The First 15 CMS Physics Papers

15	EXO-10-017	Search for Microscopic Black Hole Signatures at the Large Hadron Collider	PLB 697 (2011) 434-453	16 December 2010
14	EWK-10-002	Measurements of Inclusive W and Z Cross Sections in pp Collisions at $\sqrt{s}$ = 7 TeV	JHEP 01 (2011) 080	12 December 2010
13	QCD-10-019	Measurement of the Isolated Prompt Photon Production Cross Section in pp Collisions at $\sqrt{s}$ = 7 TeV	PRL 106 (2011) 082001	3 December 2010
12	EXO-10-003	Search for Stopped Gluinos in pp collisions at $\sqrt{s}$ = 7 TeV	PRL 106 (2011) 011801	26 November 2010
11	QCD-10-004	Charged particle multiplicities in pp interactions at $\sqrt{s}$ = 0.9, 2.36, and 7 TeV	JHEP 01 (2011) 079	25 November 2010
10	BPH-10-002	Prompt and non-prompt J/ψ production in pp collisions at $\sqrt{s}$ = 7 TeV	EPJC 71 (2011) 1575	18 November
7	EXO-10-010	Search for Dijet Resonances in 7 TeV pp Collisions at CMS	PRL 105 (2010) 211801	2010
6	QCD-10-002	Observation of Long-Range, Near-Side Angular Correlations in Proton-Proton Collisions at the LHC	JHEP 09 (2010) 091	22 September 2010
5	TRK-10-001	CMS Tracking Performance Results from Early LHC Operation	EPJC 70 (2010) 1165	14 July 2010
4	QCD-10-001	First Measurement of the Underlying Event Activity at the LHC with $\sqrt{s}$ = 0.9 TeV	EPJC 70 (2010) 555-572	11 June 2010
3	QCD-10-003	First Measurement of Bose-Einstein Correlations in proton-proton Collisions at $\sqrt{s}$ =0.9 and 2.36 TeV at the LHC	PRL 105 (2010) 032001	19 May 2010
2	QCD-10-006	Transverse-momentum and pseudorapidity distributions of charged hadrons in pp collisions at $\sqrt{s}$ = 7 TeV	PRL 105 (2010) 022002	19 May 2010
1	QCD-09-010	Transverse momentum and pseudorapidity distributions of charged hadrons in pp collisions at $\sqrt{s}$ = 0.9 and 2.36 TeV	JHEP 02 (2010) 041	4 February 2010

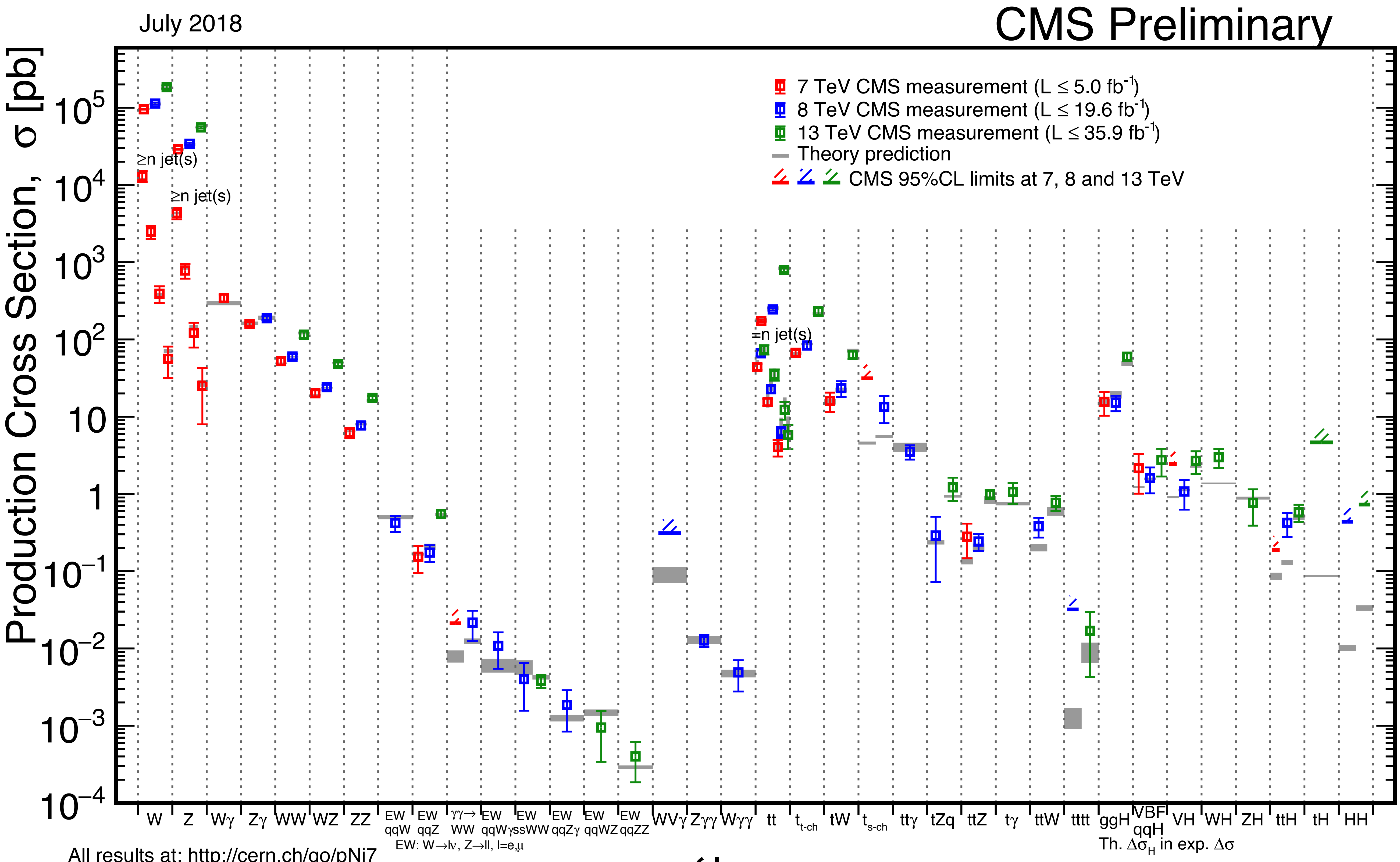
14 | EWK-10-002 | Measurements of Inclusive W and Z Cross Sections in pp Collisions at $\sqrt{s}$ = 7 TeV | JHEP 01 (2011) 080

Measurements of W and Z Cross Sections

Why W and Z bosons?

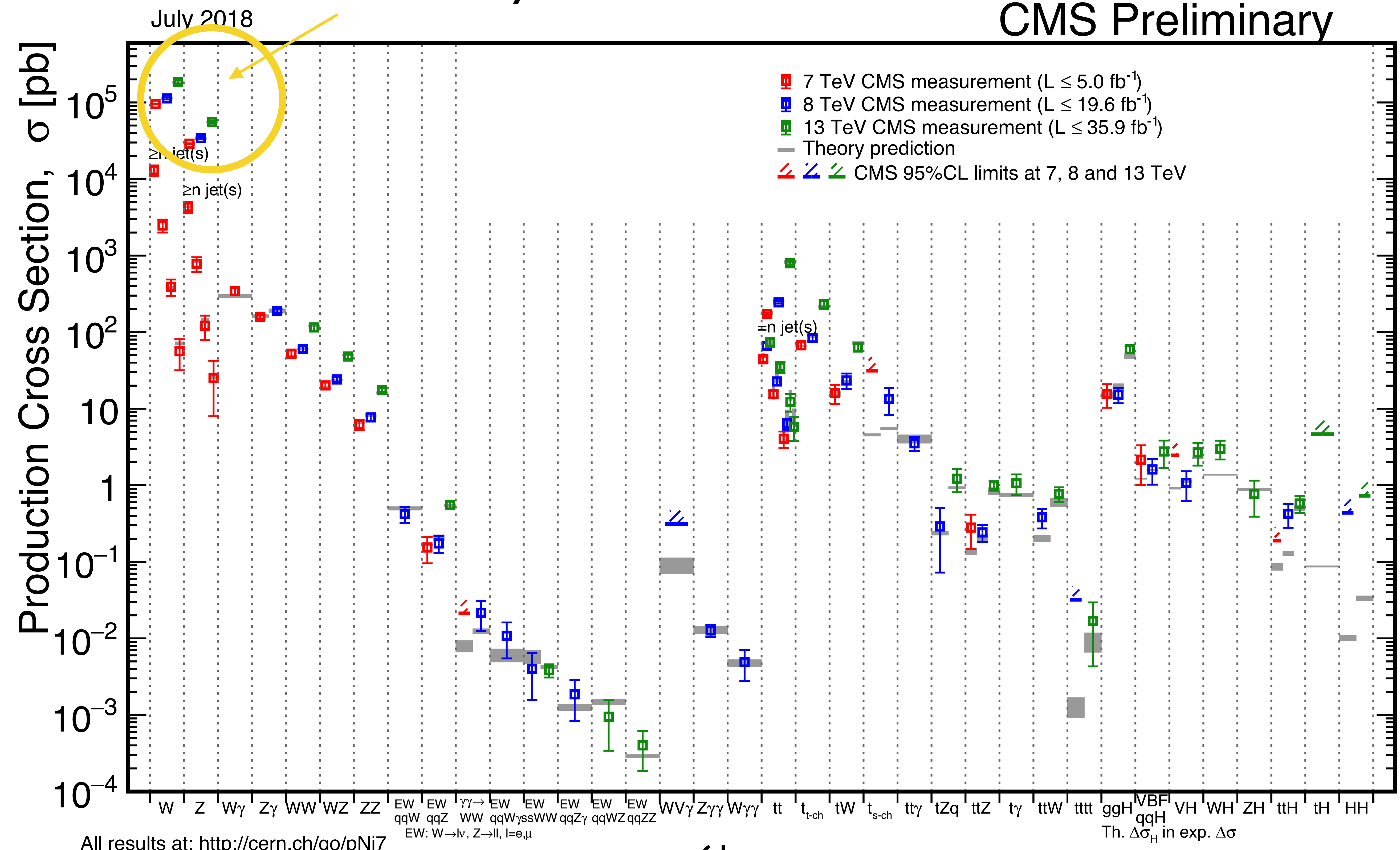
- W and Z boson signals are standard candles
  - The properties are well measured by previous experiments (also well predicted)
  - Calibration of electron, muon, and photon efficiencies
- Many BSM theories predict particles that decay to W's or Z's

Summary of SM Cross Section Measurements



Summary of SM Cross Section Measurements

We always start from W and Z!

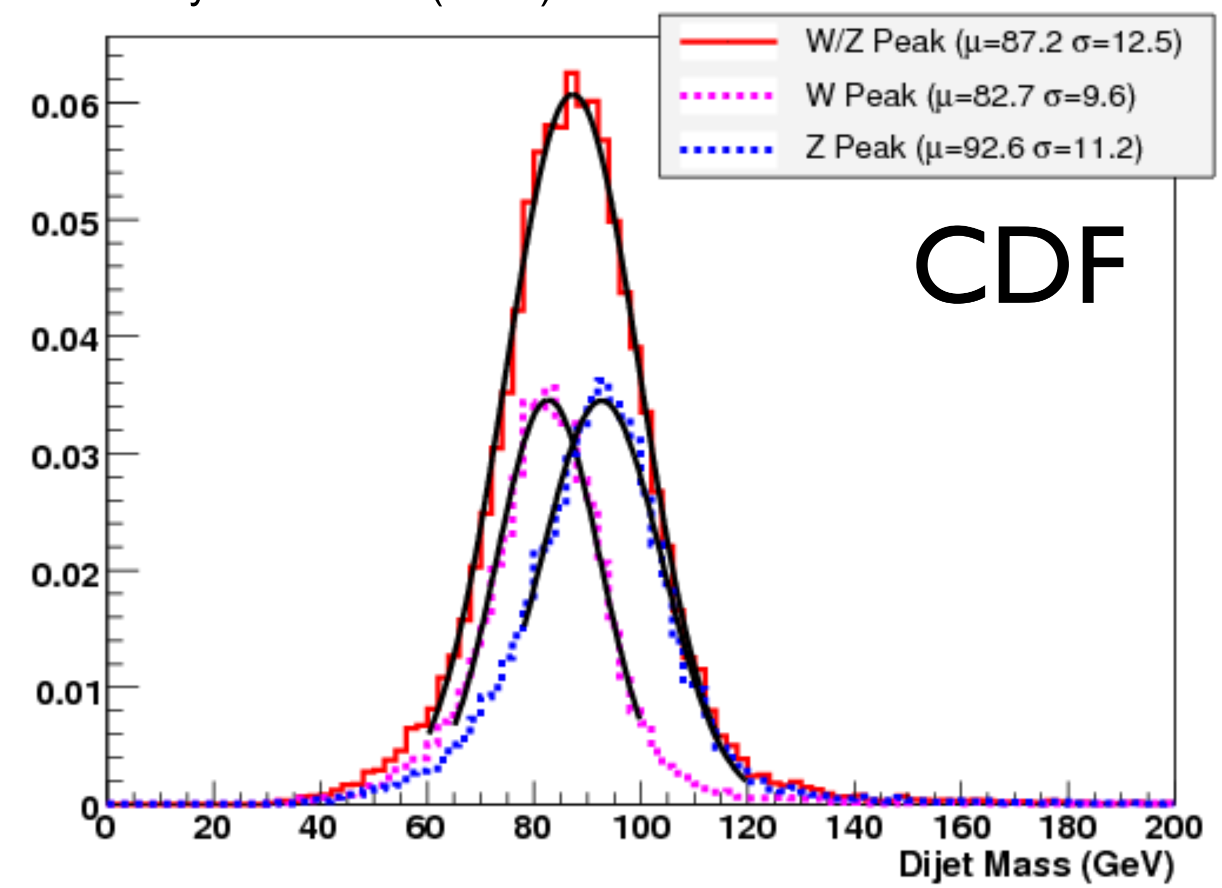


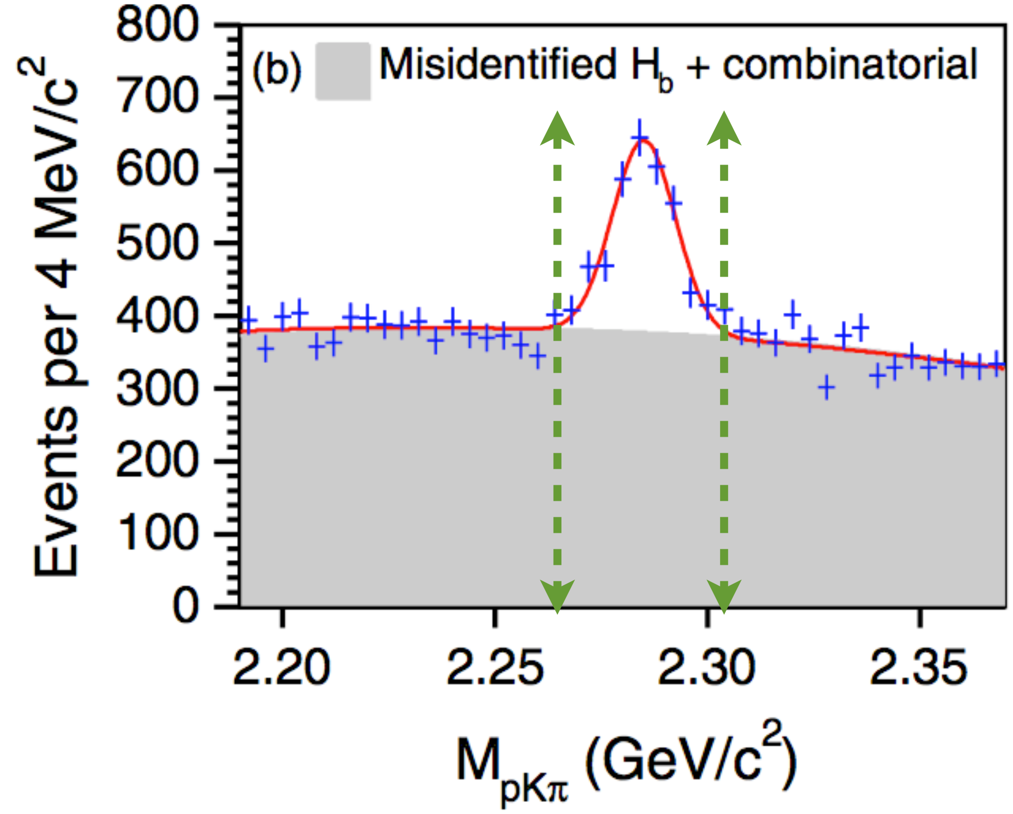
W^+ DECAY MODES		Fraction (Γ_i/Γ)
$\ell^+ \nu$	[a]	(10.86 ± 0.09) %
$e^+ \nu$		(10.71 ± 0.16) %
$\mu^+ \nu$		(10.63 ± 0.15) %
$\tau^+ \nu$		(11.38 ± 0.21) %
hadrons		(67.41 ± 0.27) %

Z DECAY MODES		Fraction (Γ_i/Γ)
$e^+ e^-$	[a]	(3.3632 ± 0.0042) %
$\mu^+ \mu^-$	[a]	(3.3662 ± 0.0066) %
$\tau^+ \tau^-$	[a]	(3.3696 ± 0.0083) %
$\ell^+ \ell^-$	[a,b]	(3.3658 ± 0.0023) %
invisible	[a]	(20.000 ± 0.055) %
hadrons	[a]	(69.911 ± 0.056) %

Why Are e/μ Channels Better

Phys.Rev. D80 (2009) 052011

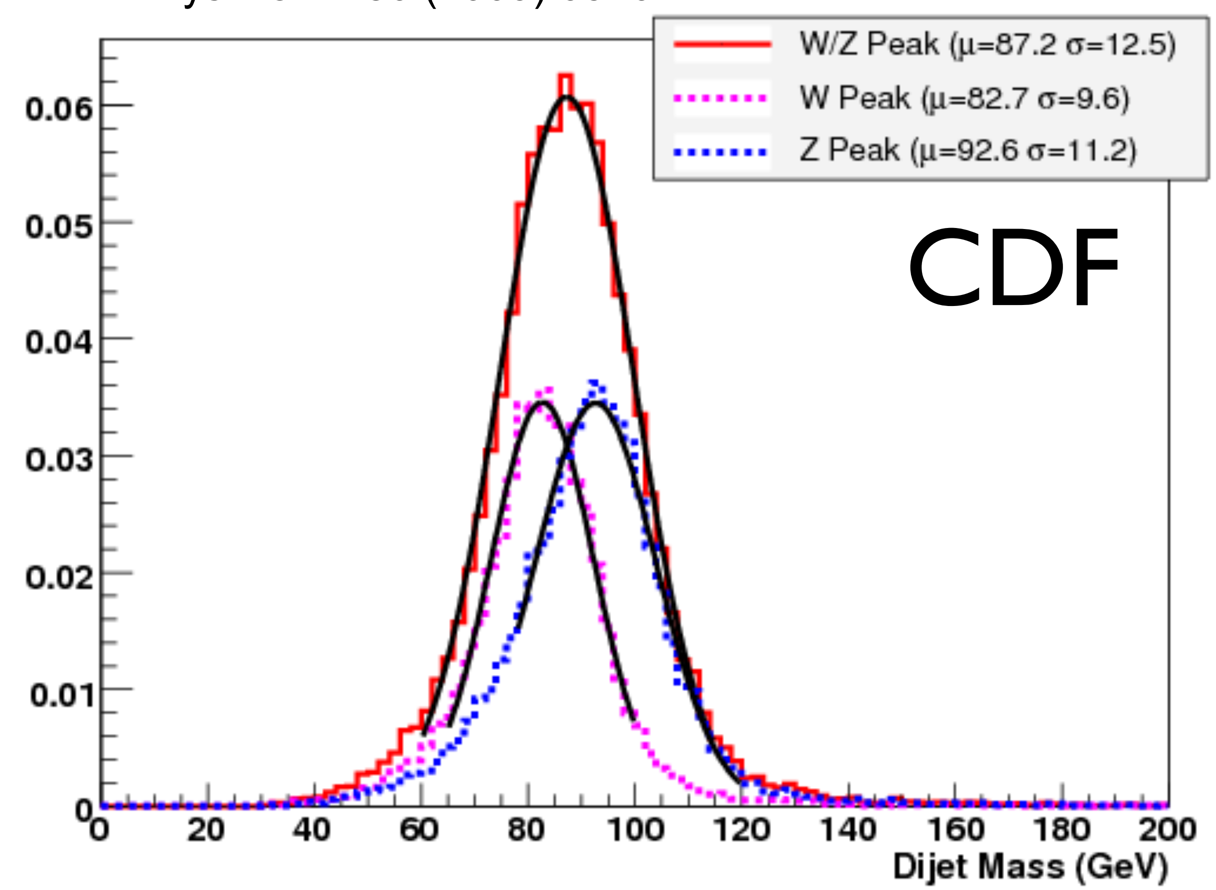


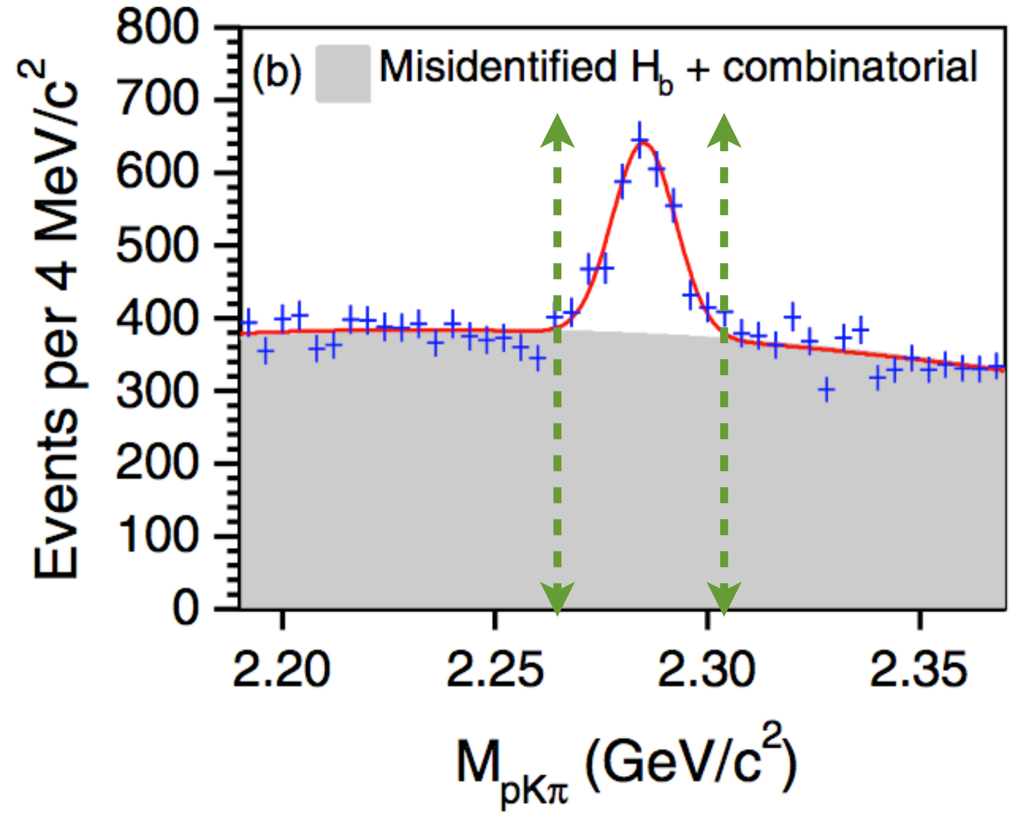


Why Are e/μ Channels Better

- Hadronic channels have huge background from the QCD dijet production

Phys.Rev. D80 (2009) 052011

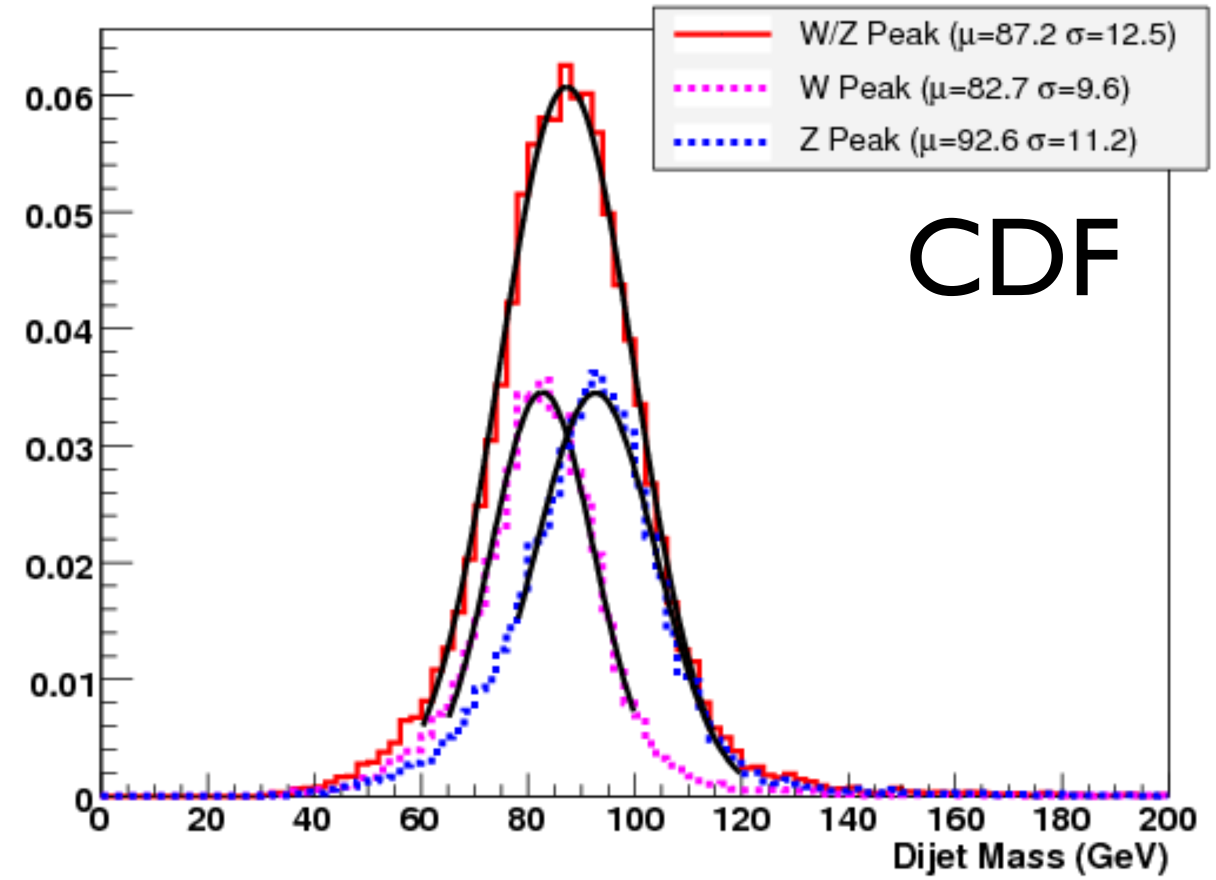


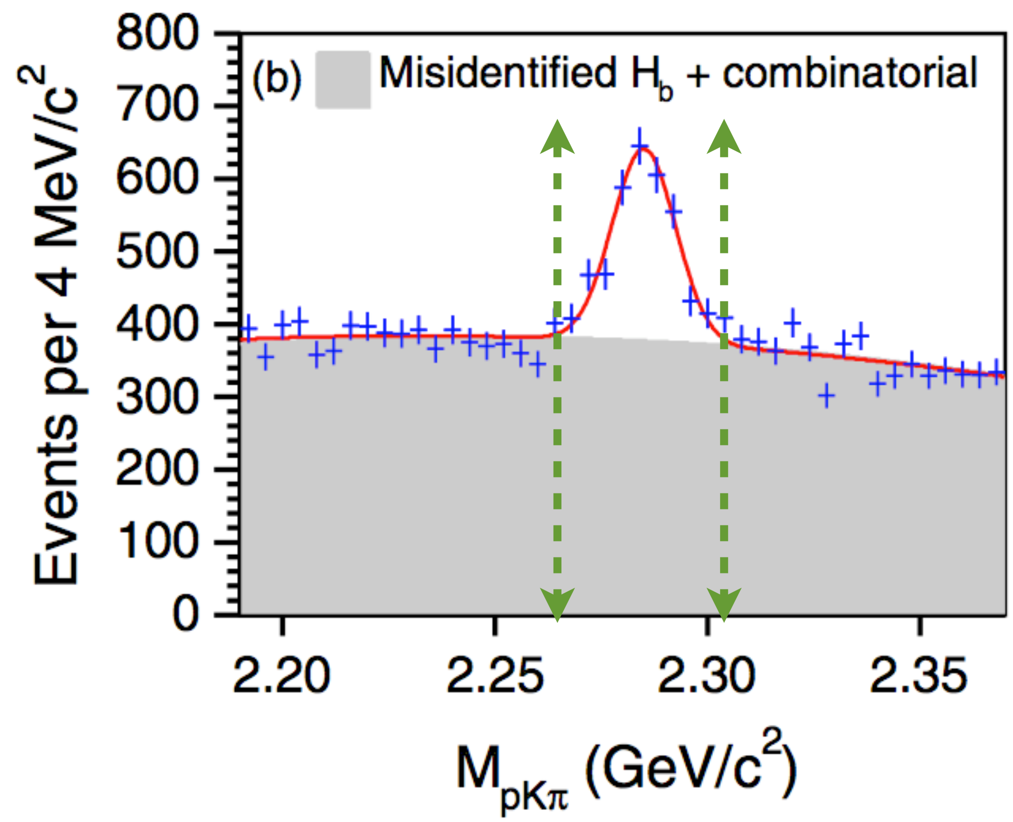


Why Are e/μ Channels Better

- Hadronic channels have huge background from the QCD dijet production
- Dijet mass resolution about 15-20%
  - driven by both jet energy and angular resolution
  - Can't separate W and Z

Phys.Rev. D80 (2009) 052011

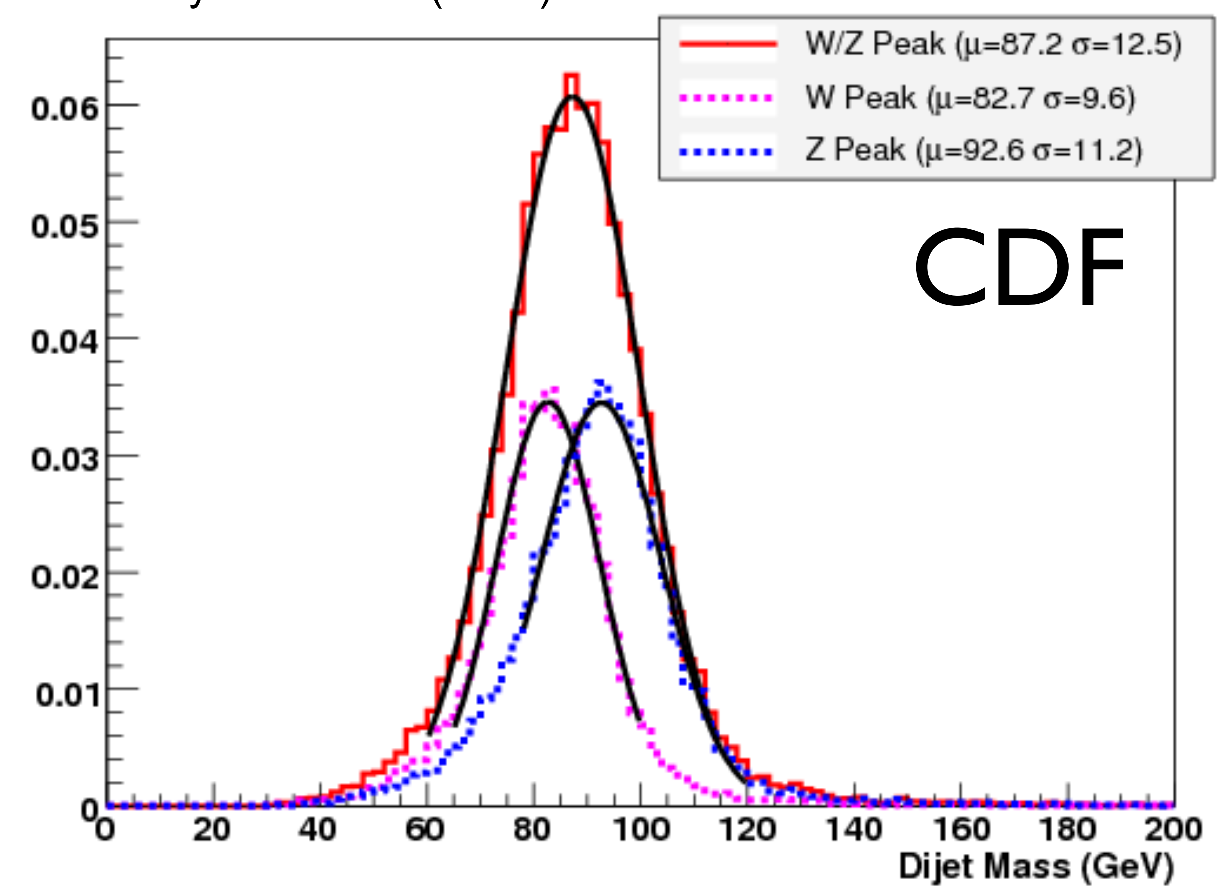


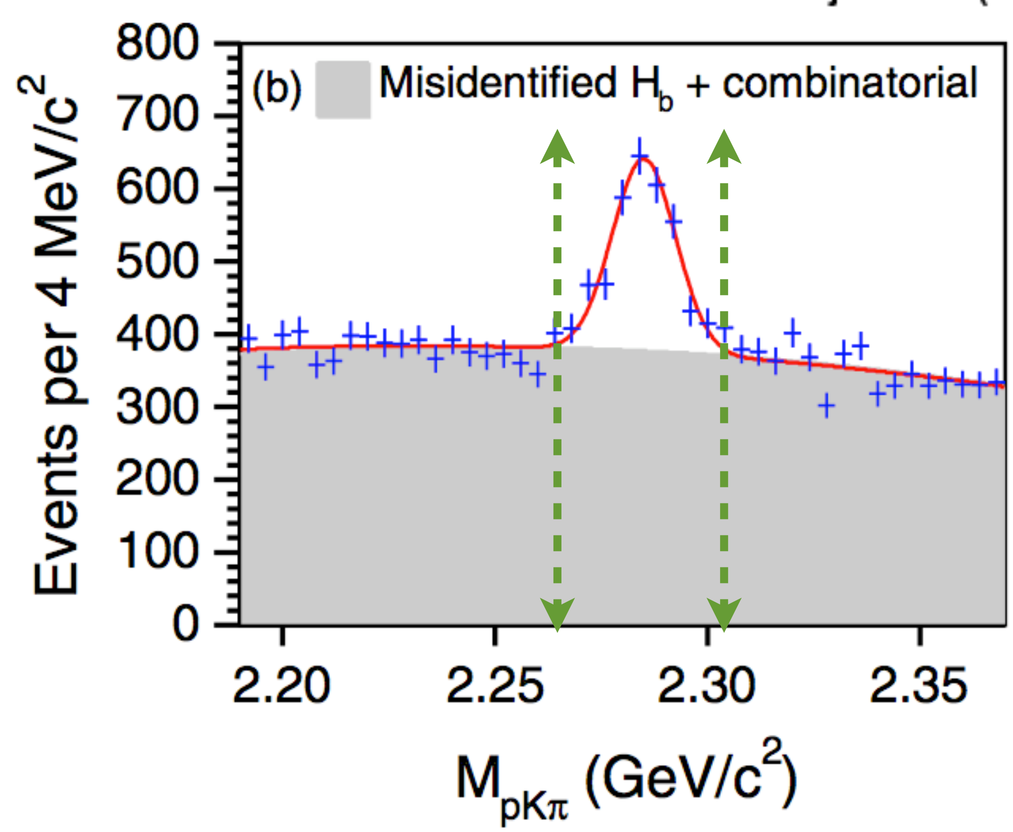


Why Are e/μ Channels Better

- Hadronic channels have huge background from the QCD dijet production
- Dijet mass resolution about 15-20%
  - driven by both jet energy and angular resolution
  - Can't separate W and Z
- Narrower mass peaks means larger signal to background ratio

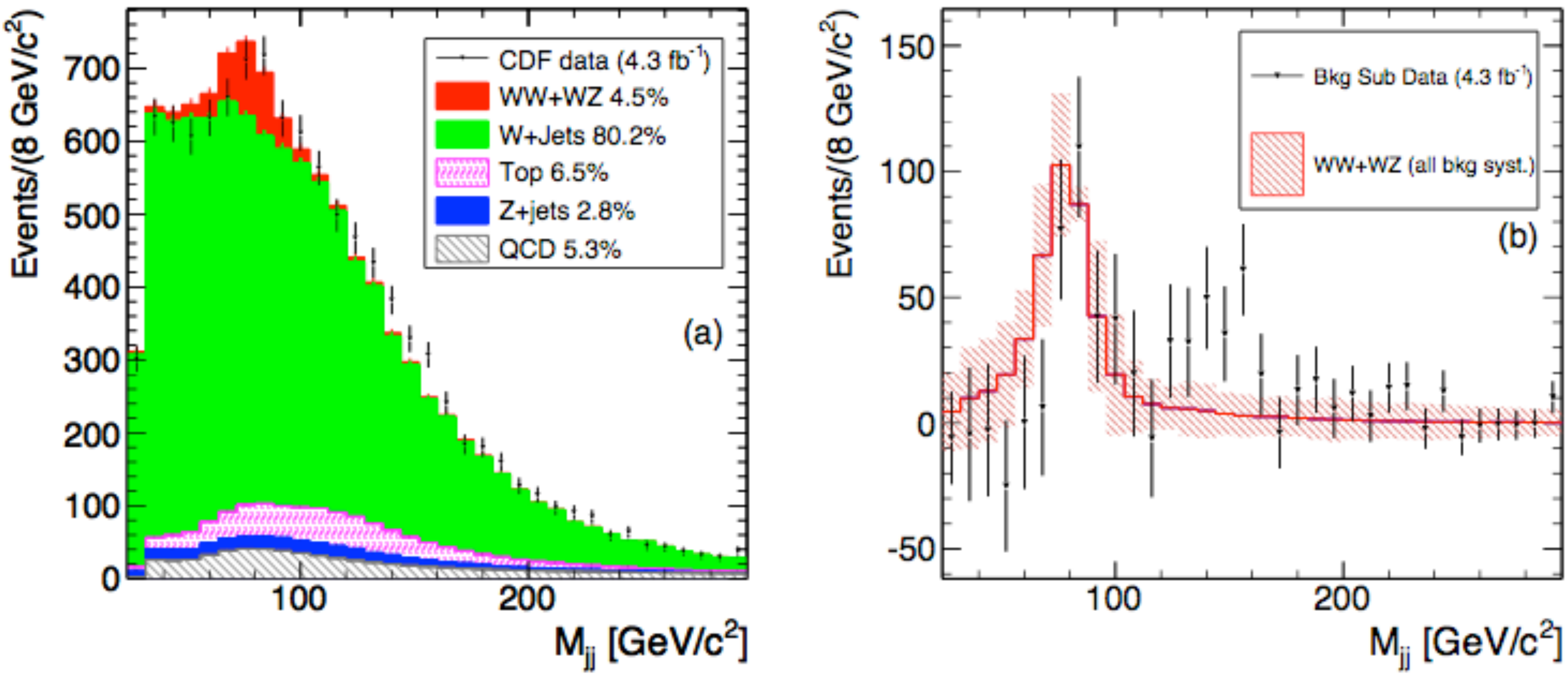
Phys.Rev. D80 (2009) 052011



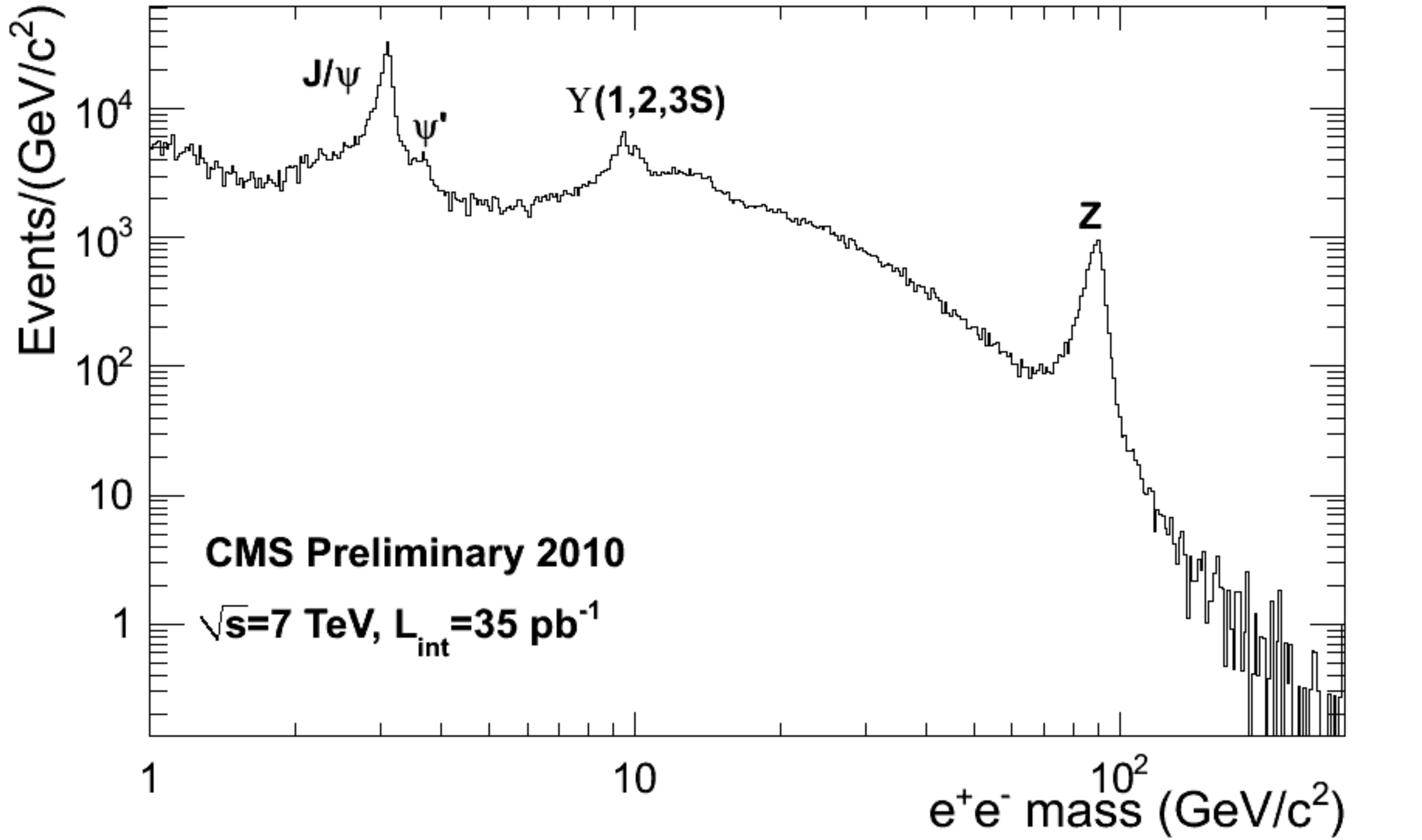


Discovery of x ?

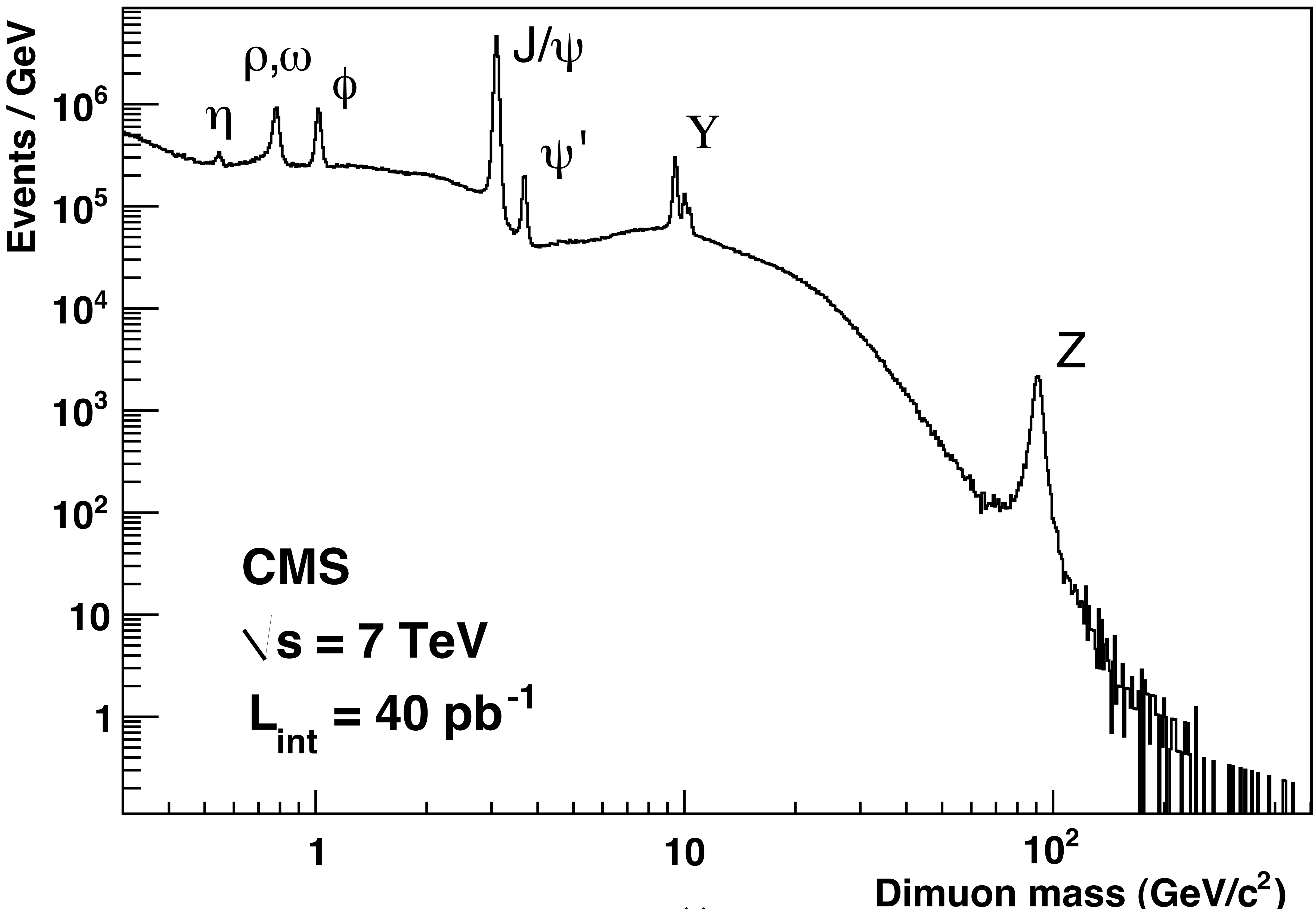
Phys. Rev. Lett. 106, 171801 (2011)



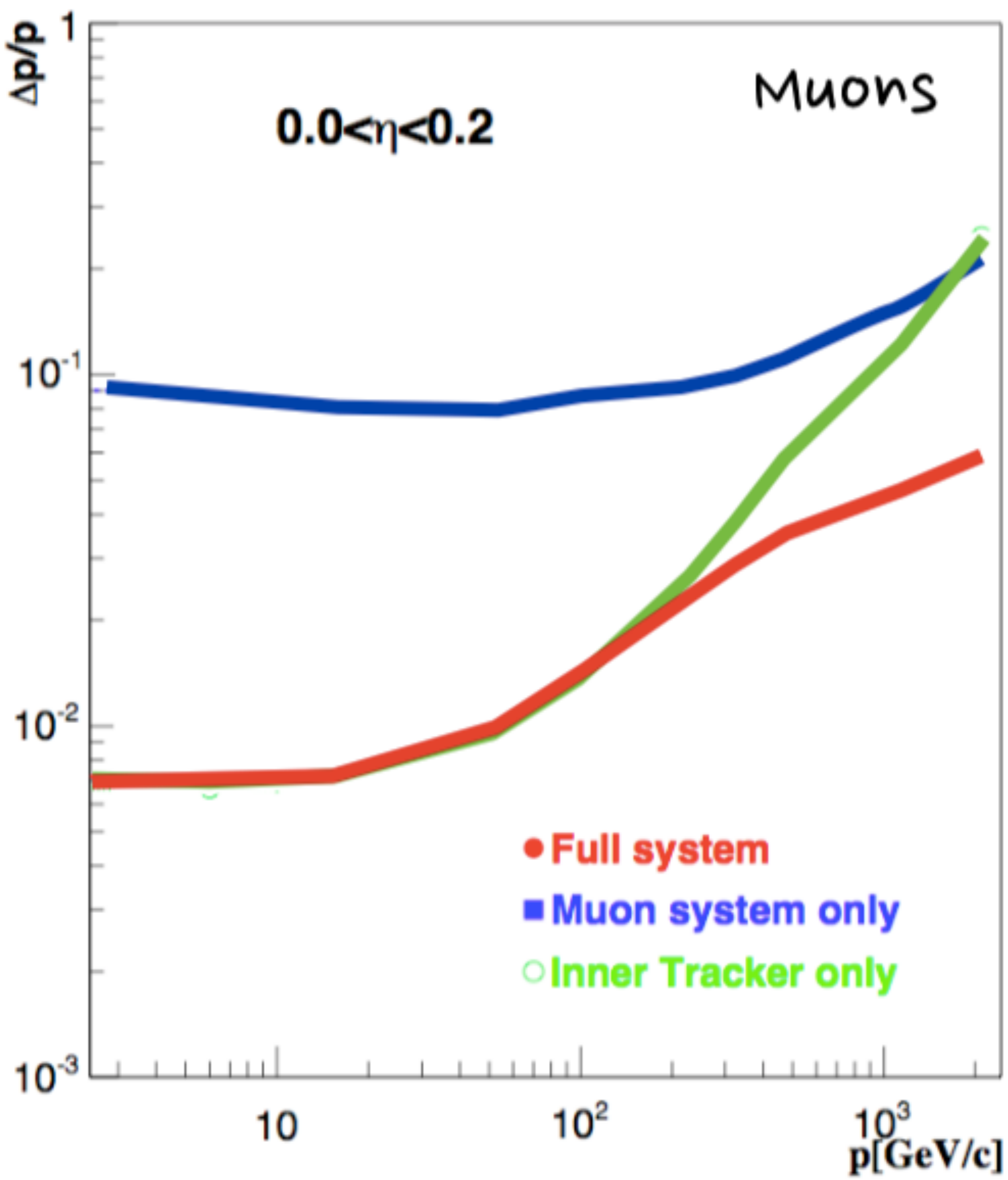
Early Di-electron Mass Spectra

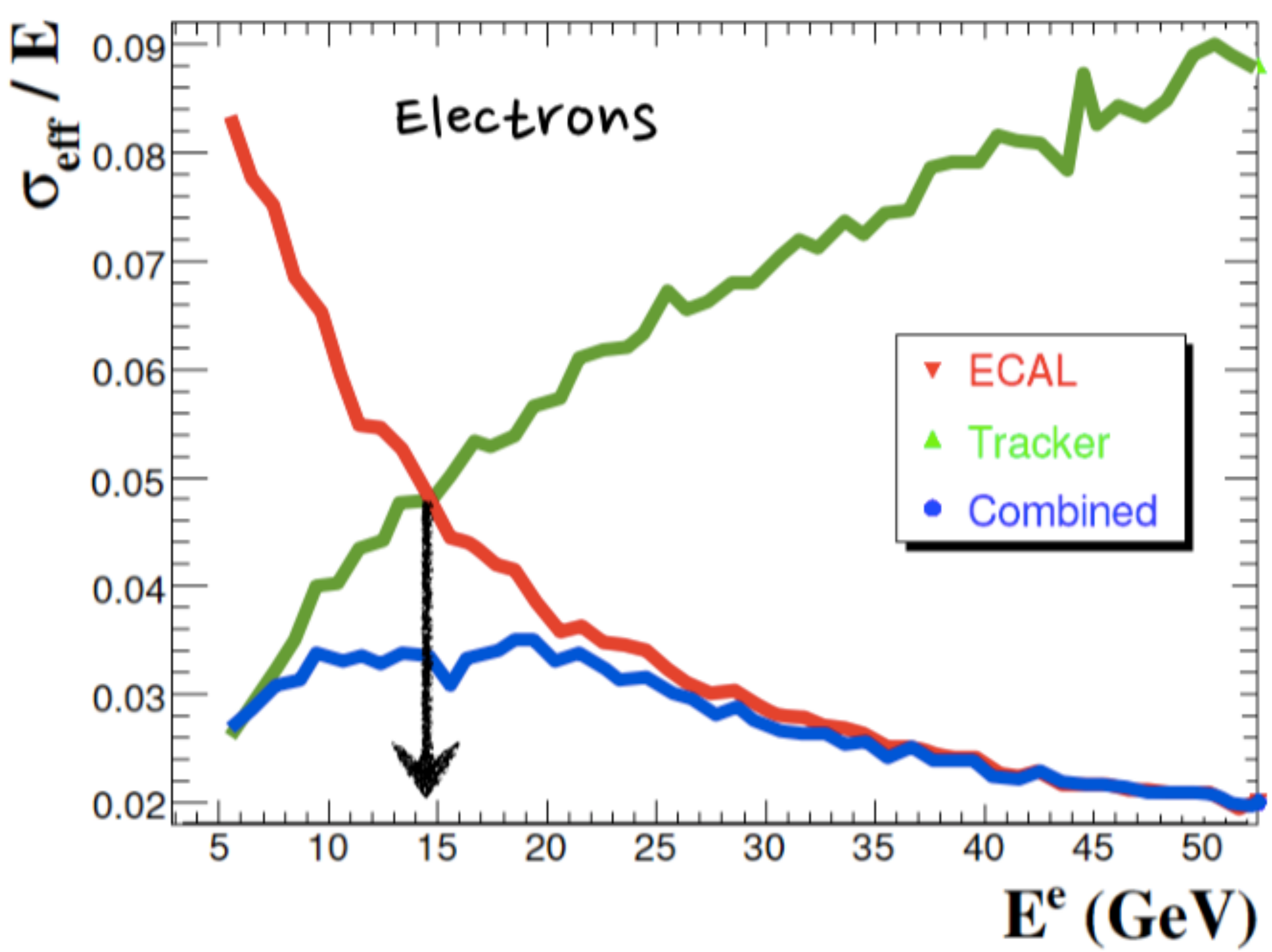


Early Di-muon Mass Spectra



Muon and Electron Energy Resolution



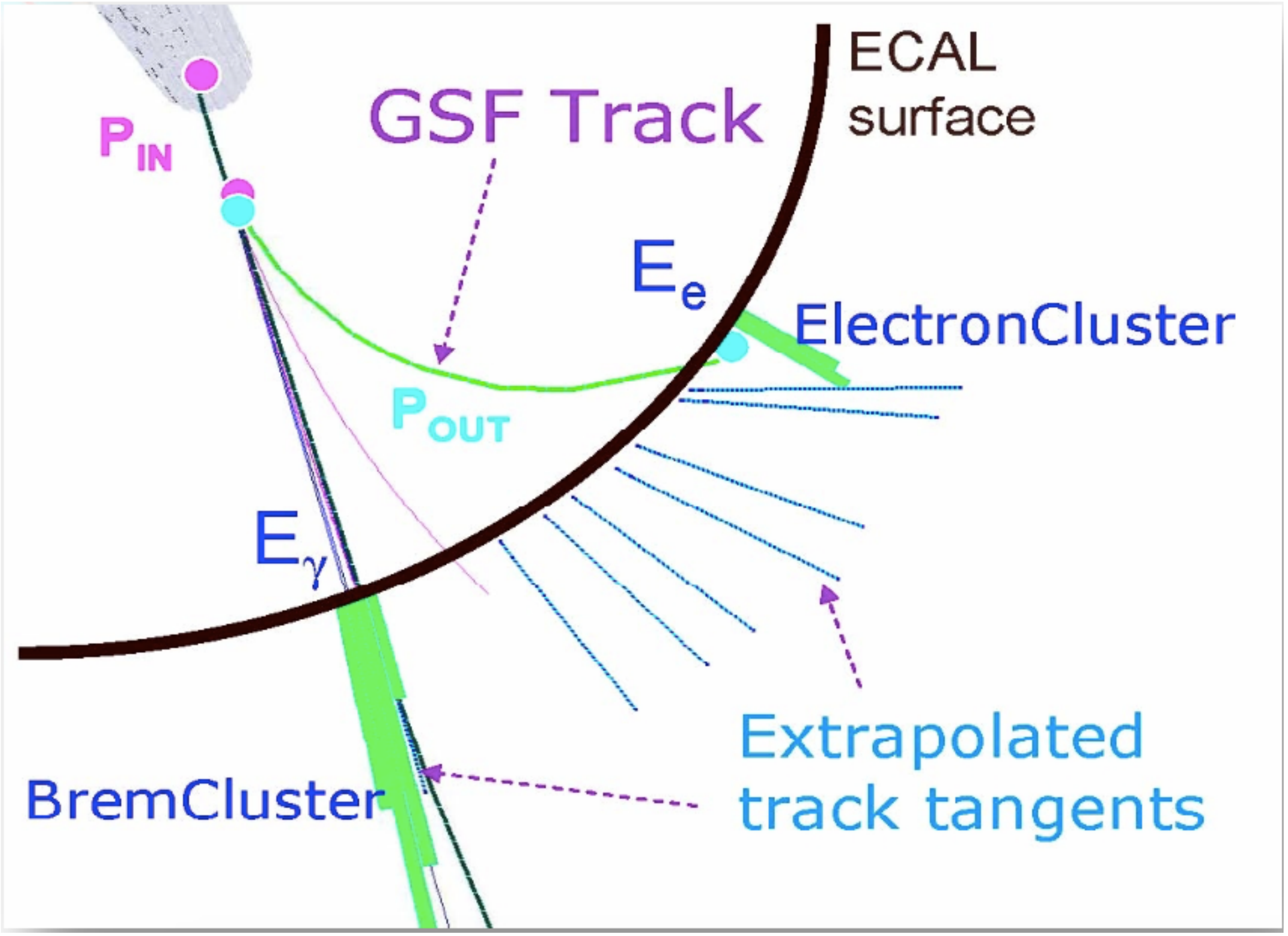


by R. Cavanaugh

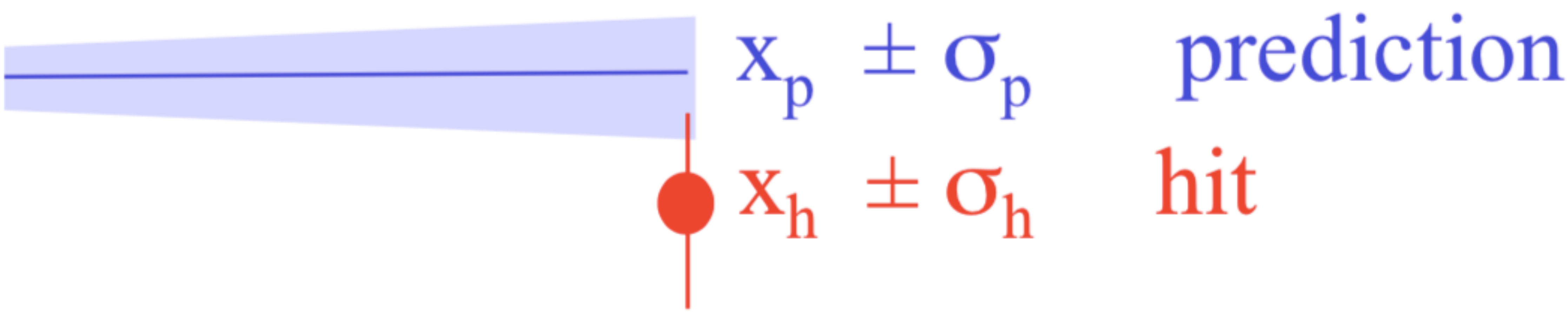
Electron

- Ideally, like a photon with a track
  - But energy spreads in Φ due to tracker material
  - Need to add 4-momentum of photons back

More about Gaussian Sum Filter Algorithm



Electron



$$\text{New } x = \frac{(x_p / \sigma_p^2) + (x_h / \sigma_h^2)}{(1 / \sigma_p^2) + (1 / \sigma_h^2)} = \text{weighted average}$$

Kalman Filter, figure by D. Stuart

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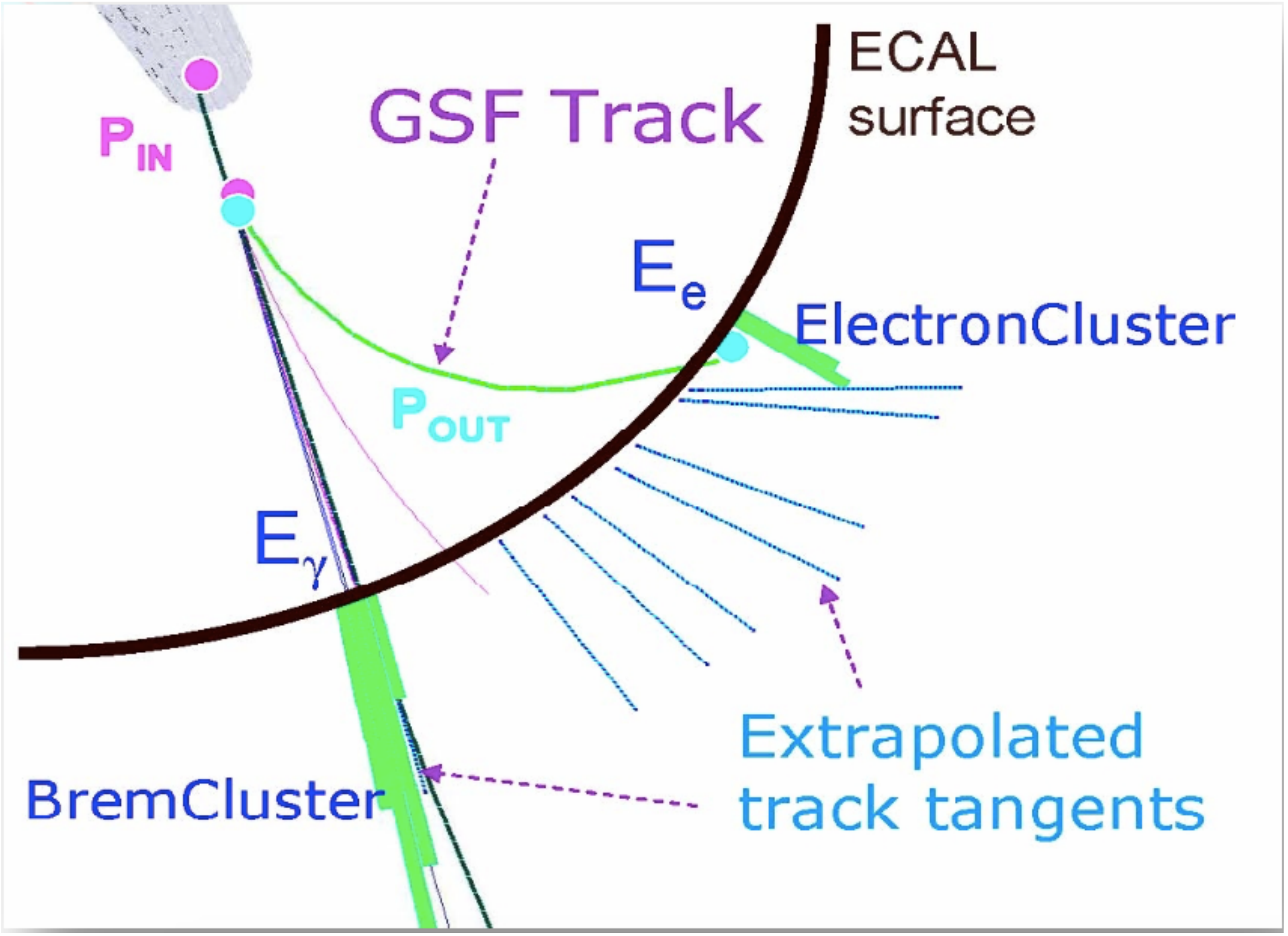
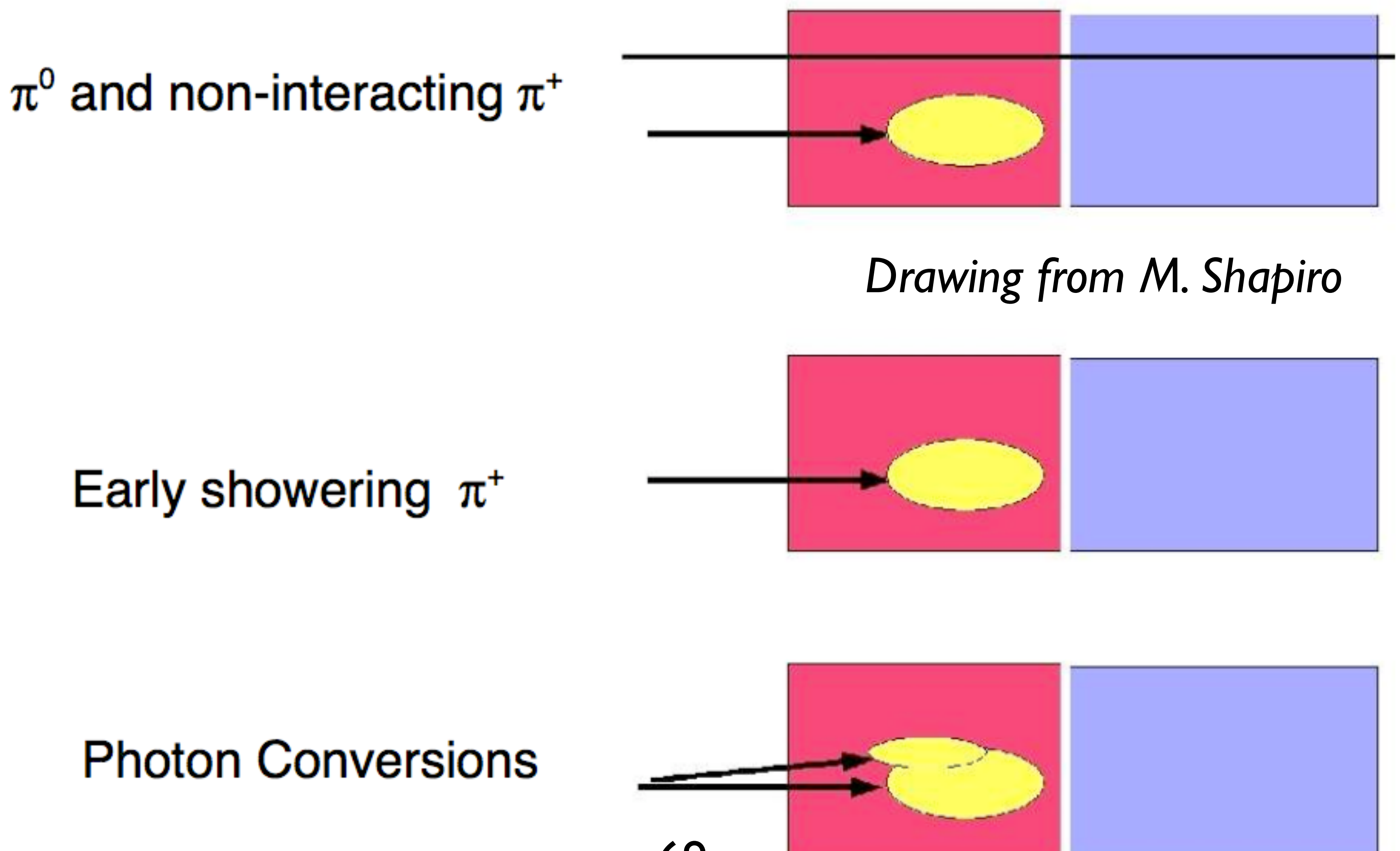
More about Gaussian Sum Filter Algorithm



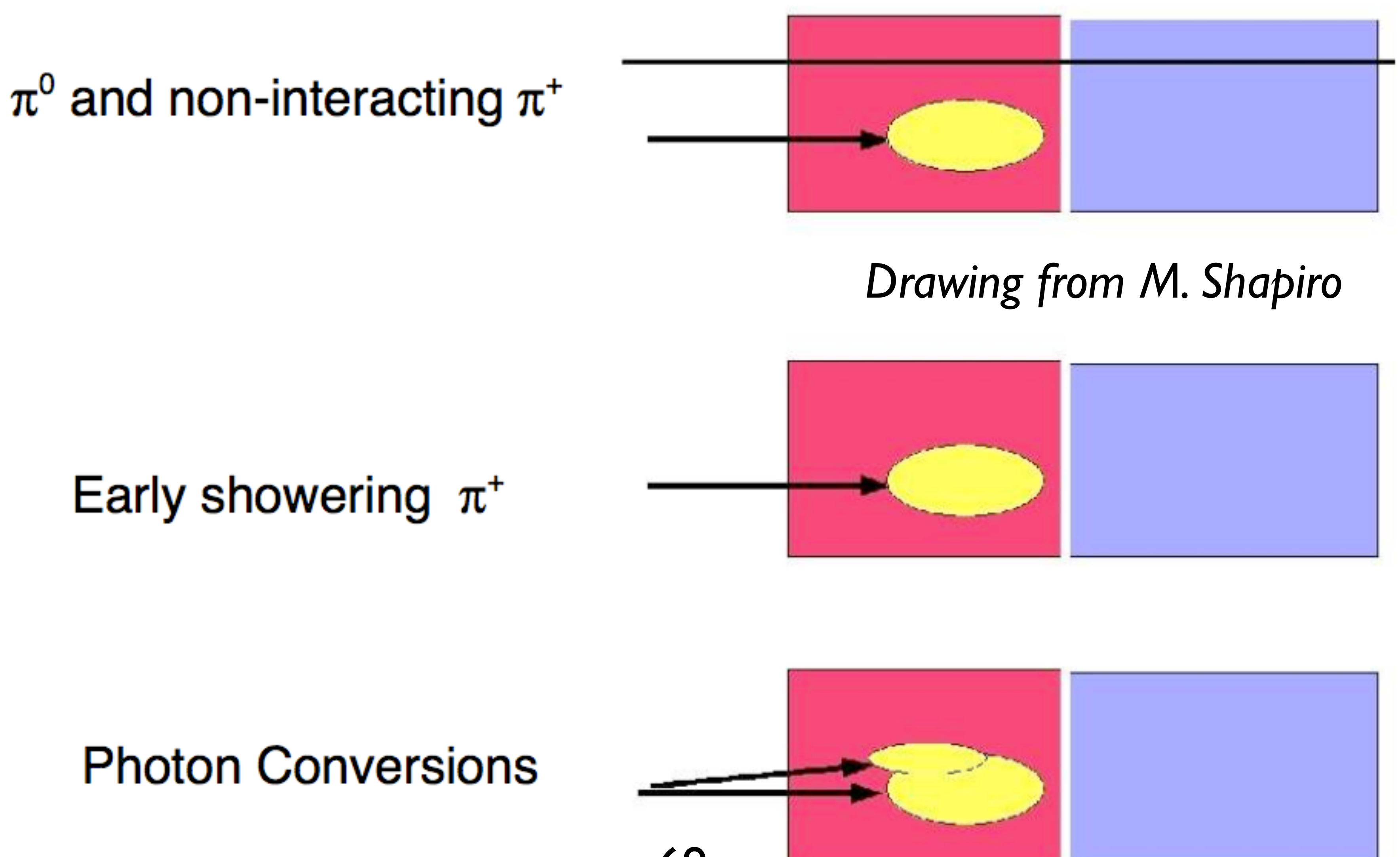
Background to Electrons of Interest



Drawing from M. Shapiro

Background to Electrons of Interest

- Photons that convert early or overlap of a random track with a photon



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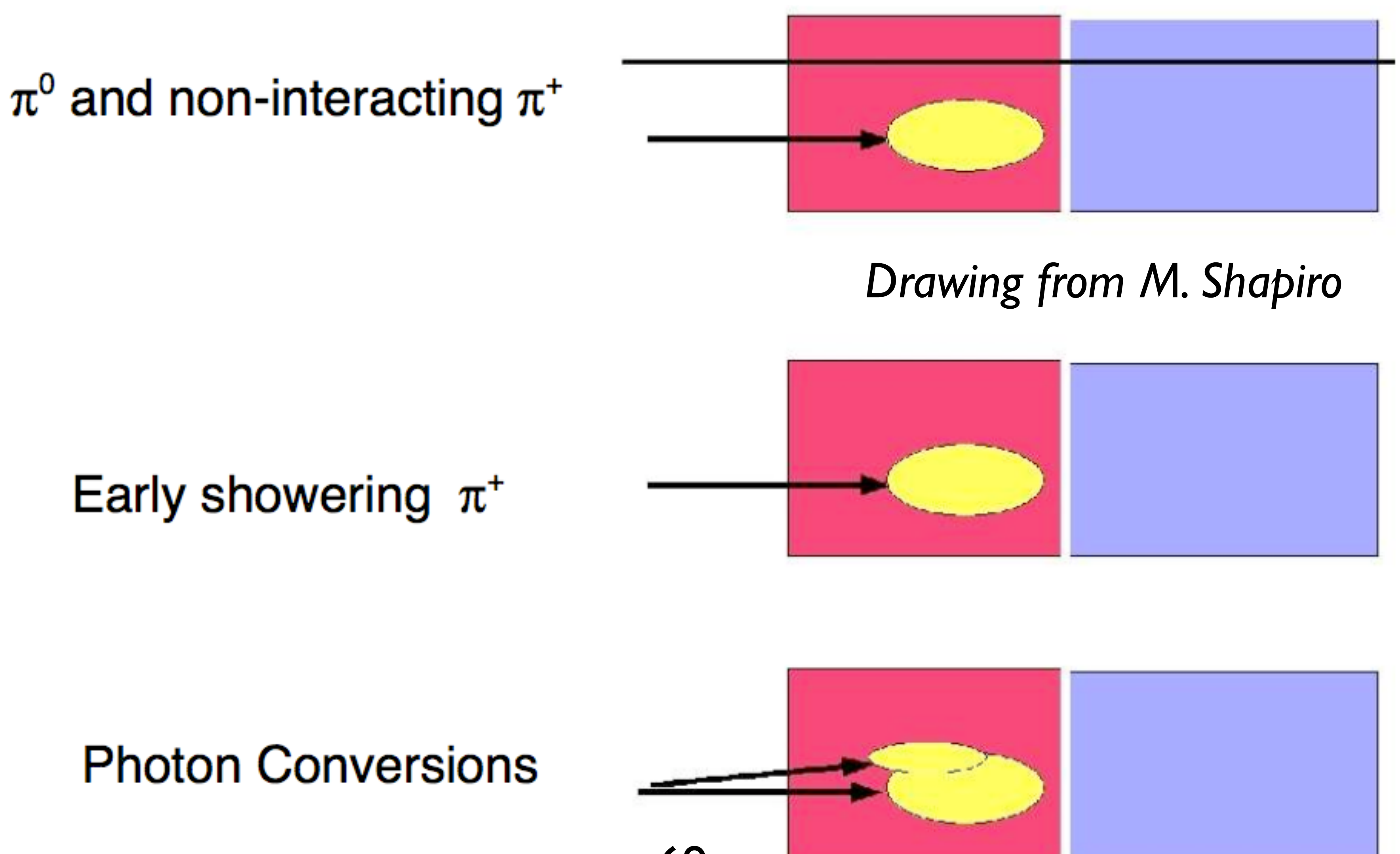
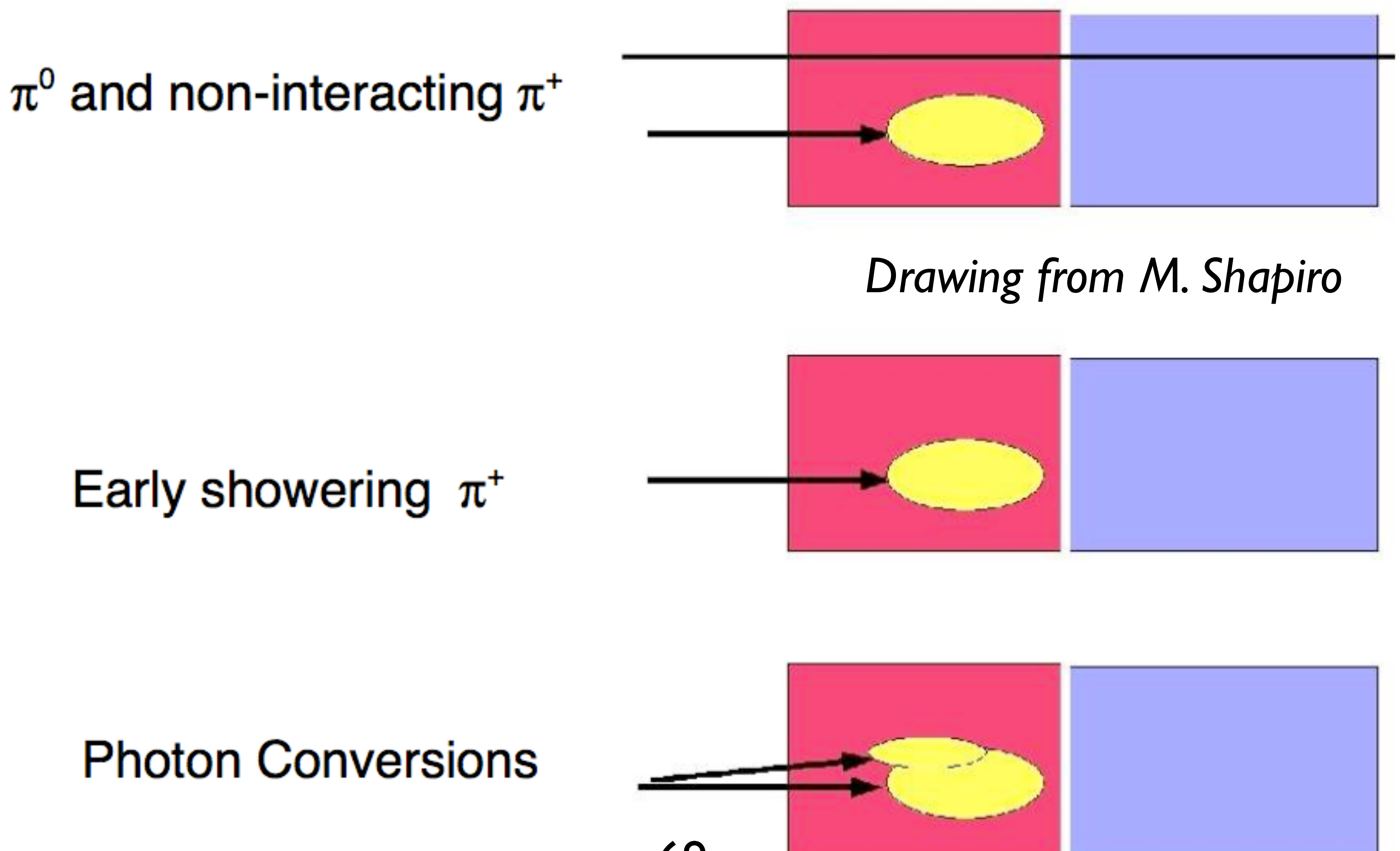


Drawing from M. Shapiro

Background to Electrons of Interest

- Photons that convert early or overlap of a random track with a photon
- Hadrons (early shower, overlap)
- Semileptonic decays of hadrons

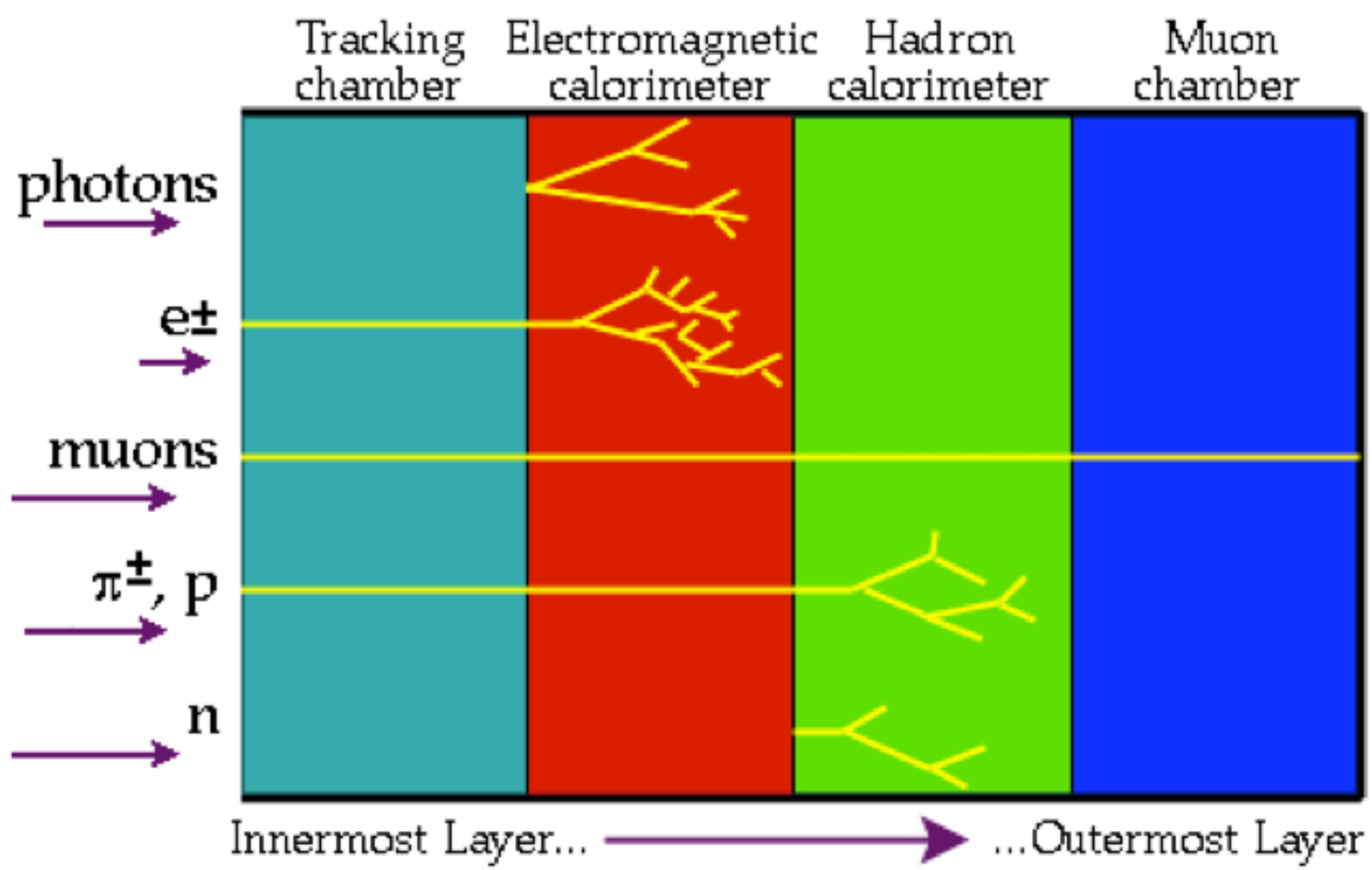


Drawing from M. Shapiro

Electron ID Variables

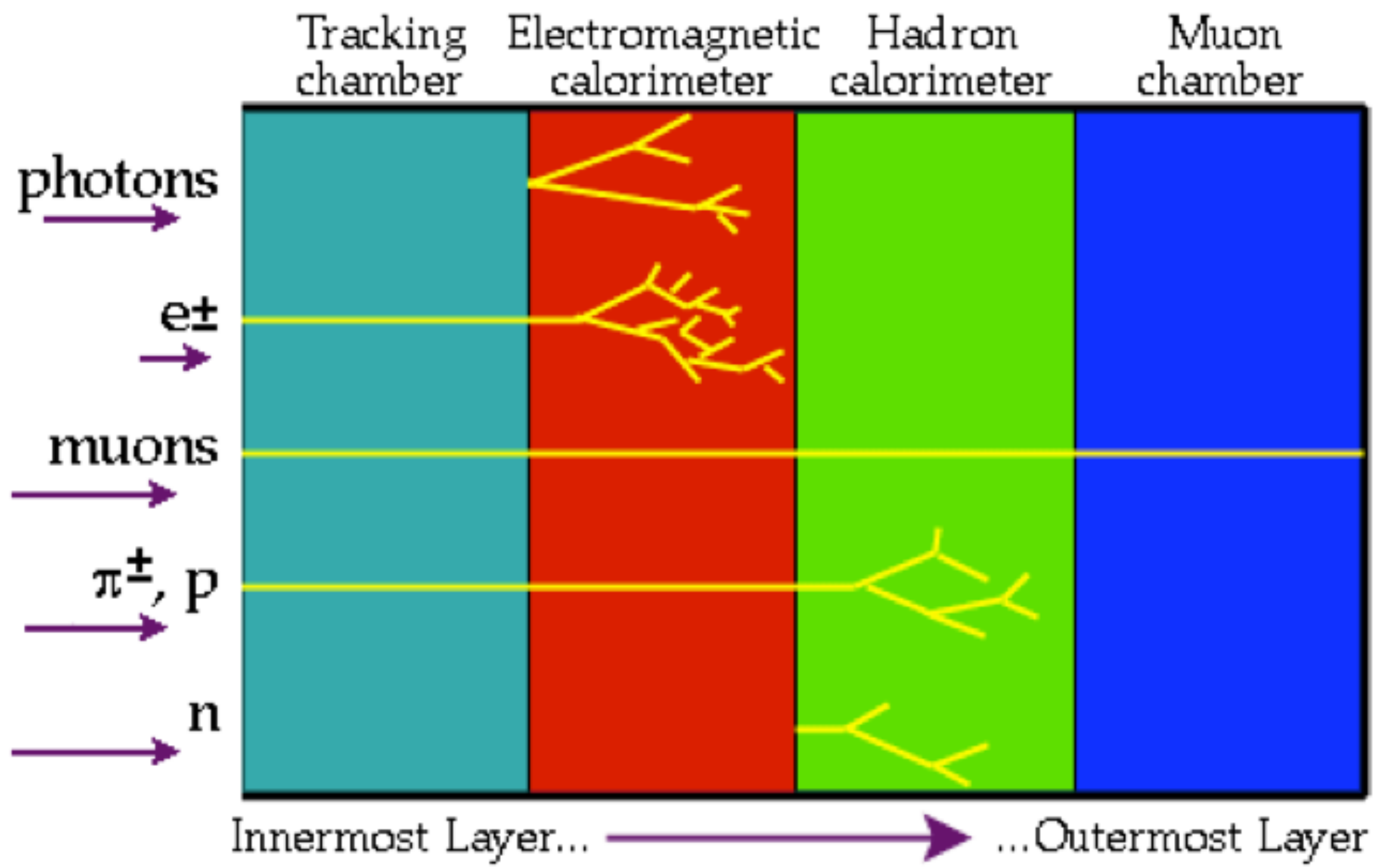
- Basically the same as photon ID variables, with addition of tracker-calorimeter matching
  - Shower shape
  - Isolation
  - Require hits in the most inner layer of tracker or reconstruct conversions explicitly (reduce photon conversions)

The Cleanest Object: Muon



The Cleanest Object: Muon

- High reconstruction (~99%) and identification efficiency (~95%)



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  - Decay in flight
  - Punch through
  - Overlap of random tracks with noise in the muon chamber

The Cleanest Object: Muon

π^+ DECAY MODES

$\mu^+ \nu_\mu$	[a]	(99.98770 ± 0.00004) %

D^+ DECAY MODES

e^+ semileptonic	(16.07 ± 0.30)
μ^+ anything	(17.6 ± 3.2)

$B^\pm / B^0 / B_s^0 / b$-baryon ADMIXTURE

$\ell^+ \nu_\ell$ anything	[a]	(10.69 ± 0.22) %

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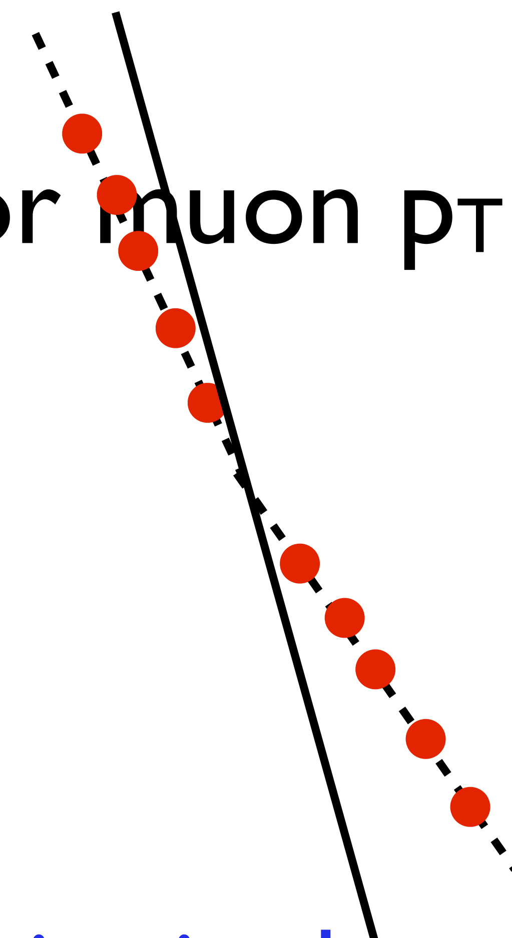

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Muon ID Variables

- Isolation
- Minimum amount of energy in calorimeters
- Matching quality between tracker and muon chamber information
- Track quality
    - Number of hits
    - Impact parameter
    - Fit chi-square

Event Selection Criteria

- W
  - An electron or a muon candidate
  - Remove events with a second isolated leptons
- Z
  - Two isolated electrons or two isolated muons
- Form transverse mass for W, invariant mass for Z

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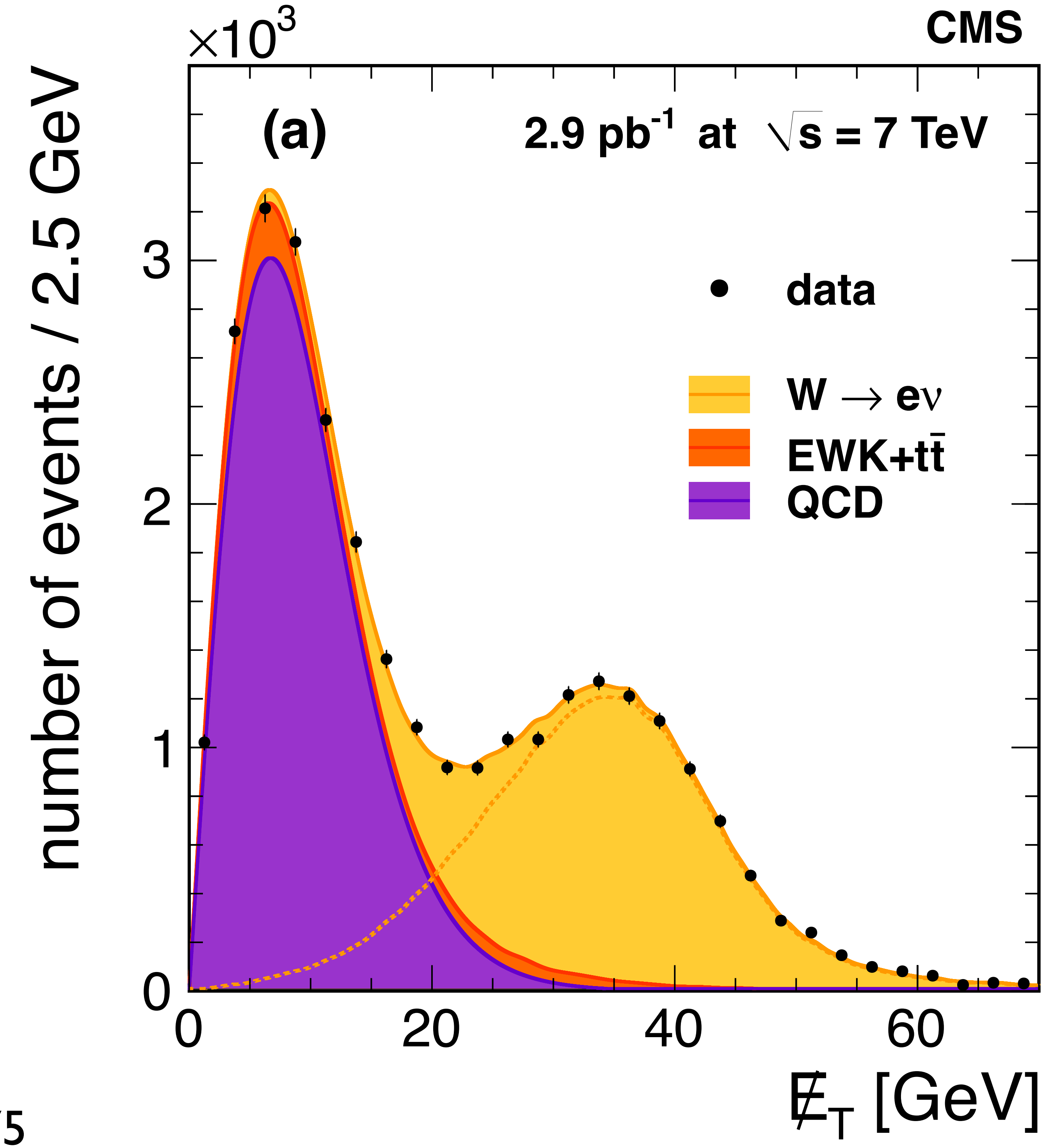
Homework

Background Processes

- W
  - QCD multi-jet events
  - Photon + jet events
  - Drell-Yan production with one missing lepton
  - Leptonic decays of tau-channel of W and Z production
  - Top quark pair and di-boson production
- Z
  - QCD multi-jet events
  - Top quark pair, di-boson production

W Candidates (Electron Channel)

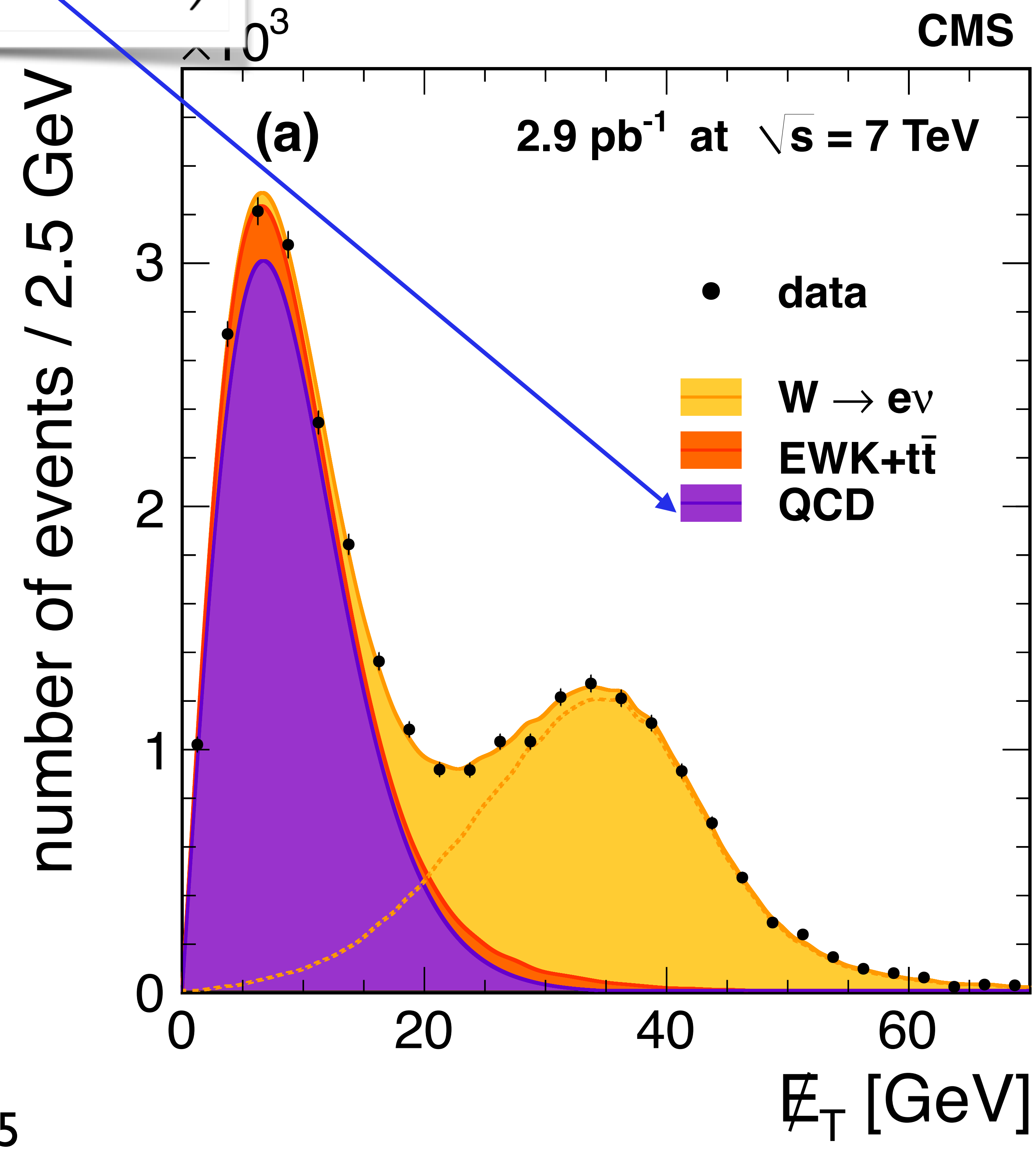
- Signal shapes from simulation
- Background shapes validated with simulation and control data with inverted selection



W Candidates (Electron Channel)

$$f(\not{E}_{\mathrm{T}}) = \not{E}_{\mathrm{T}} \times \exp\left(-\frac{\not{E}_{\mathrm{T}}^2}{2(\sigma_0 + \sigma_1 \not{E}_{\mathrm{T}})^2}\right)$$

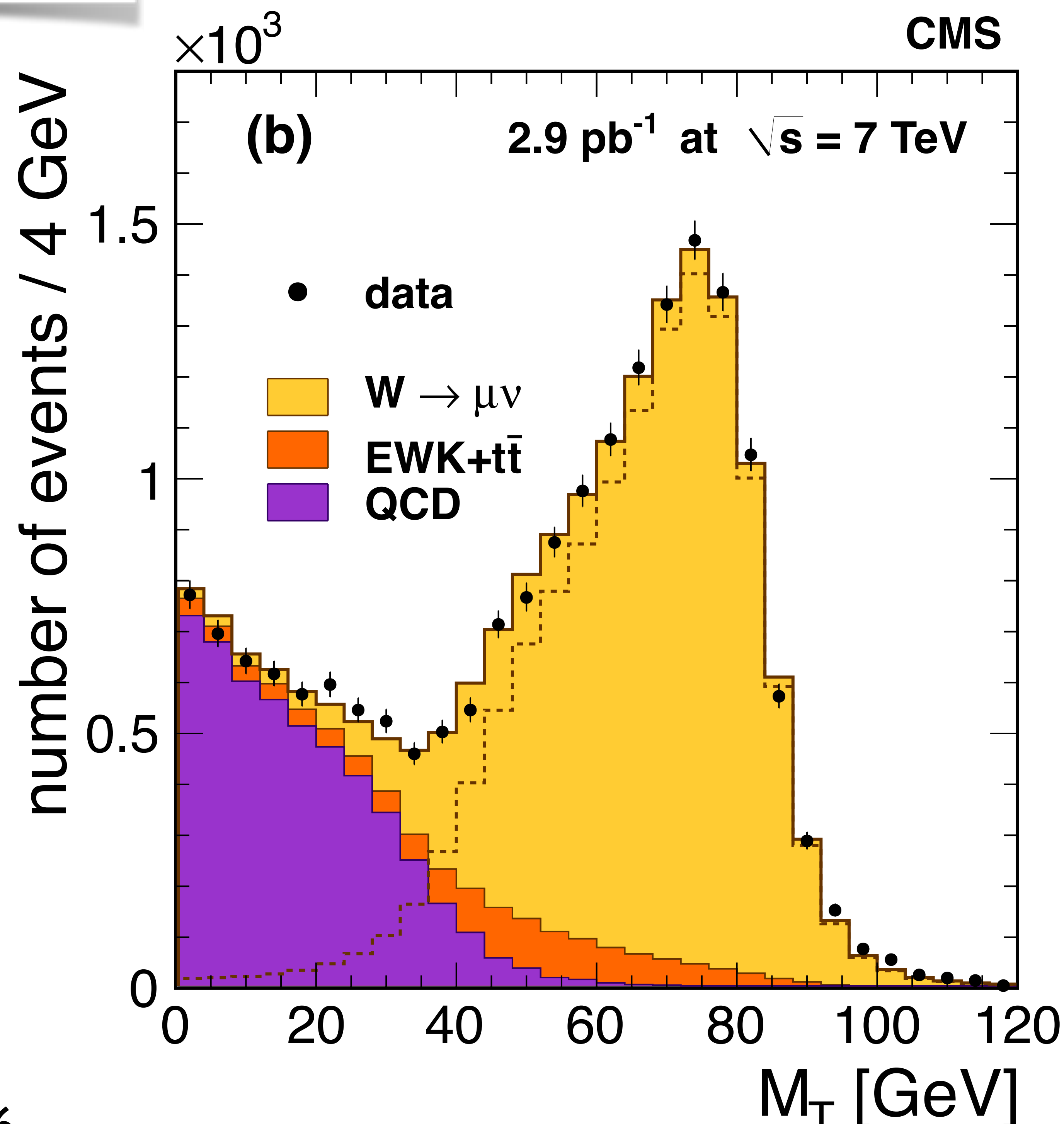
- Signal shapes from simulation
- Background shapes validated with simulation and control data with inverted selection



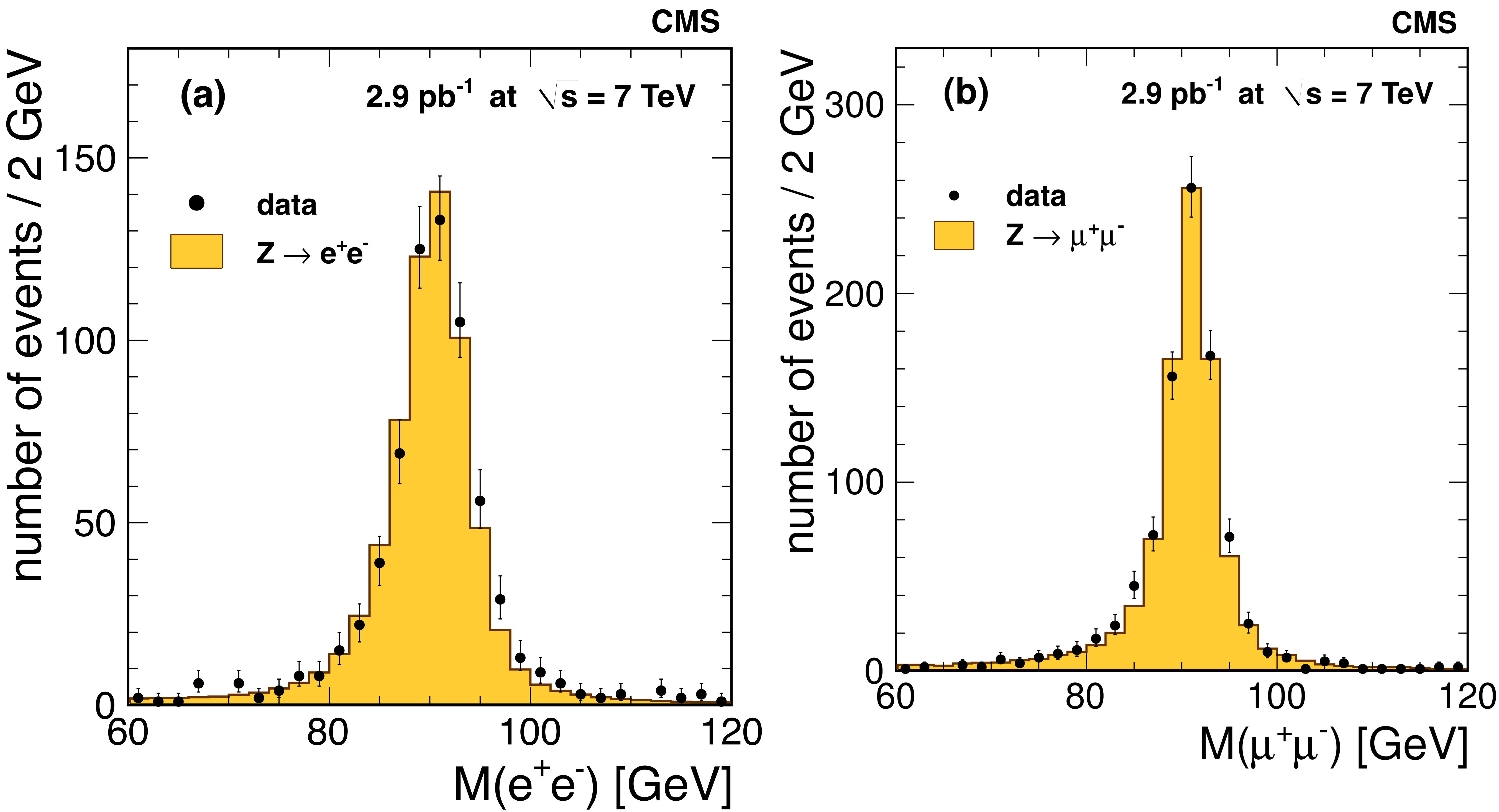
W Candidates (Muon Channel)

$$m_T = \sqrt{2\, p_T^{\ell}\, E_T^{\text{miss}}\, (1 - \cos\Delta\phi)}$$

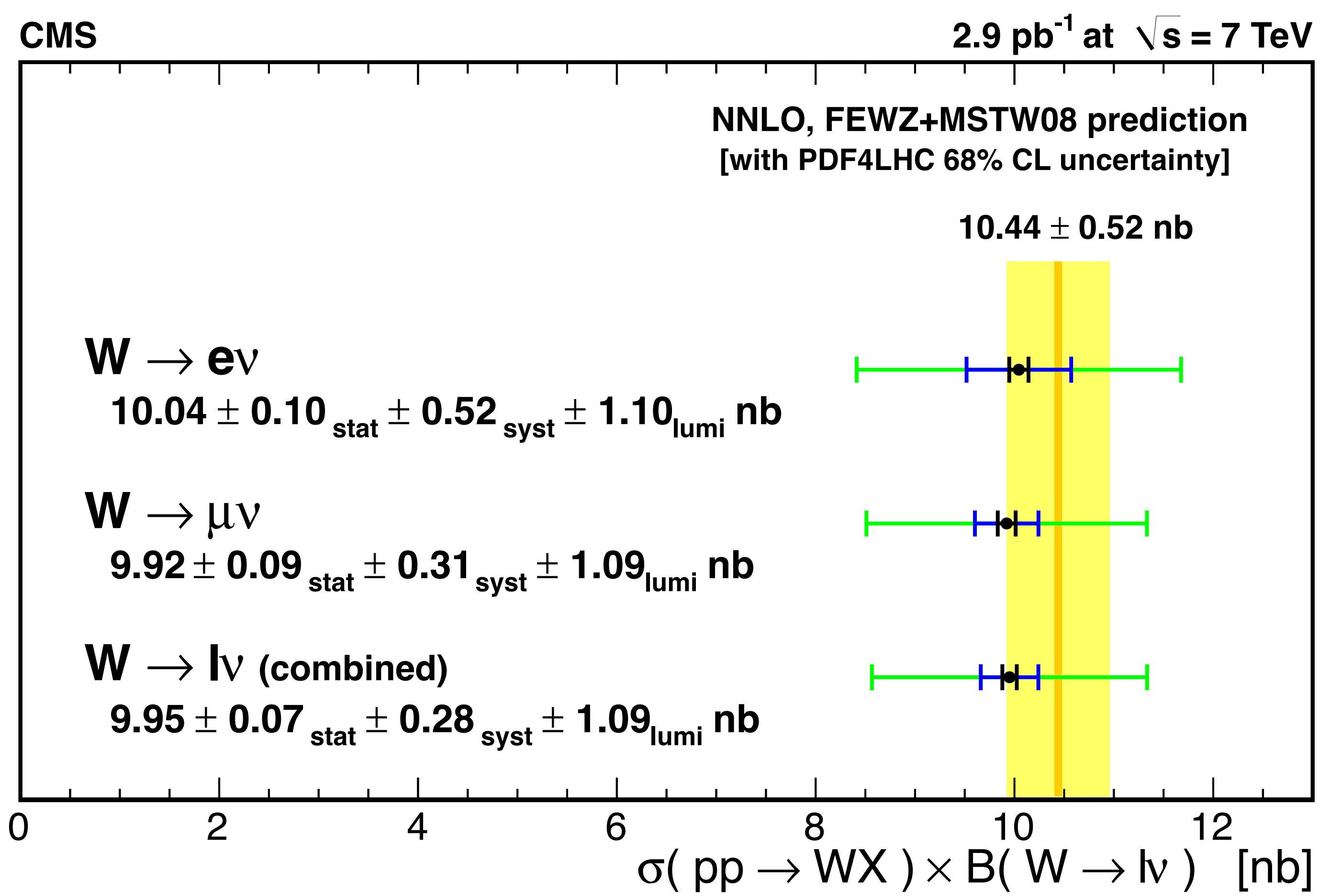
- Signal and most background shapes from simulation
- QCD Background shape from control data with inverted isolation

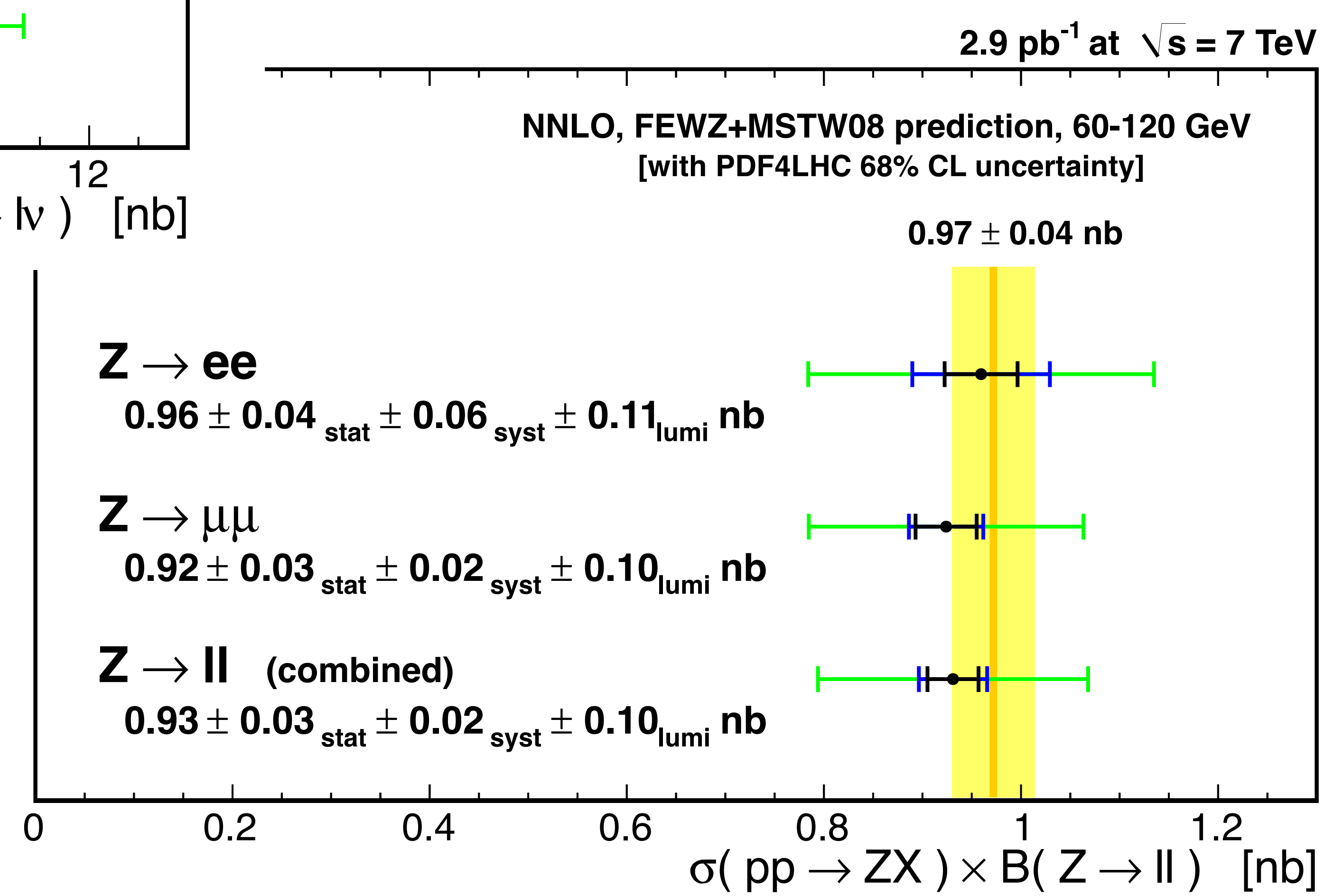


Z Candidates



Summary of W and Z Cross Sections





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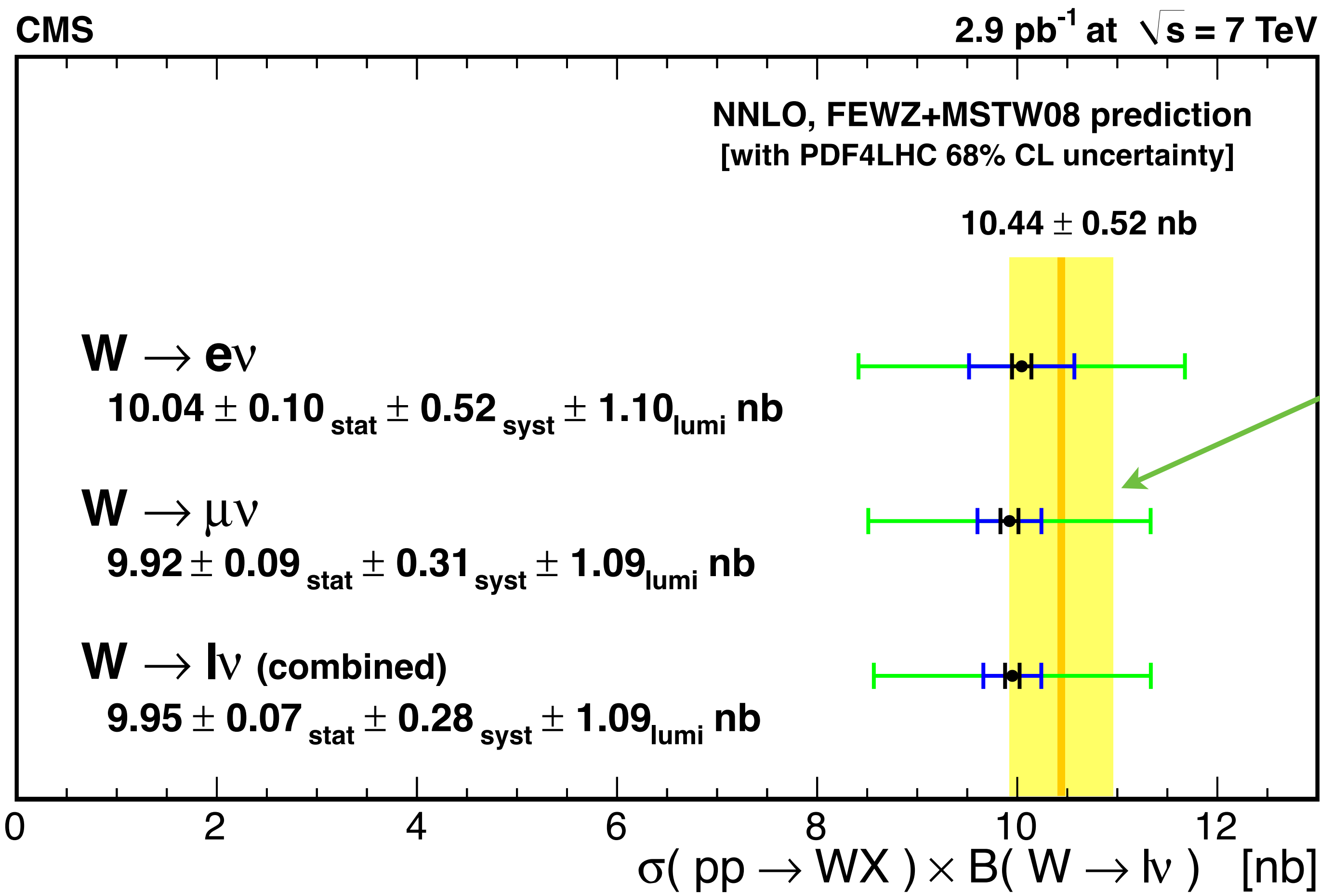
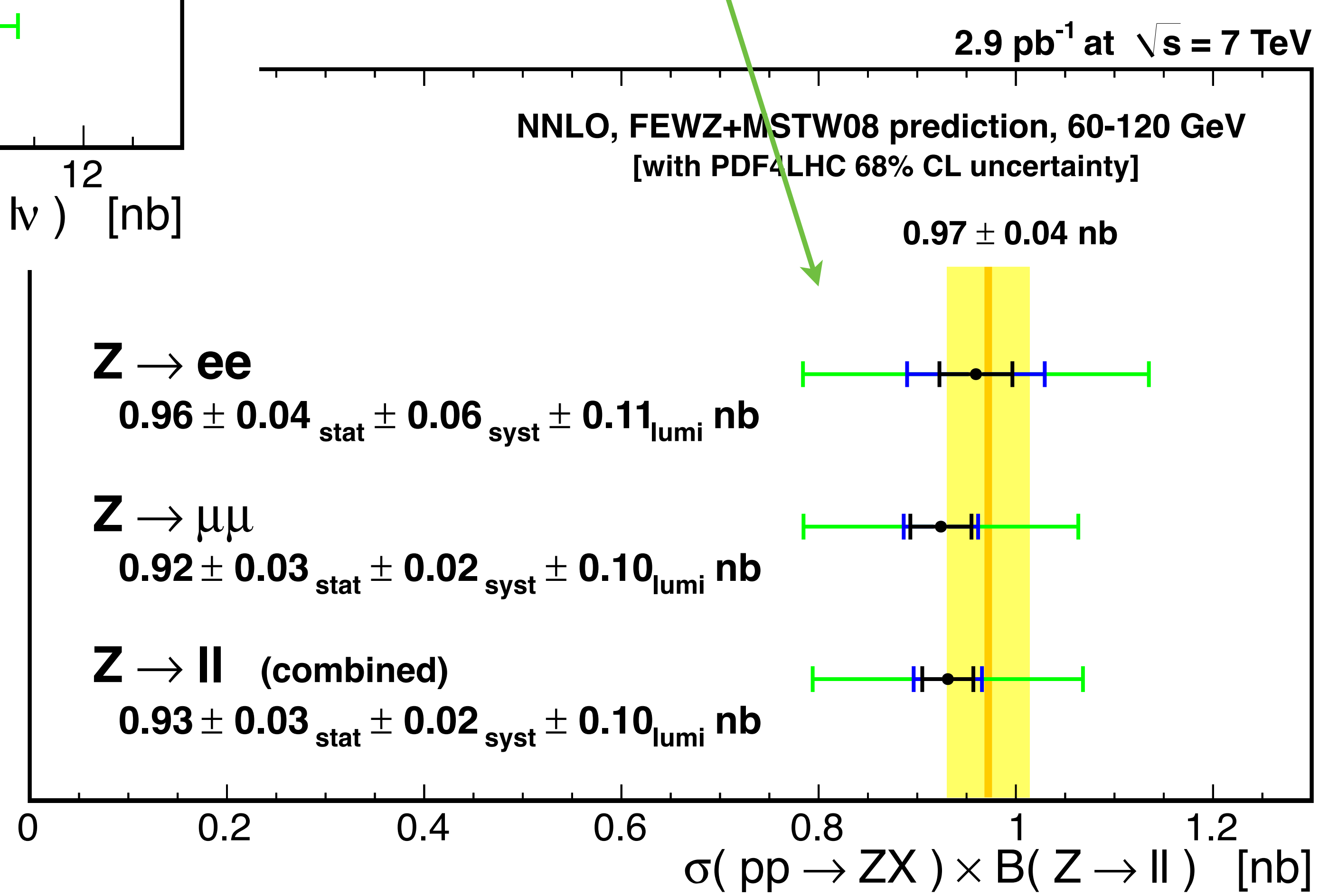


11% uncertainty from initial luminosity measurement



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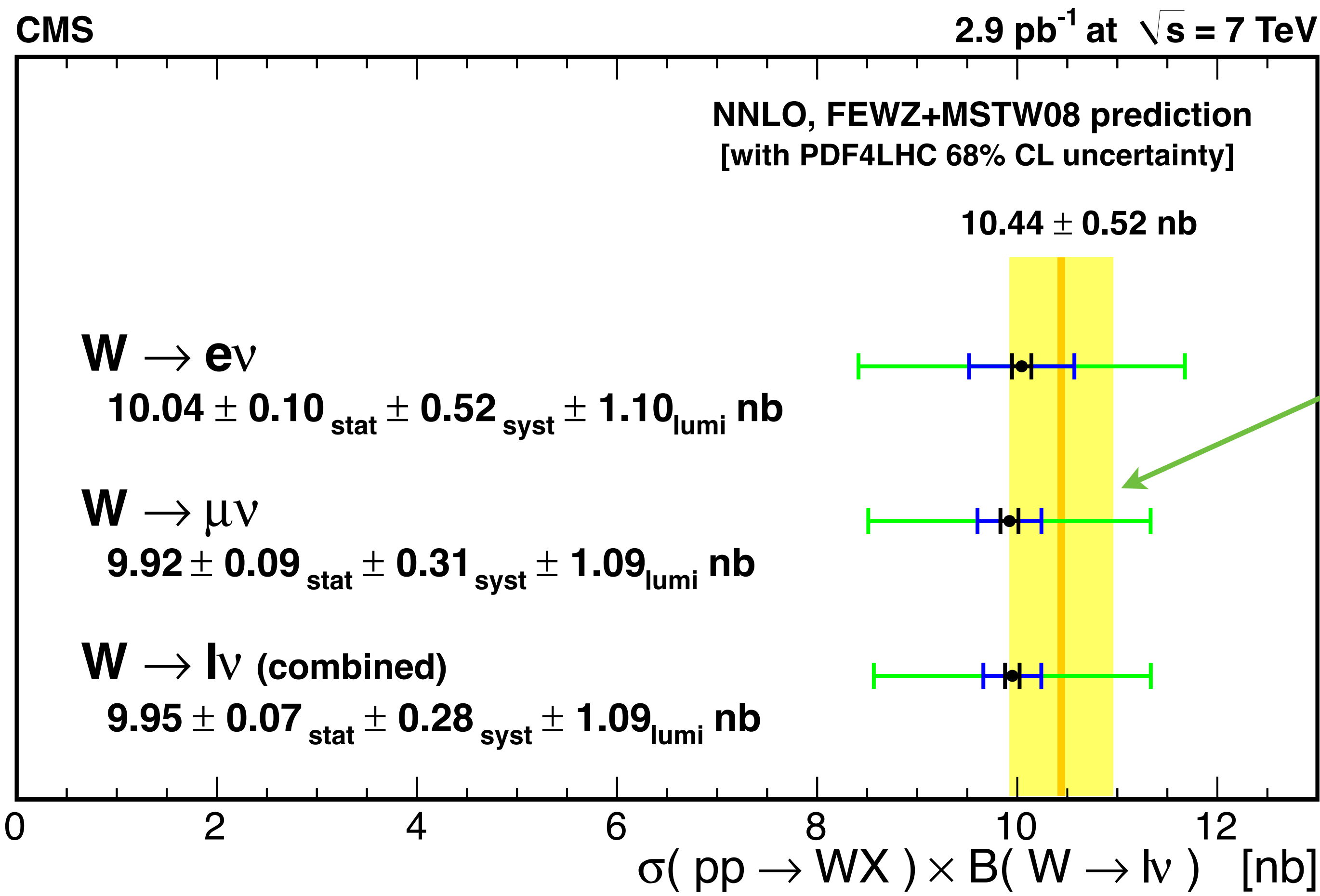

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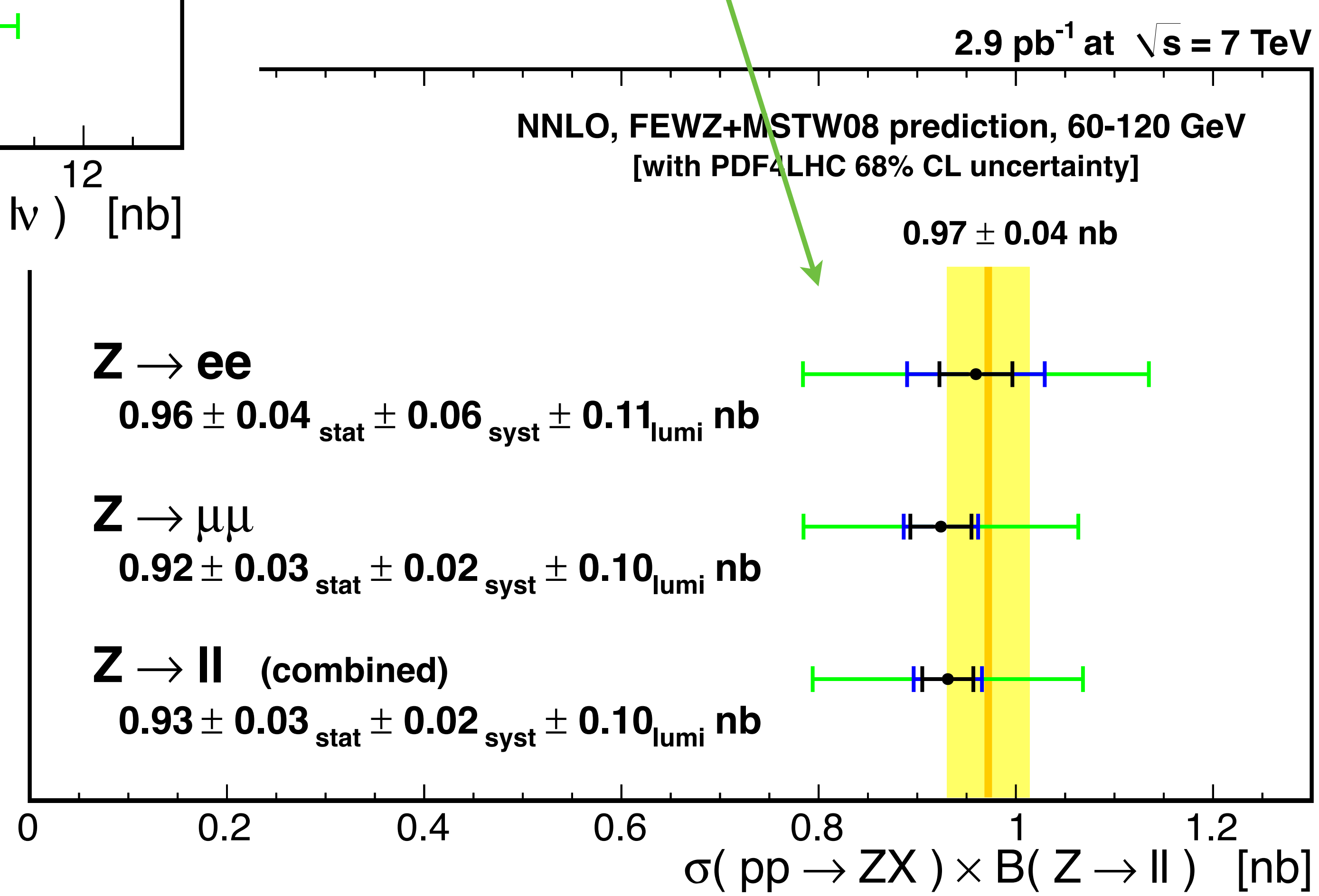
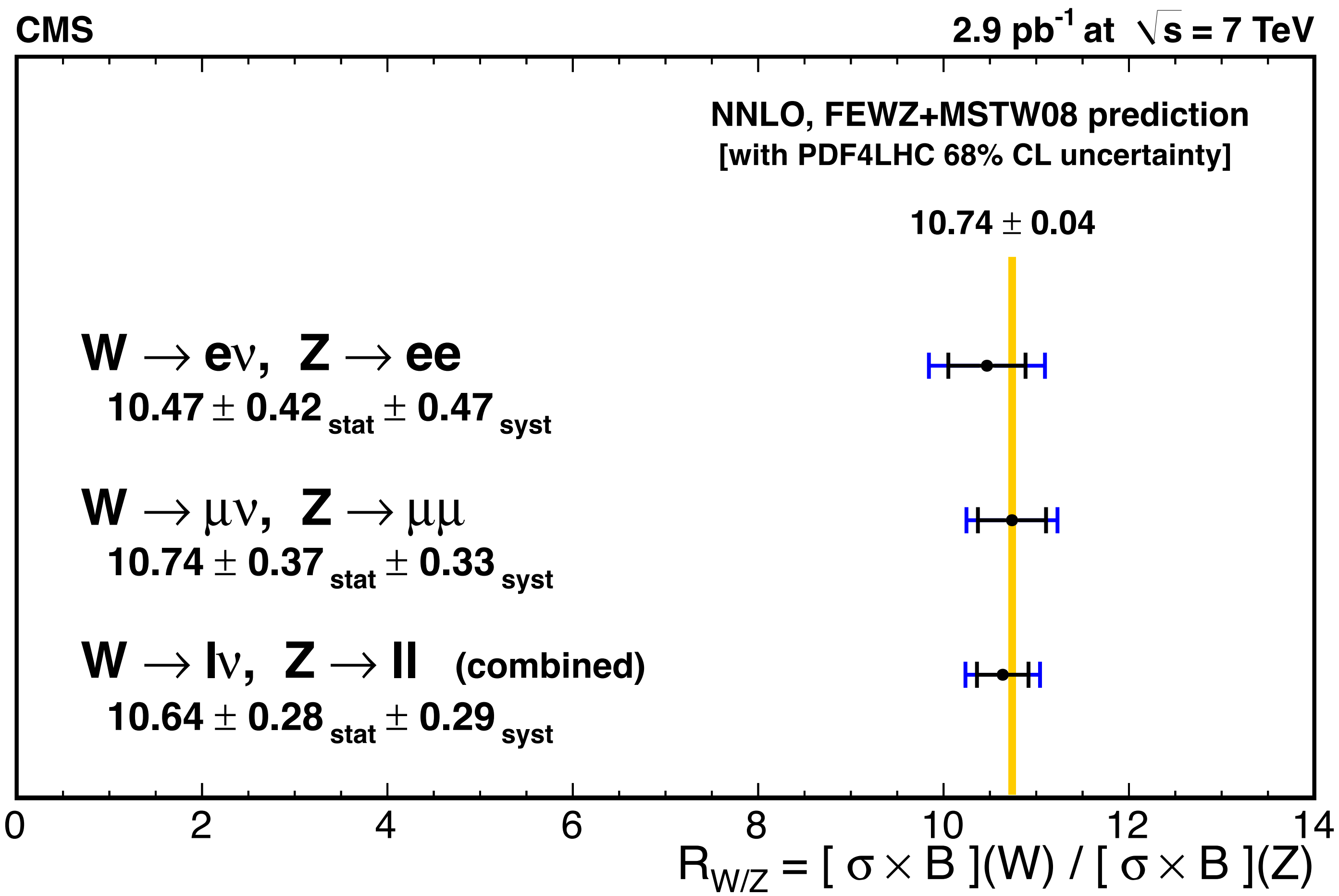
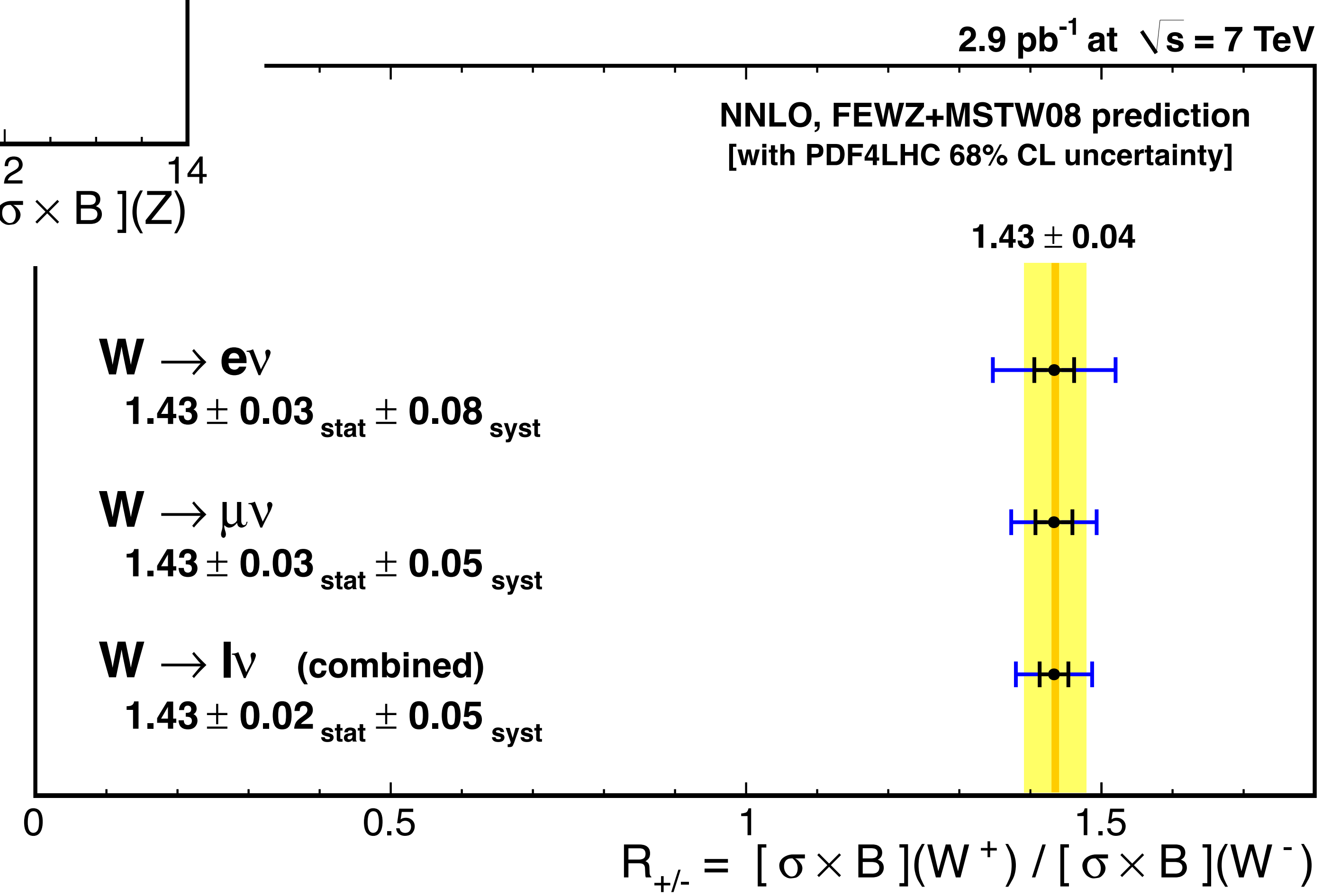


Apart from luminosity uncertainty, experimental uncertainty comparable to theoretical uncertainty

Ratio of Cross Sections





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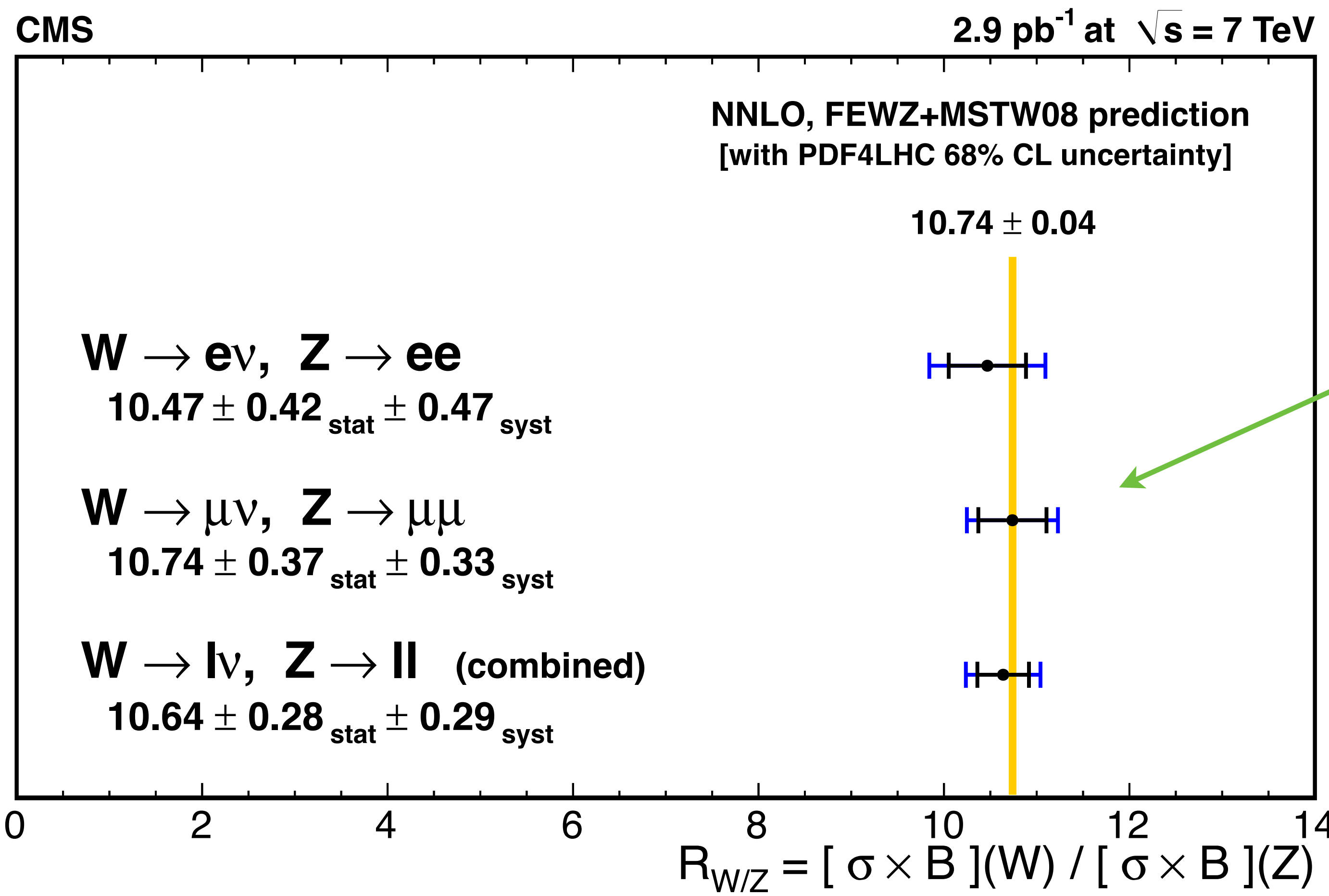
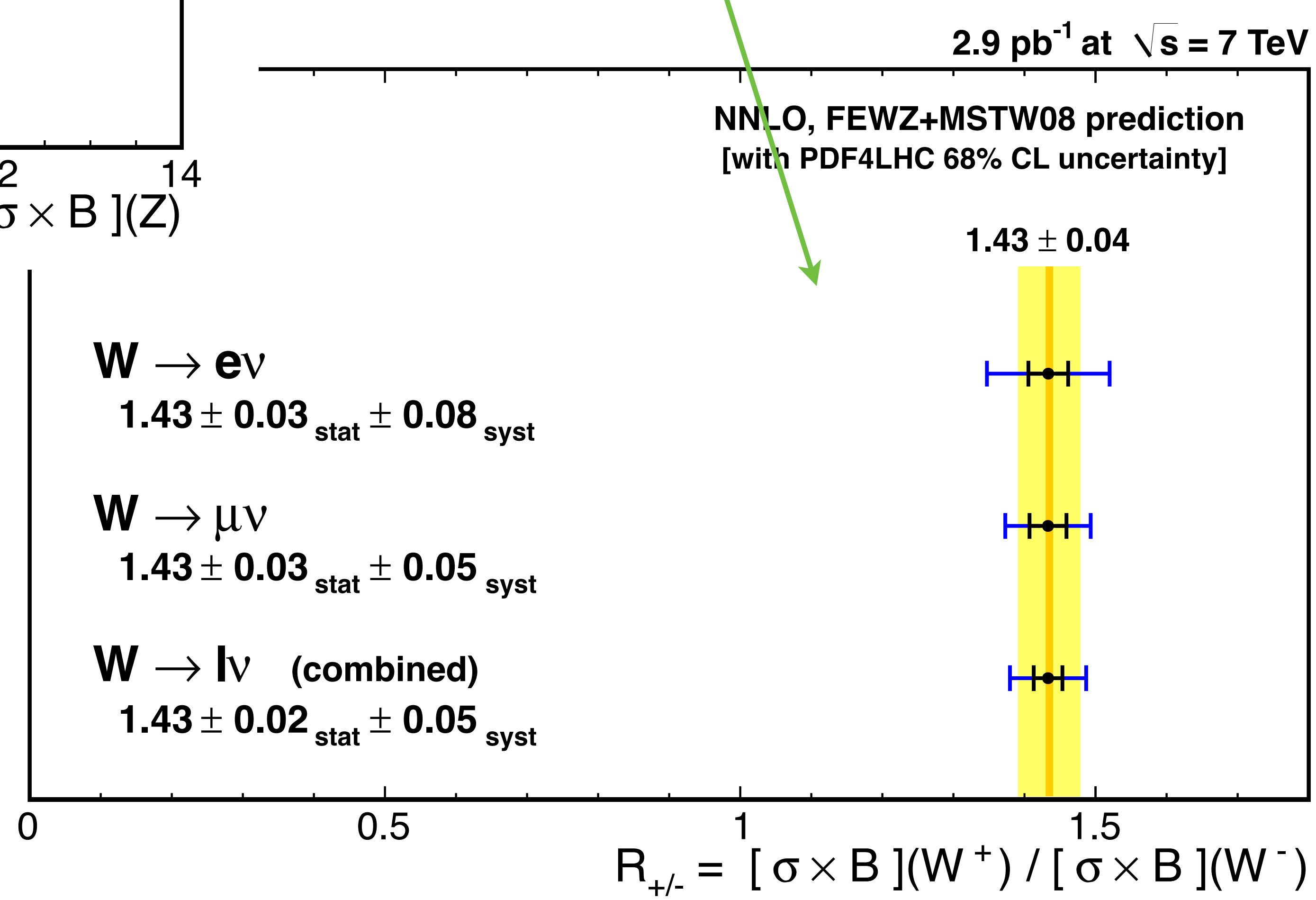


11% uncertainty disappears in the ratio



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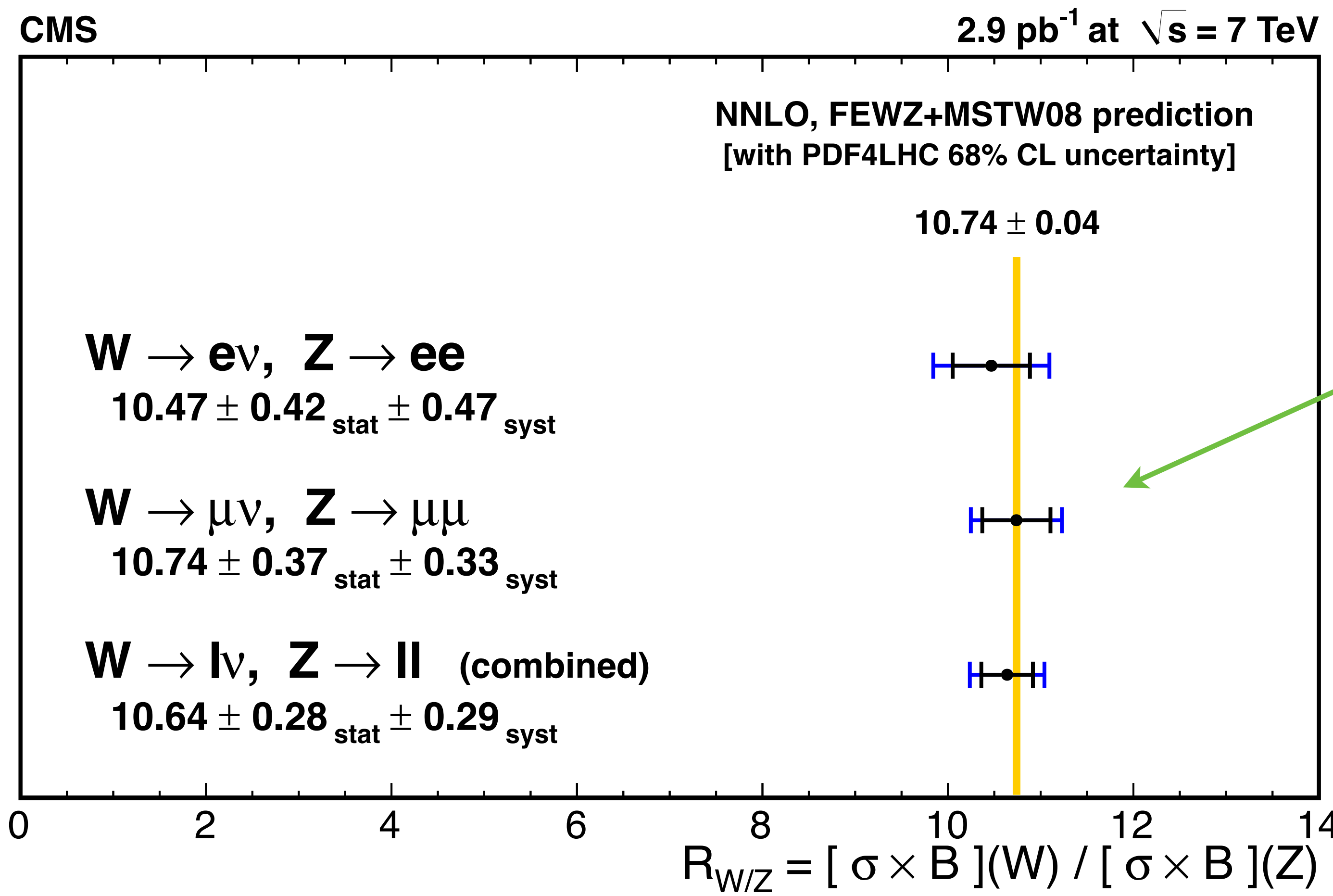

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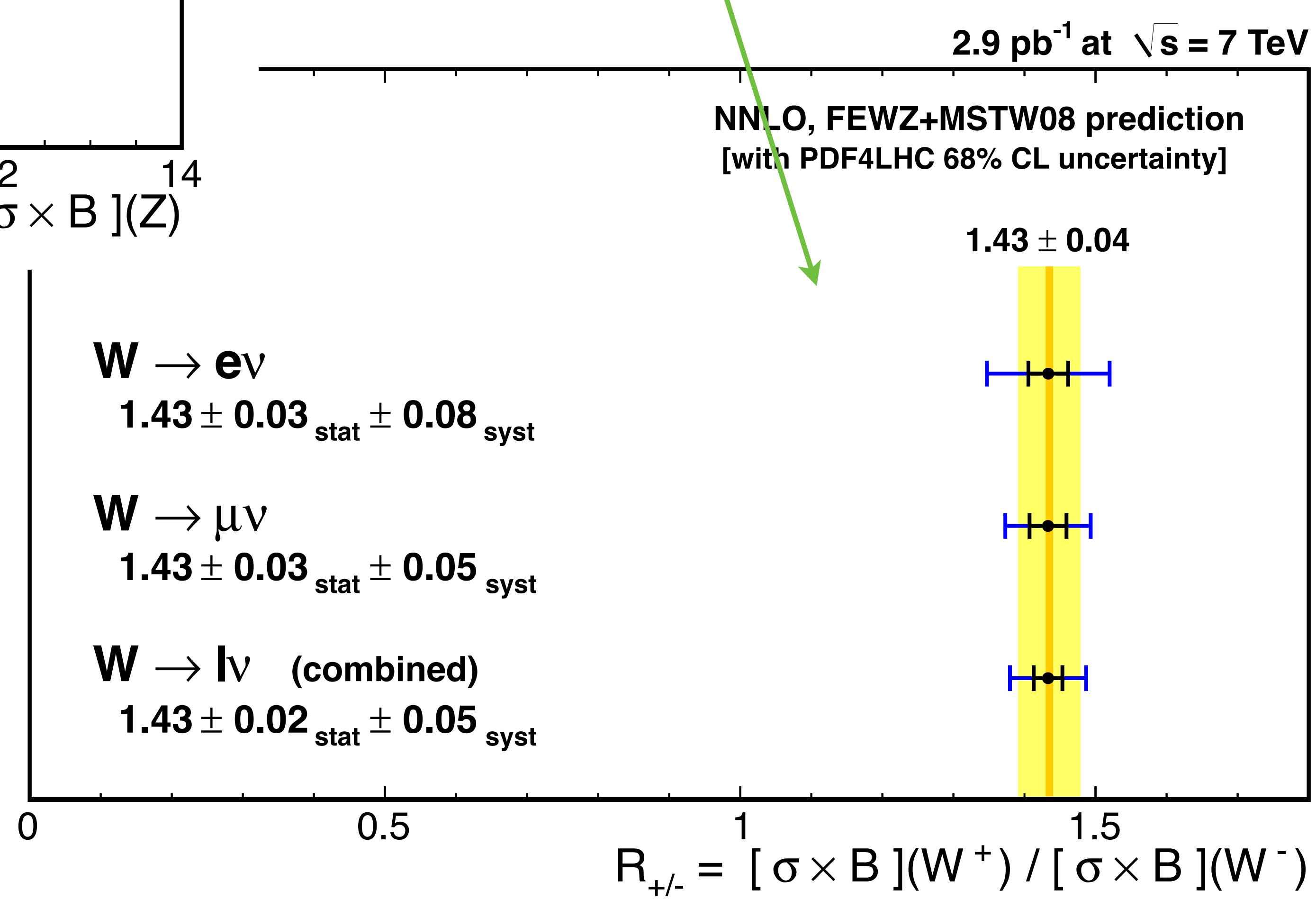

More W^+ than W^- because this is a pp collider

Comparison with Other Measurements