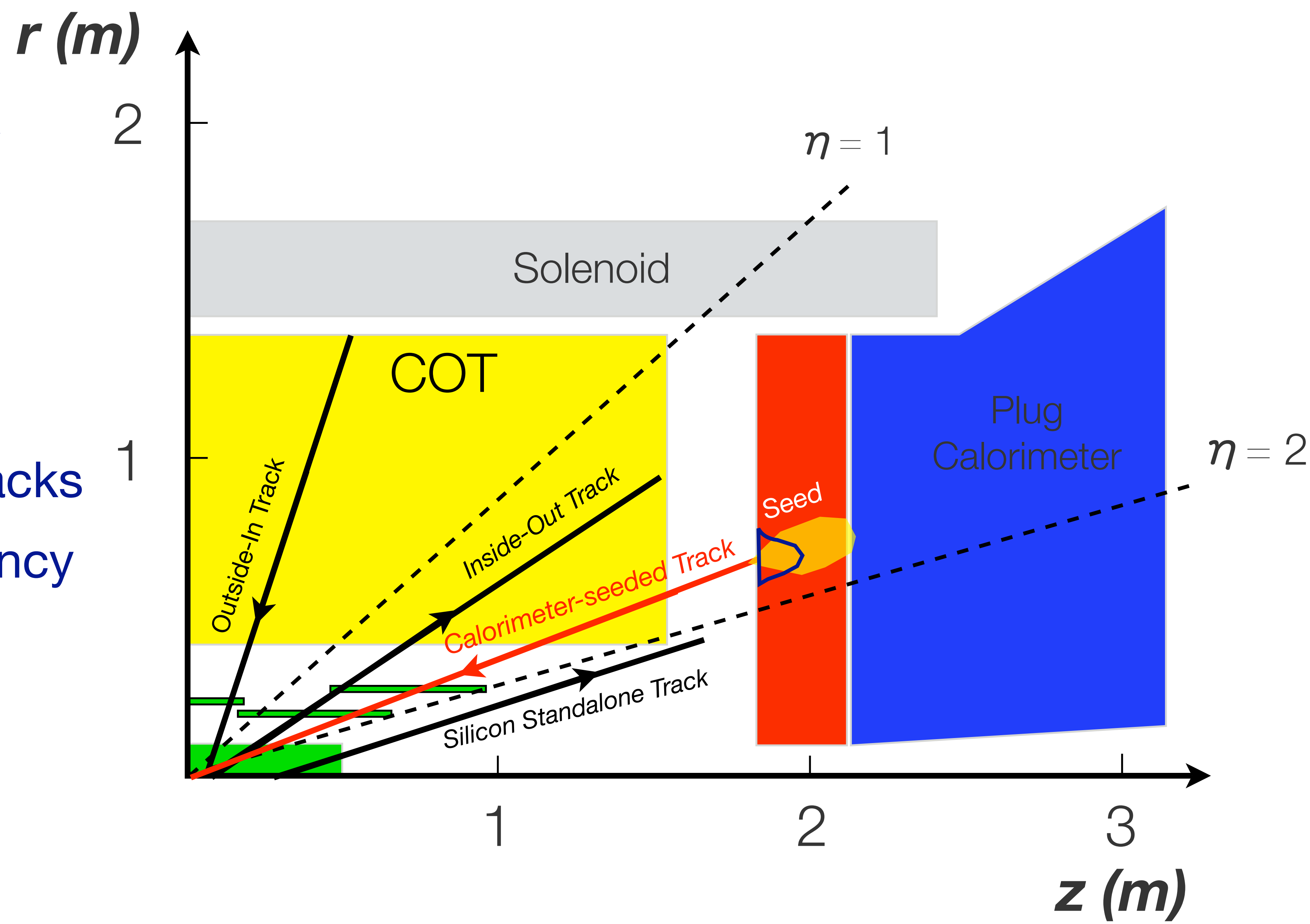
$$\frac{\sigma_E}{E} = \frac{13.5\%}{\sqrt{E}} \quad \frac{\sigma_{p_T}}{p_T} = 0.05\% p_T$$

Lepton	50 GeV	250 GeV
e	2%	0.9%
μ	2.5%	12.5%

- Tracking at CDF is efficient and pure for $|\eta| < 1$
- Forward tracking $|\eta| > 1$ is difficult
- I have worked with a student on a new algorithm to increase pure and efficient tracking coverage to $|\eta| \sim 2$

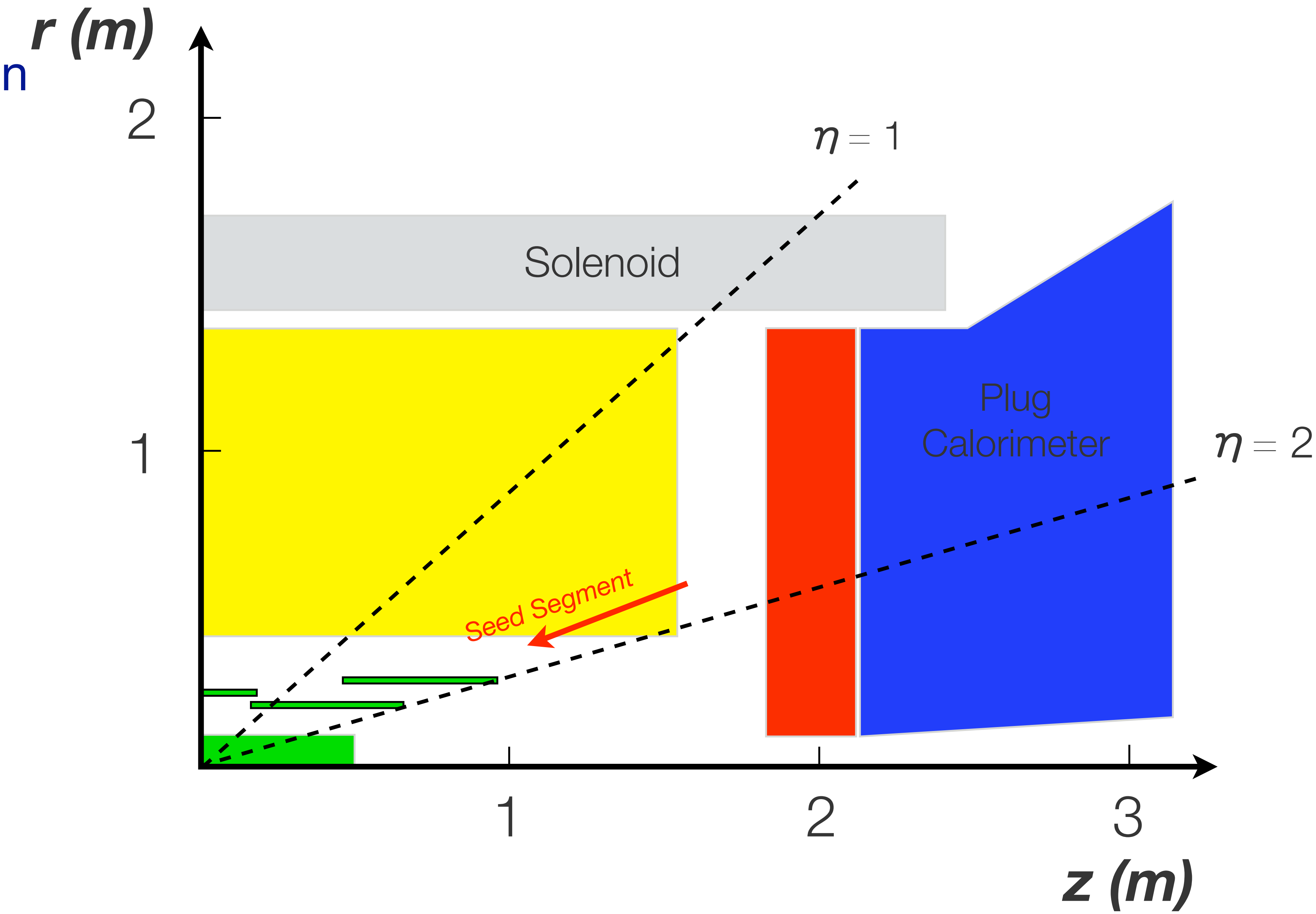
CDF Tracking Algorithms

- Outside-In
  - Efficient when track propagates through entire COT
  - Add Silicon
- Silicon Stand-alone
  - Can find forward tracks
  - Lower purity, efficiency
  - Inside-out
- Calorimeter-seeded (electrons only)



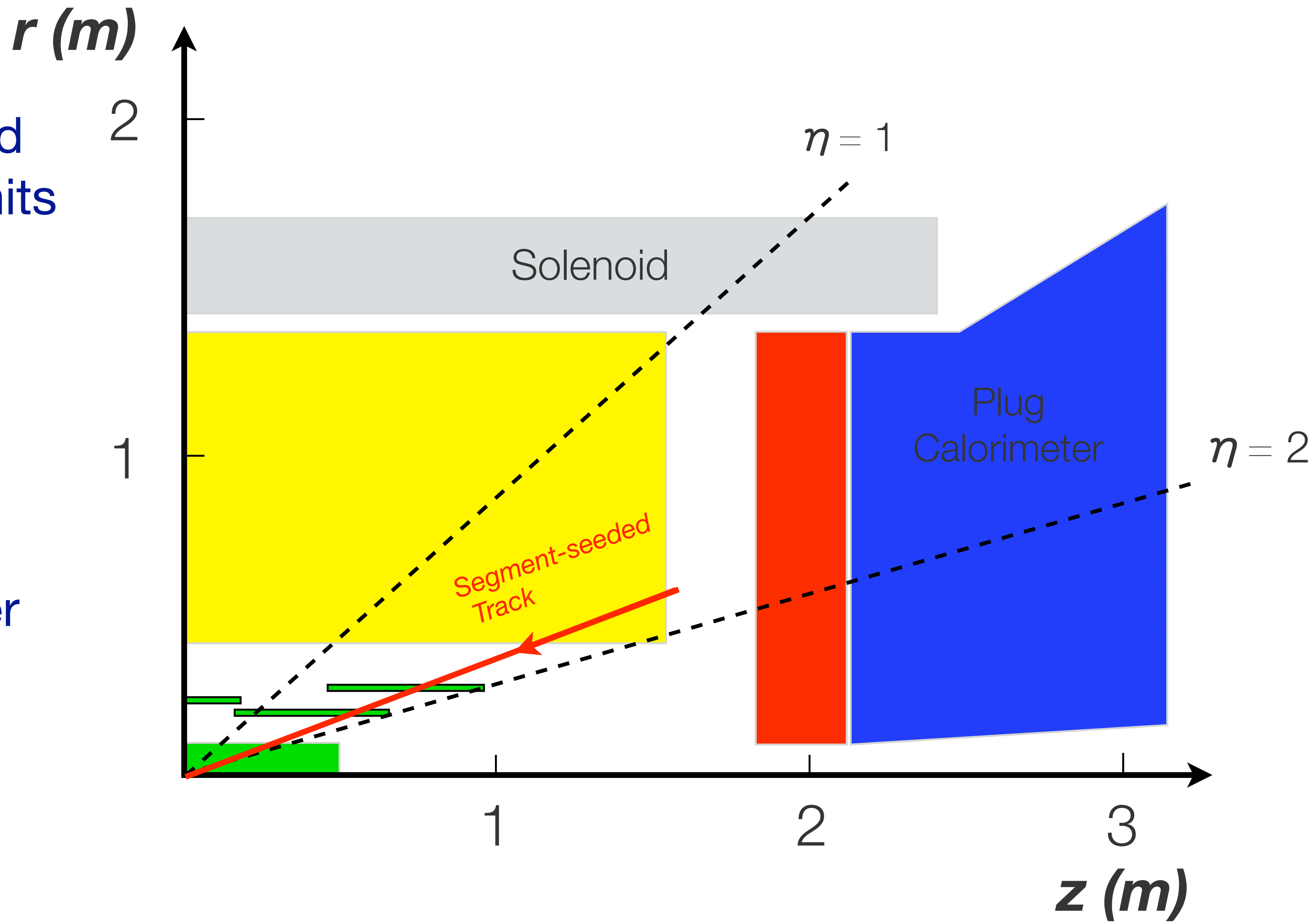
Segment Seeded Tracking

- Can we start with hits in the COT instead of electron measured in calorimeter?

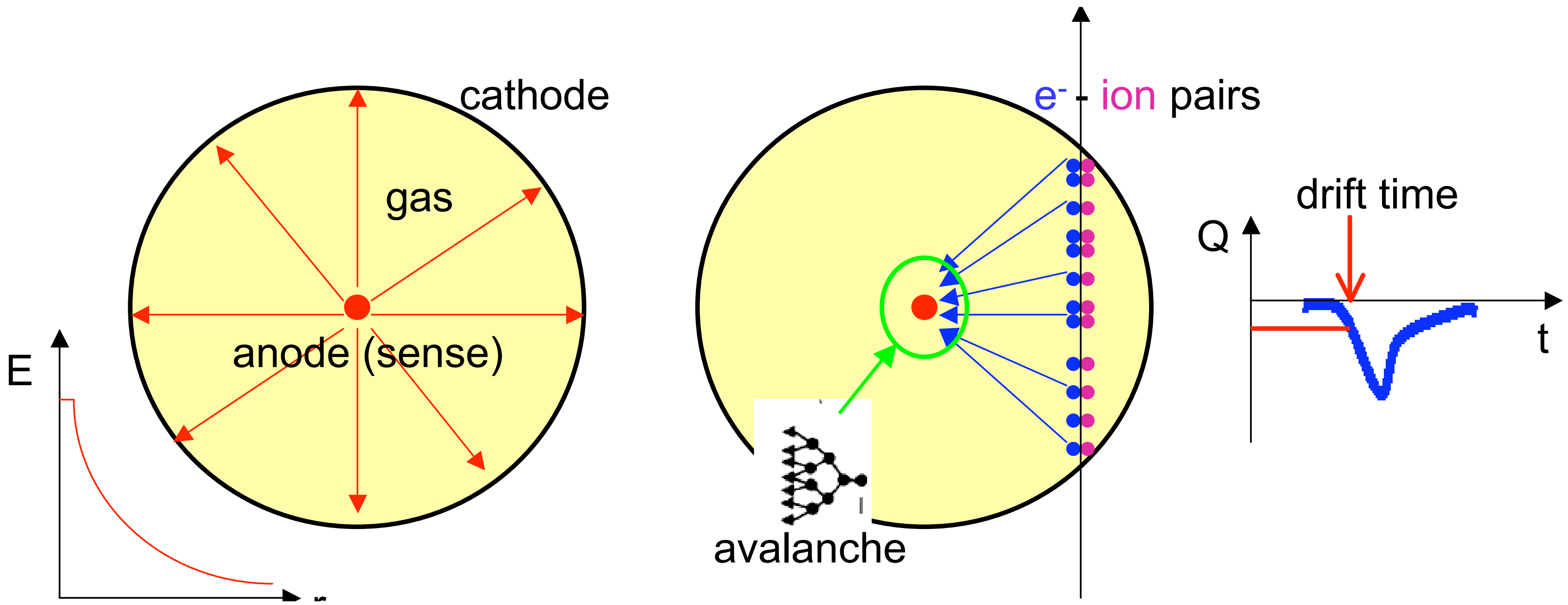


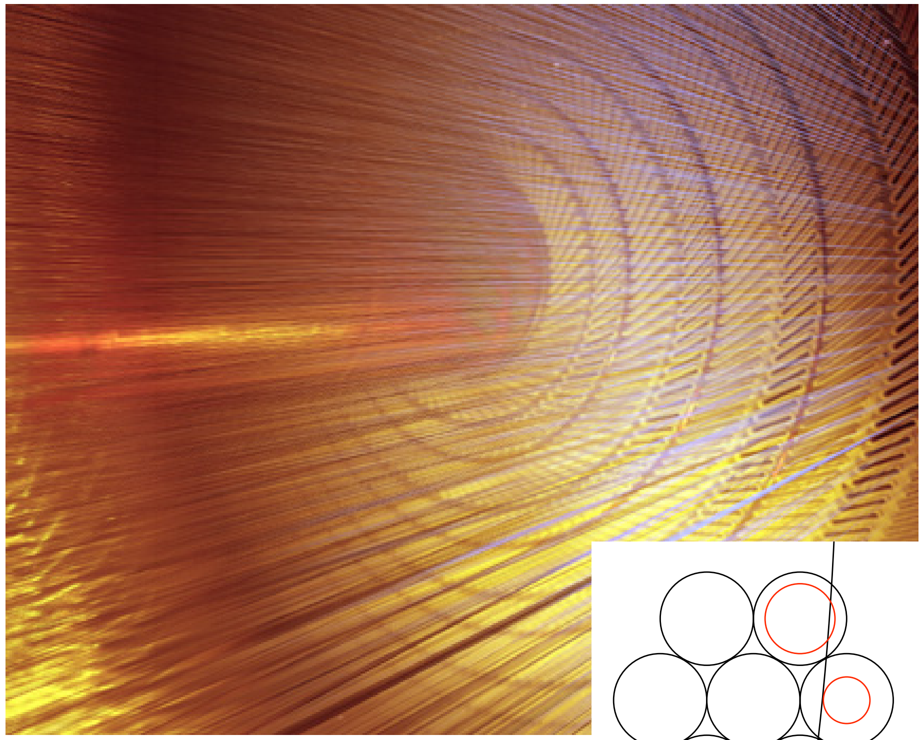
New Segment-seeded Tracking

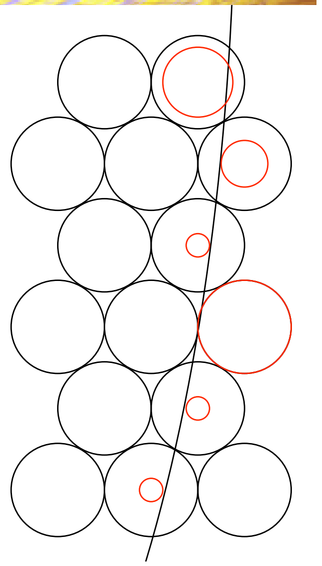
- Segment and primary vertex used to form road to search in silicon for hits
- Efficient to |η| ~2
- Implemented in final version of CDF offline software
  - Major rewrite of other algorithms
  - Many other improvements



Drift Chambers



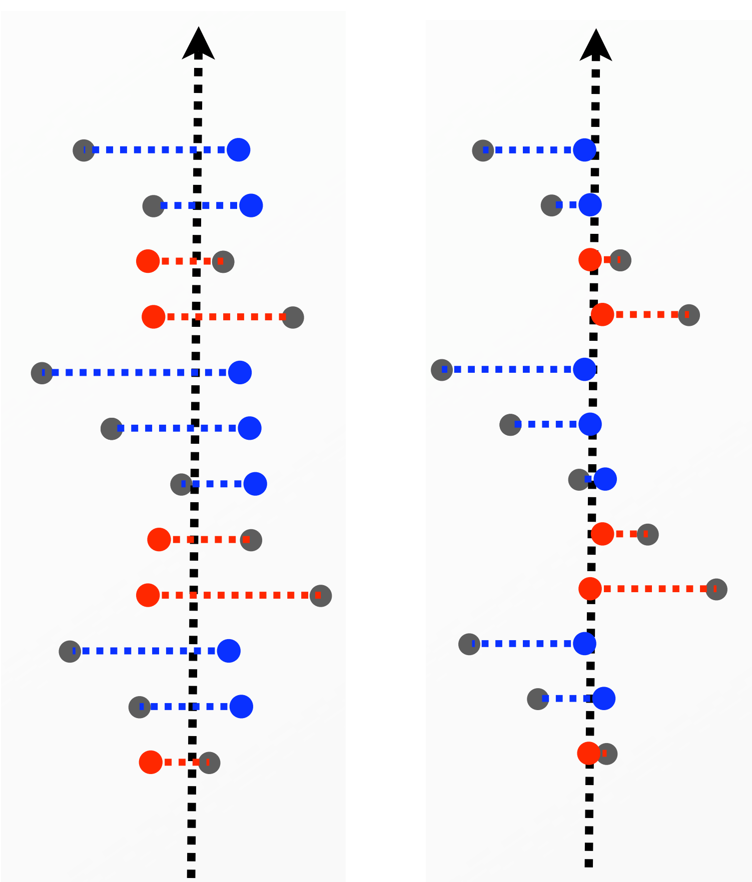


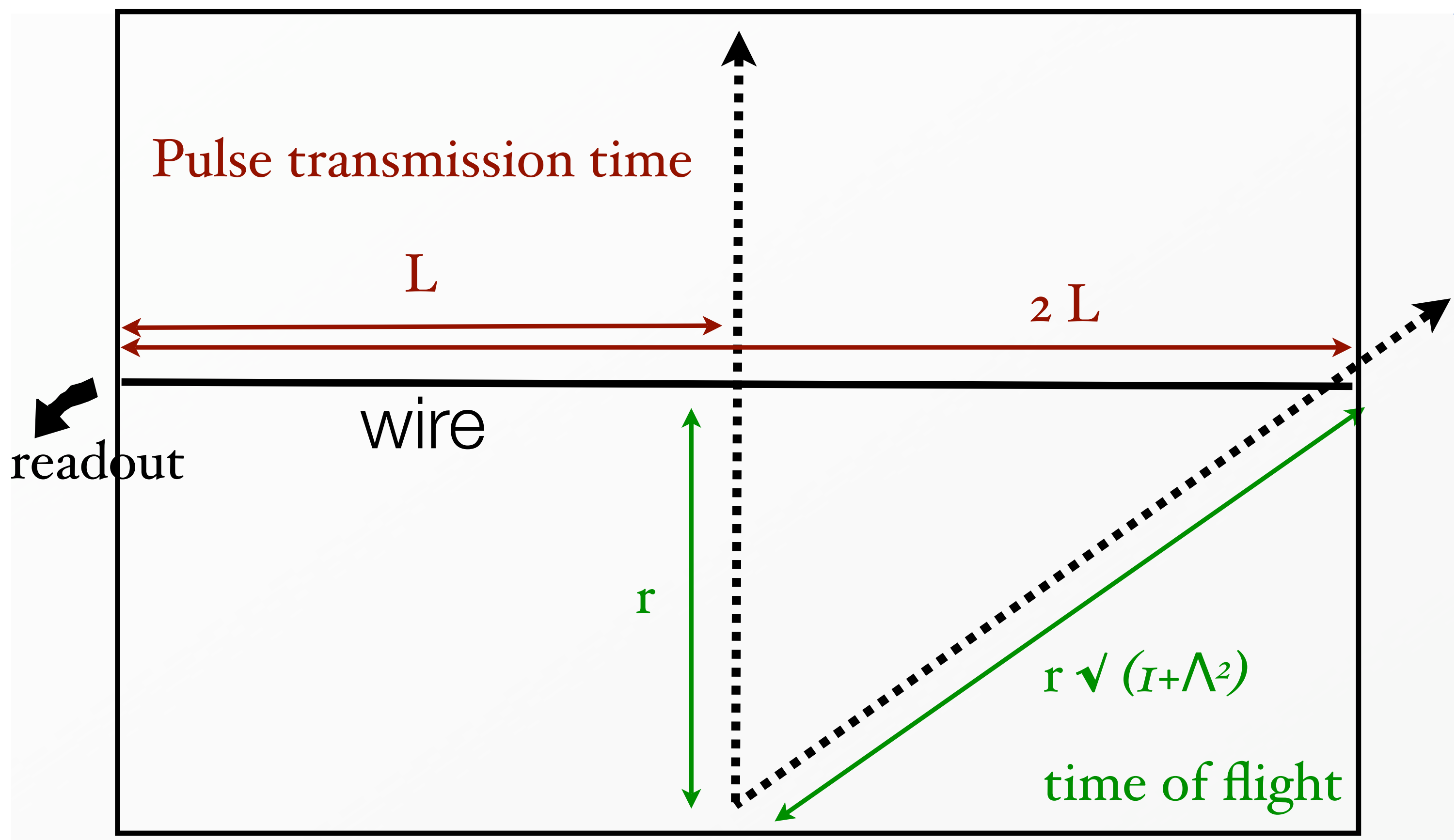


- Measure momenta of charged particles by measuring trajectories in uniform magnetic field
- Principle: position measurements of ionization in gas
  - Sense wire at large potential (~radial E field)
  - Electrons drift ~1 cm at a constant velocity
    - Typical drift velocity: 50 μm/ns
  - Know v: drift time measurement is a position measurement
  - Many measurements provide trajectory

Drift Chamber Timing Corrections

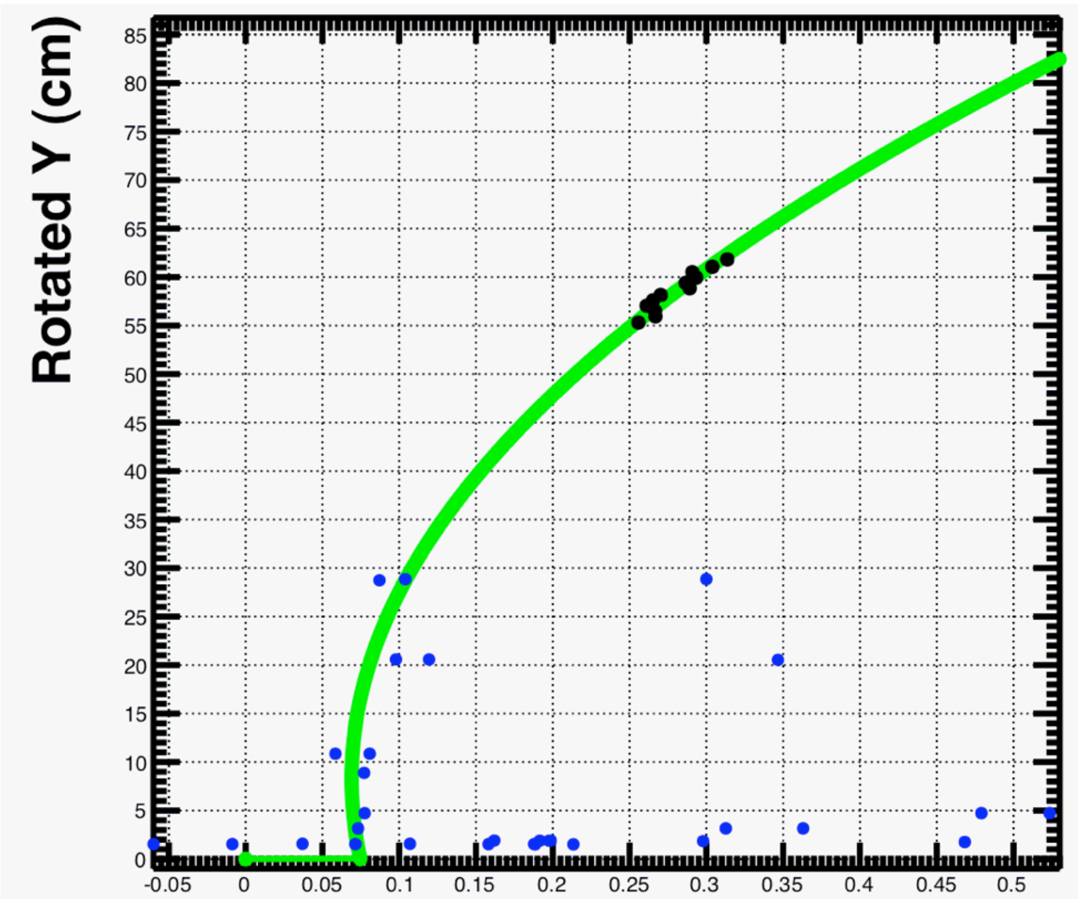
- Segment-Seeded tracking requires accurate position measurements: accurate timing measurements
- Forward segments have different time corrections
- Segments need corrections to provide a useful seed for adding silicon hits

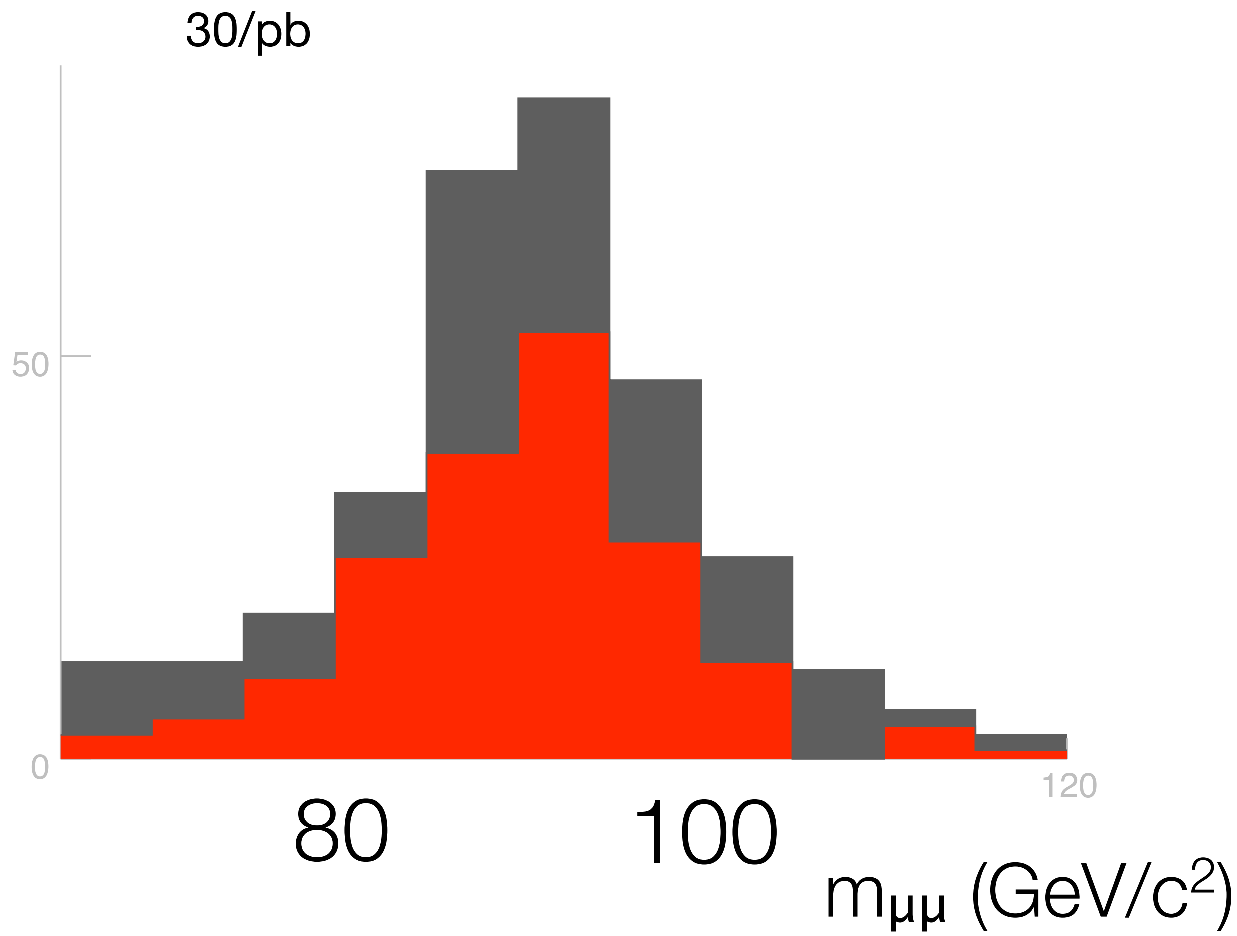




Forward hits have a different drift time correction.

New Segment-seeded Tracking



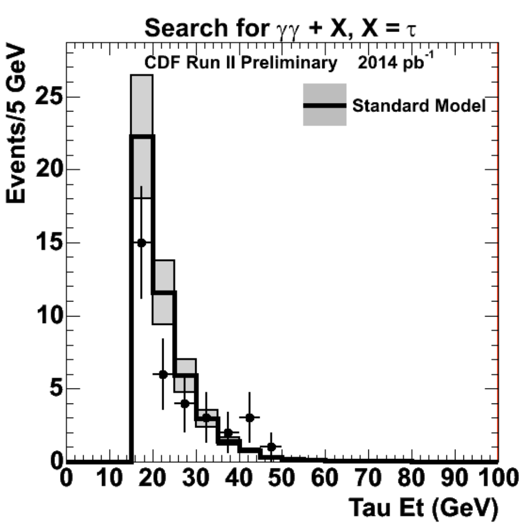


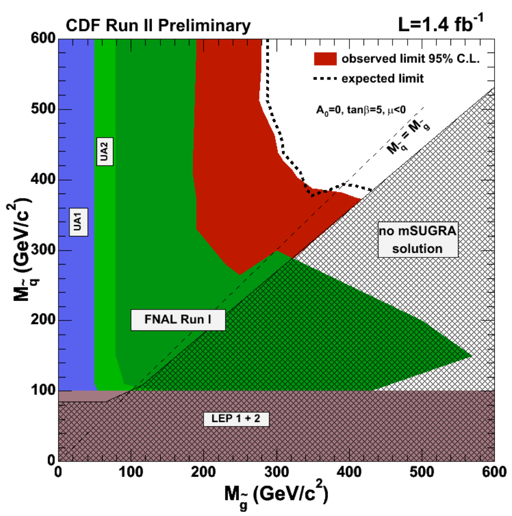
- Start with unused hits in COT
- Correct timing
- Form segment
- Fit for a search trajectory

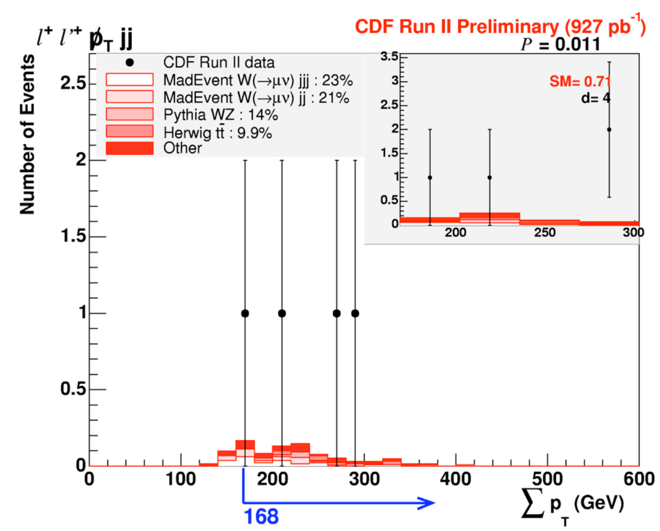
- Search for hits in silicon
- Refit track
- Implement to extend muon coverage to |η| ~2 in analysis

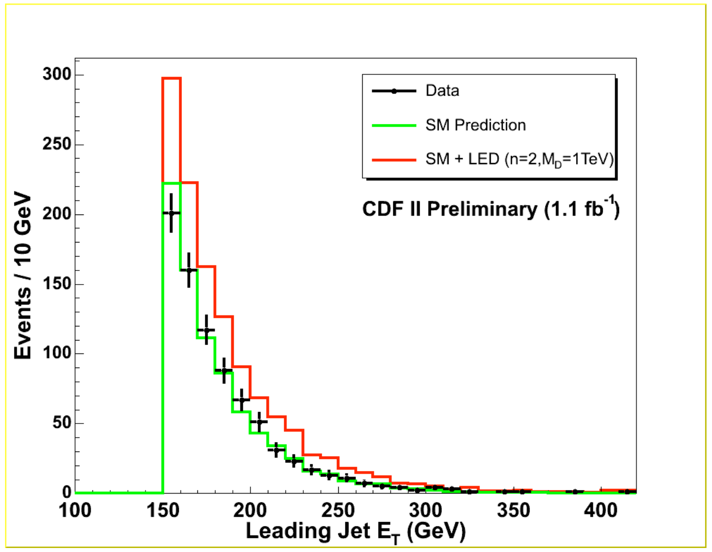
CDF Exotics Group

- CDF “Very Exotic Physics” Subgroup Convener June 2006 - July 2007
- CDF “Exotics” Group Convener July 2007 - December 2008
- Sent Six New Results (since Winter Conferences) to Lepton Photon 2007







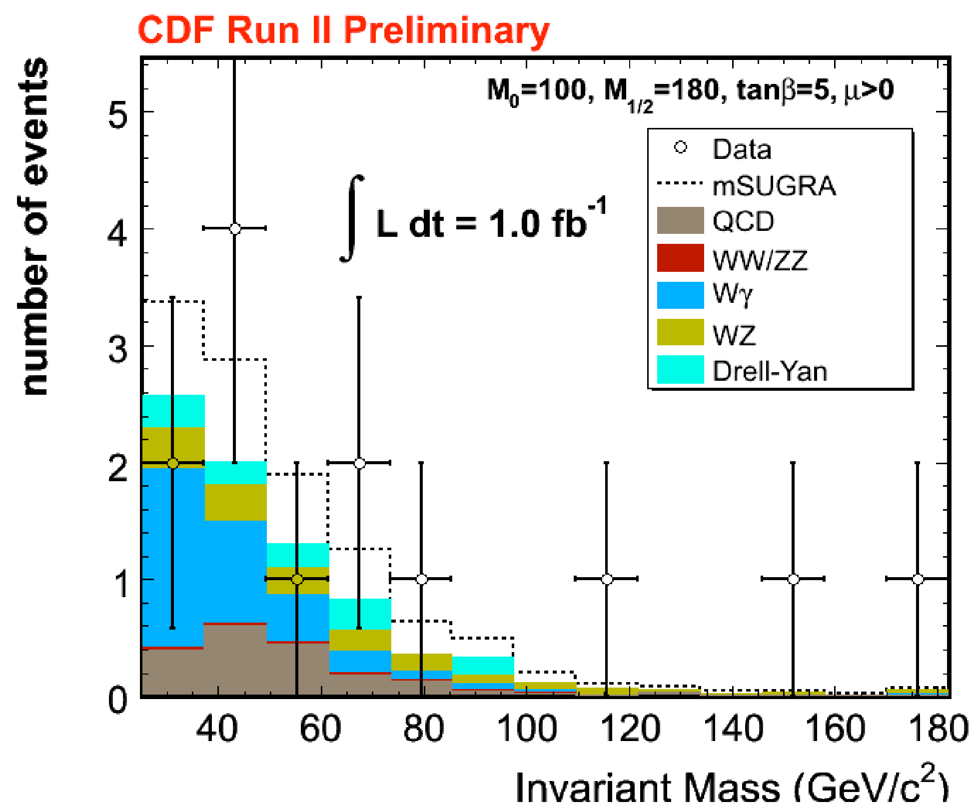


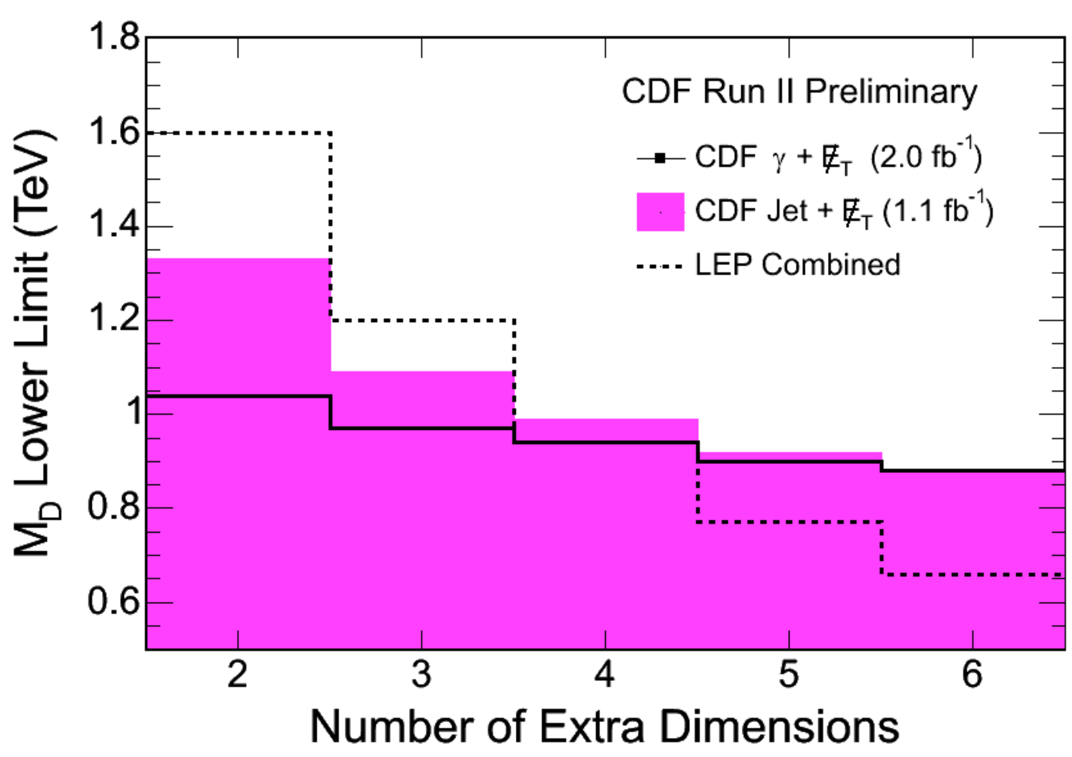
Exotic Physics

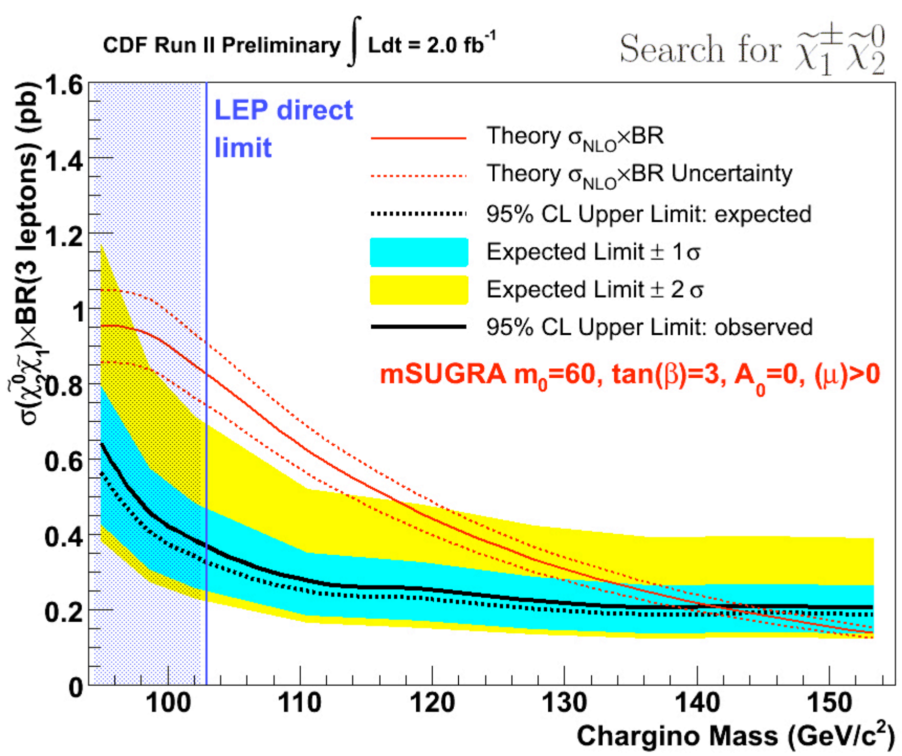
Analysis	Luminosity	More Information
Search for Anomalous Production of γ γ τ	2 fb^{-1}	WebPage
Search for Direct Production of Squarks and Gluinos	1.4 fb^{-1}	WebPage
Search for Heavy Quarks in Dileptons+X	1.2 fb^{-1}	WebPage
Global Search for New Physics at High-p_T	1 fb^{-1}	WebPage Note
Search for Large Extra Dimensions using MET+1 Jet Events	1 fb^{-1}	WebPage
Search for high mass resonance decaying to e^+e^-	1 fb^{-1}	WebPage

CDF Exotics Group

- 12 Analysis + 1 Detector Abstracts Submitted to APS
  - SUSY Trilepton result 2/fb (First mSUGRA Limit!)
  - Exclusive gamma+MET 2/fb
- 20 Analyses in the pipeline
  - Anticipate ~10 new results for Winter Conferences
- Now is a great time to be searching at CDF







Outlook

- Significantly improved lepton acceptance
  - Cross sections for NP scenarios is small
  - Search for $X \rightarrow ZZ \rightarrow eeee$: Efficiency to fourth power
    - Improved $A^*\epsilon$ from 15% to ~60%
    - Robust data-based method for background estimation
    - Submitted to PRD: arXiv:0801.1129 [hep-ex]
    - Methods are being adopted by other analyses
- Exotics Convener
  - Now is a great time to be searching at CDF
  - Squeeze results out of Tevatron with large datasets

Outlook

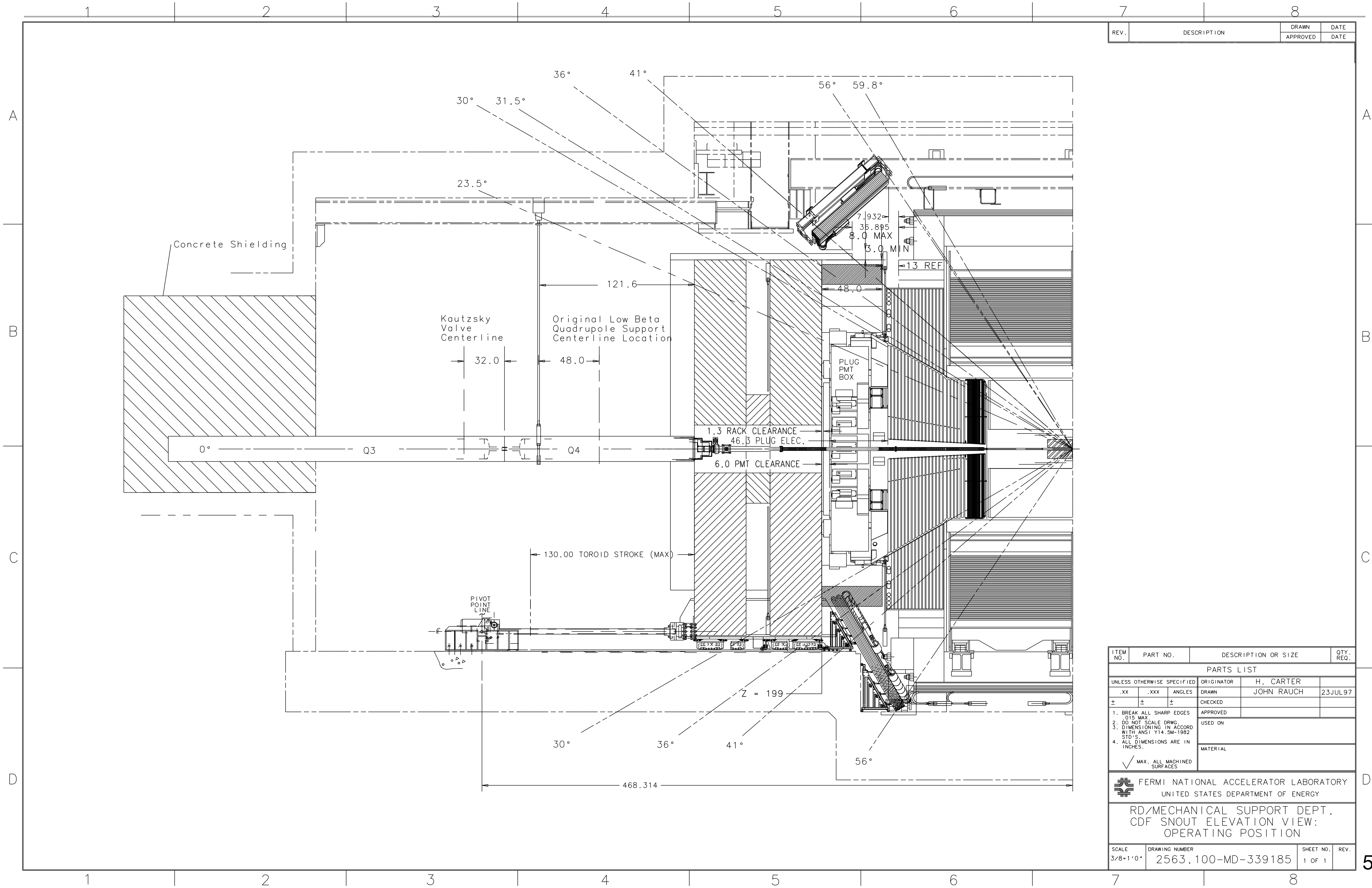
- LHC will be a different game
  - Quickly understand the detector and data
    - Misalignments, ‘features’ in the data and code, etc.
  - Robust methods
    - Look broadly
    - Model-independent
      - ➡Leptons and bosons which we can understand quickly

BACKUP SLIDES

Other Projects and Activities

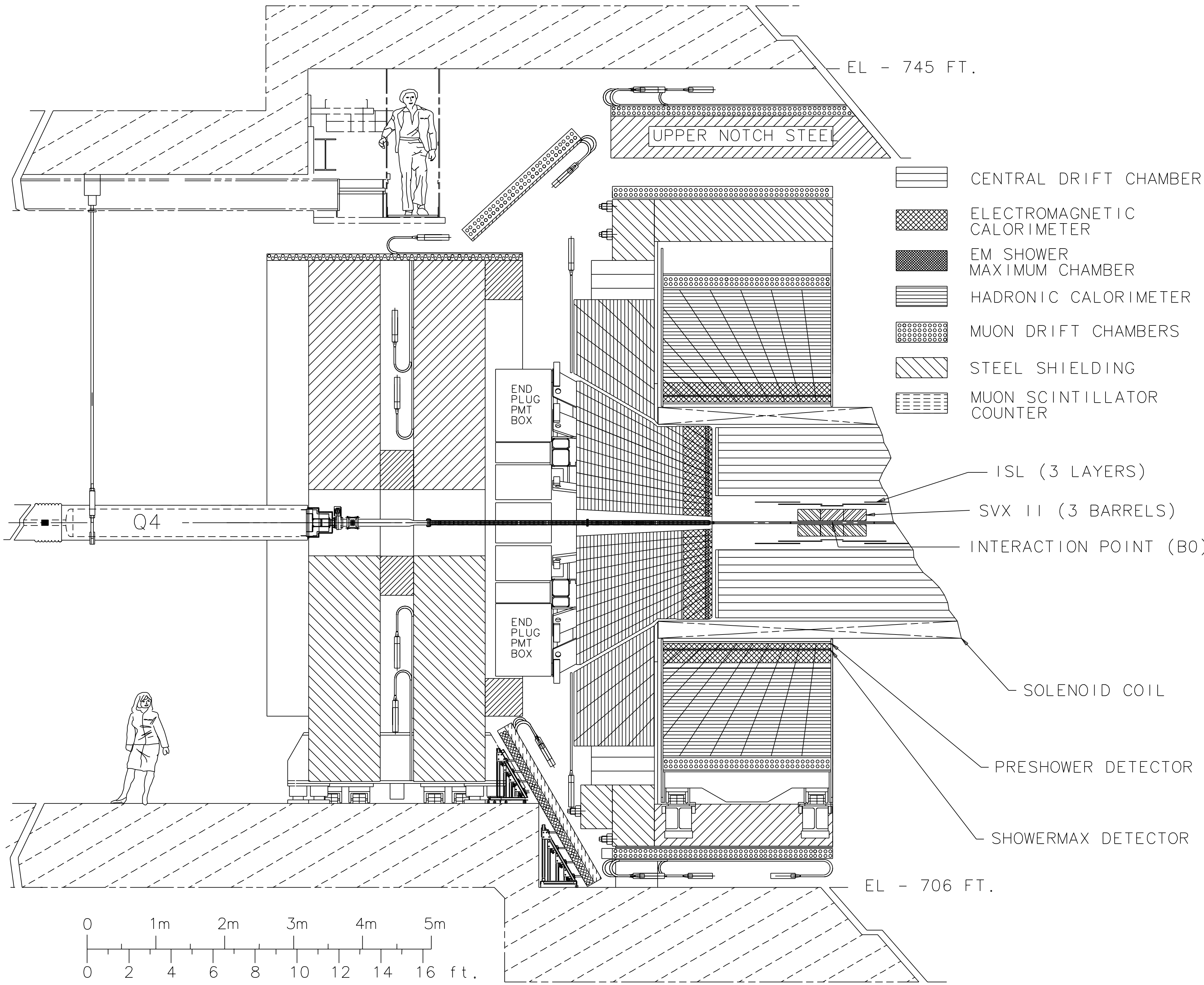
- L00 d0 Resolution studies
- Silicon Pager Carrier
- Silicon monitoring WG leader
  - Program of silicon longevitiy studies
  - Monitoring tools (offline efficiencies)
- Silicon resolution function measured in data
- L00 efficiency improvements
- L00/ISL Cooling impact
  - tracking
  - b-tagging
- VEP Convener
- CDF Exotics Convener

CDF

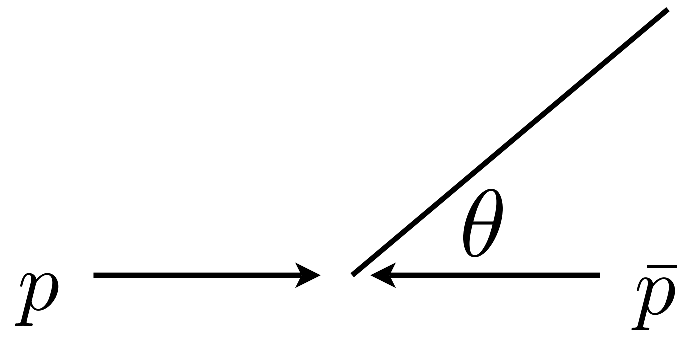


Concrete Shielding
Kautzsky Valve Centerline
Original Low Beta Quadrupole Support Centerline Location
32.0
48.0
121.6
130.00 TOROID STROKE (MAX)
PIVOT POINT LINE
0°
Q3
Q4
1.3 RACK CLEARANCE
46.3 PLUG ELEC.
6.0 PMT CLEARANCE
PLUG PMT BOX
7.932
36.895
8.0 MAX
3.0 MIN
13 REF
48.0
Z = 199
468.314
23.5°
30°
31.5°
36°
41°
56°
59.8°
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
RD/MECHANICAL SUPPORT DEPT.
CDF SNOUT ELEVATION VIEW:
OPERATING POSITION
H. CARTER
JOHN RAUCH
23JUL97
PARTS LIST
3/8=1'0"
2563.100-MD-339185
1 OF 1

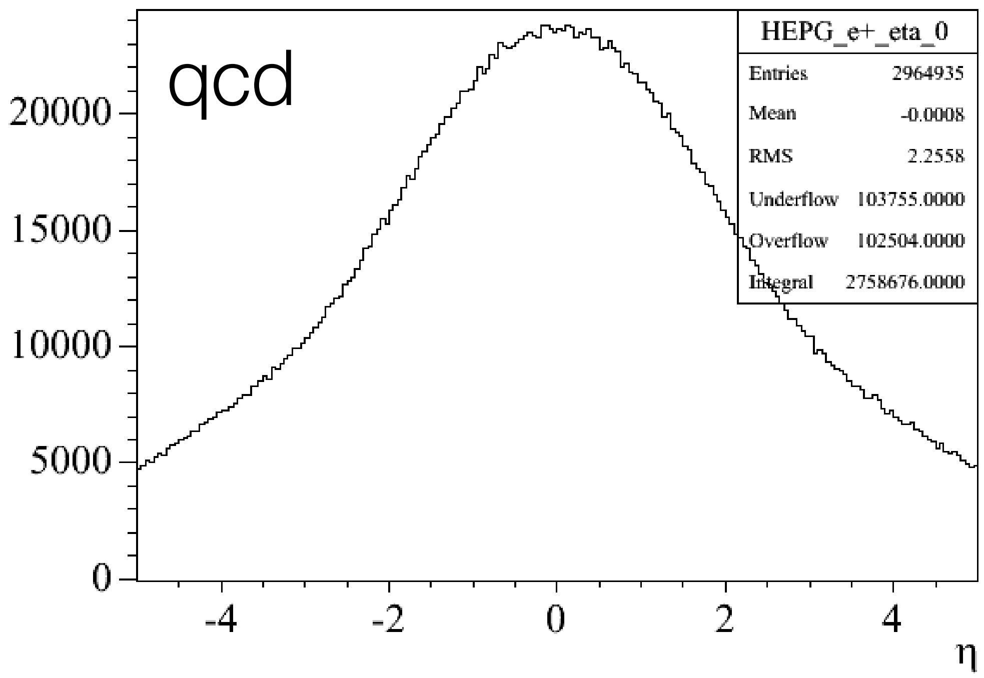
CDF

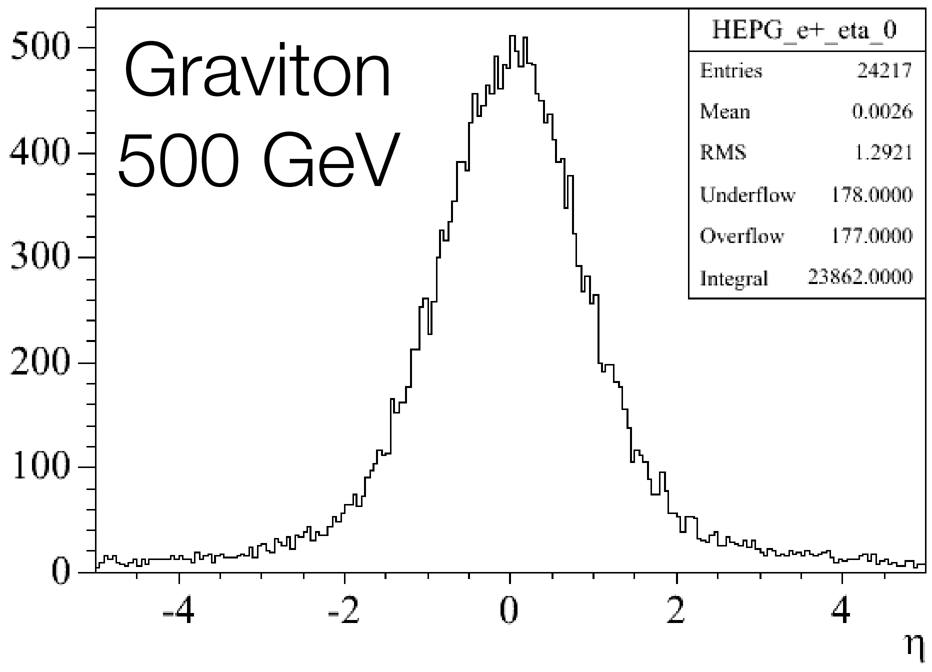

EL - 745 FT.
UPPER NOTCH STEEL
CENTRAL DRIFT CHAMBER
ELECTROMAGNETIC CALORIMETER
EM SHOWER MAXIMUM CHAMBER
HADRONIC CALORIMETER
MUON DRIFT CHAMBERS
STEEL SHIELDING
MUON SCINTILLATOR COUNTER
END PLUG PMT BOX
END PLUG PMT BOX
Q4
ISL (3 LAYERS)
SVX II (3 BARRELS)
INTERACTION POINT (B0)
SOLENOID COIL
PRESHOWER DETECTOR
SHOWERMAX DETECTOR
EL - 706 FT.
0 1m 2m 3m 4m 5m
0 2 4 6 8 10 12 14 16 ft.

Pseudorapidity



$$\eta = -\ln\left[\tan\left(\frac{\theta}{2}\right)\right]$$



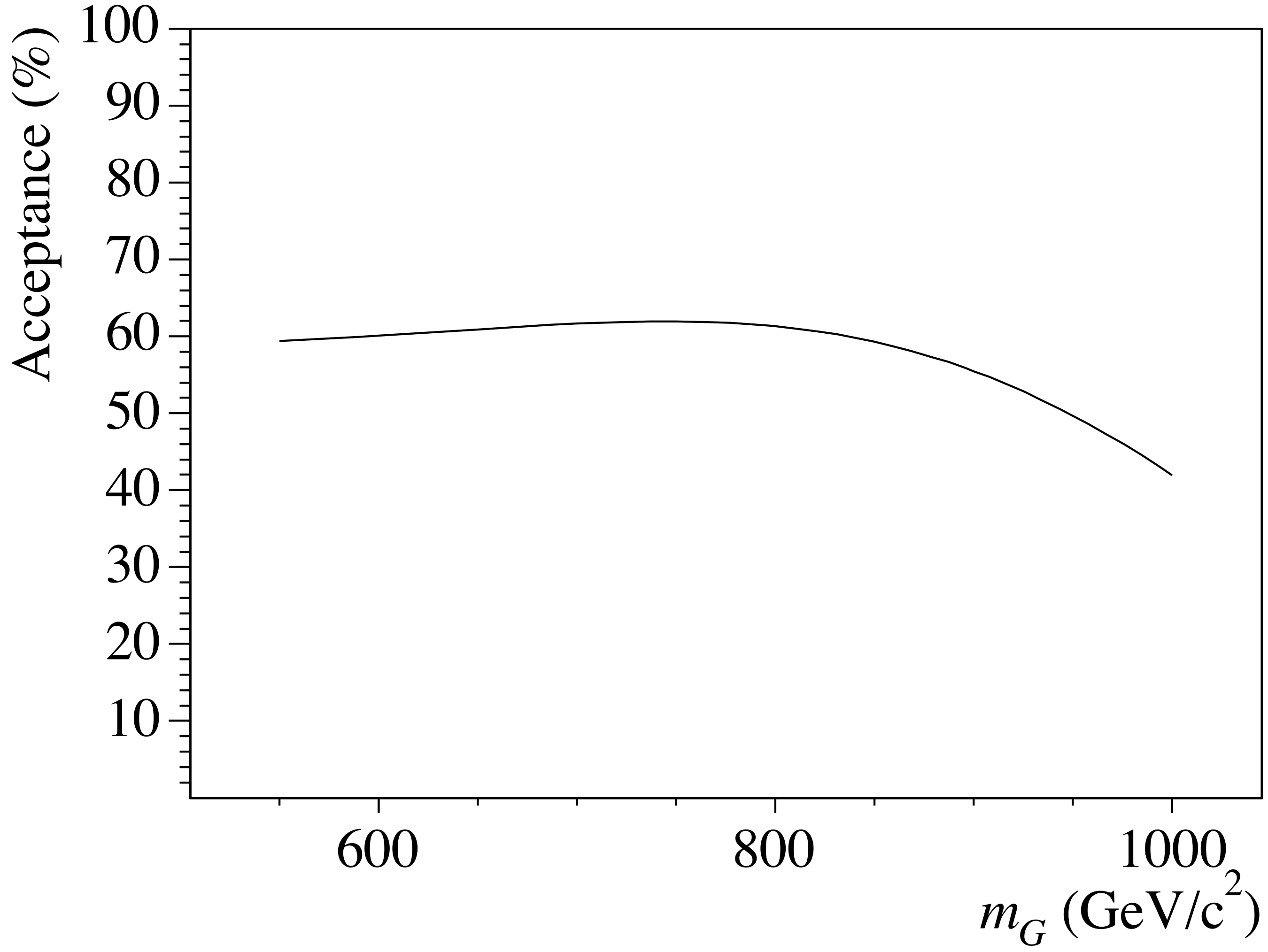


- In hadron collisions, particle production is constant (to some approximation) as a function of pseudorapidity
- $|\eta| < 1.0$ is “Central”, $|\eta| > 1.0$ is “Forward”
- New physics often is enhanced in the central region

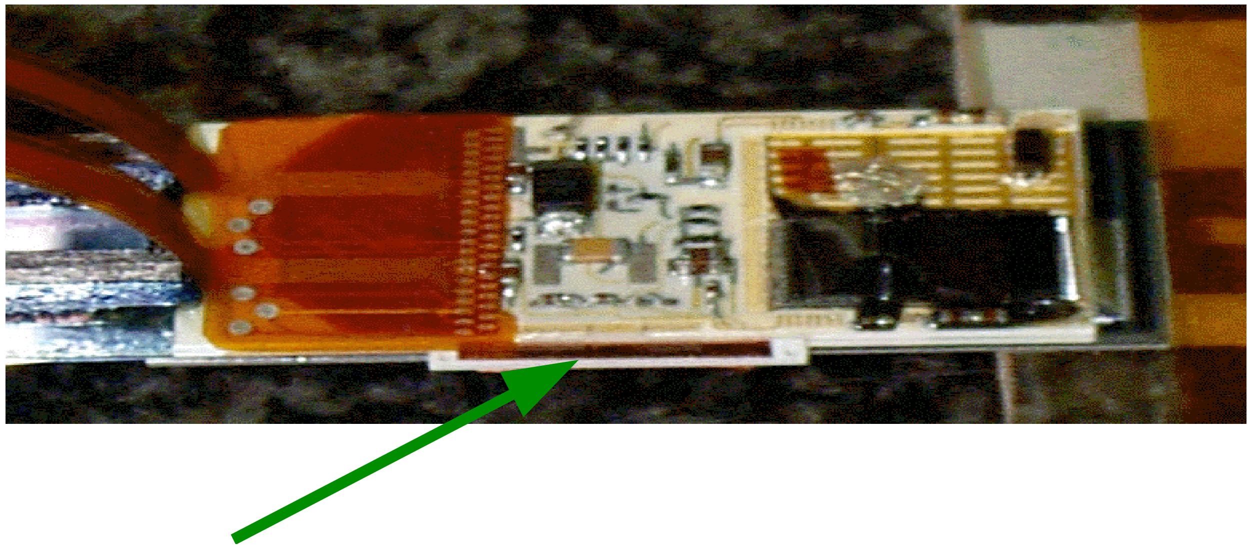
Optimized Electron Selection

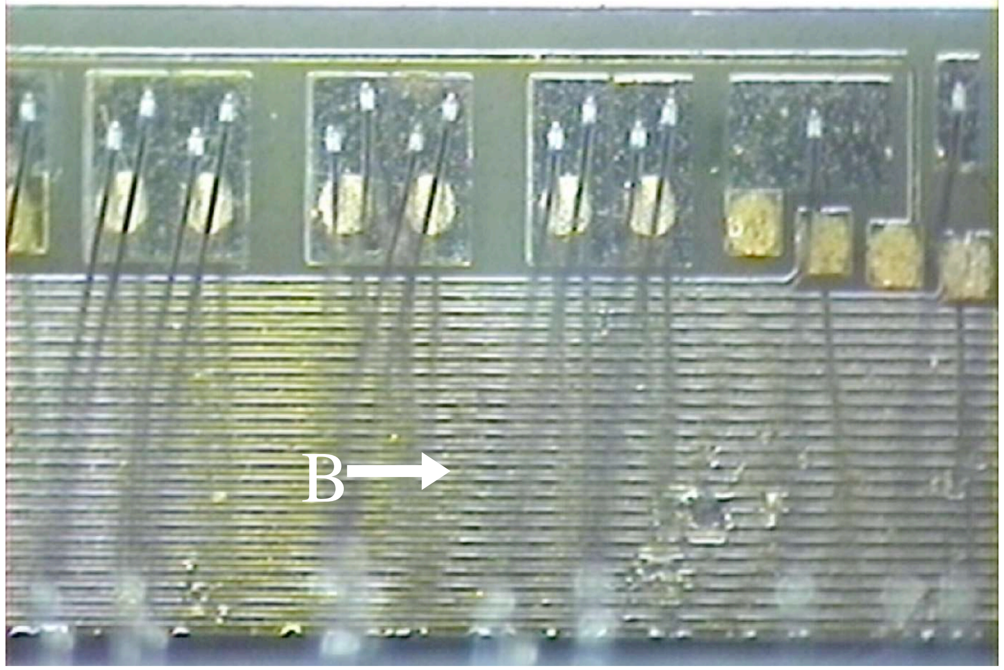
- Much looser selection; more background. Will reject later with $ZZ \rightarrow eeee$ event kinematics
- Simplify! Not required: Δz_{CES}, $\Delta x_{CES} \cdot q$, E/p, CES strip $\chi2$, PES5x9U/V, ΔR, PEM 3x3 $\chi2$...
- One Central "Seed" Electron (satisfying trigger requirements):
  - Fiducial, $E_T > 20$ GeV, $E_{HAD}/E_{EM} < 0.055 + 0.00045 * E$, $p_T > 10$ GeV, $|\text{track } z_0| < 60$, LshrTrk < 0.4, Isolation < 0.2
- Central electrons:
  - Fiducial, $E_T > 5$, $|\text{track } z_0| < 60$, $E_{HAD}/E_{EM} < 0.055 + 0.00045 * E/\text{GeV}$, Isolation < 0.2
- Plug electrons:
  - $E_T > 5$, $E_{HAD}/E_{EM} < 0.05$, Isol < 0.2, $1.1 < |\eta_{DET}| < 2.5$
- Isolated track electrons:
  - Pointing at calorimeter gaps, $|z_0| < 60$, 3 Axial, 2 Stereo, $p_T > 10$ GeV

Acceptance



Silicon Wirebond Failures





- Wirebonds connect φ and z sides of hybrid
- Observed loss of power to z side during periods of synchronous readout
- Lorentz forces perpindicular to wires
- 2mm wirebond natural ω ~15 kHz
- In CDF, B=1.4T, current in bond ~200mA: forces on bonds ~5E-4N
- Reproduced wirebond failure on bench
- Synchronous readout now halts DAQ