Status of LHC Physics: Precision Theory View

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Preface

Why Do We Still Need the LHC?

Crucial Step Toward Resolving Fundamental Outstanding Issues:

- Big and Little Hierarchy Problems
- Number of Families
- Fermion Masses
- Baryon Stability
- Union of QM & Gravity

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- Origin of CP Violation
- Origin of Lambda
- Dark Matter, …..

Much Theory Effort: New Physics – Still on the Table

*String Theory: Solves Everything in Principle but Trouble in Practice – $> 10^{500}$ candidate "solutions"!

*String Inspired Theory:

-- Large Extra Dimensions

-- KK Excitations, …

* MSSM,
* D(EW)SB,
* ANTHROPICITY
* NEW PARADIGMS

$\Rightarrow$ NEW DEVICES:

* NEW PARADIGMS:

1005.3394(EPJC71(2011)1686) -- 3 or more New Heavy Families w SM quarks-New Leptons, SM leptons-New Quarks: M_{GUT} ~100TeV, proton stable, coupling unification,… ⇒ TLEP, VLHC,…

1008.1046 -- RQG w Asymptotic Safety ⇒ $\rho_\Lambda \cong (2.40 \times 10^{-3}\,\text{eV})^4$ ⇒ FOR SUSY, FLIPPED COPY ⇒ TLEP, VLHC,…

1010.1415 – Classicalons, ….

1304.3464 – Higgsogenesis ….

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** CURRENT STATUS AT LHC (De Roeck-LP13): BEH Boson

	CMS		ATLAS	
Decay	Expected	Observed	Expected	Observed
ZZ	7.1 σ	6.7 σ	4.4 σ	6.6 σ
γγ	3.9 σ	3.2 σ	4.1 σ	7.4 σ
WW	5.3 σ	3.9 σ	3.7 σ	3.8 σ
bb	2.2 σ	2.0 σ	1.0 σ	-0.4 σ
ττ	2.6 σ	2.8 σ	1.7 σ	1.1 σ

CMS: Mass = 125.7 GeV
ATLAS: Mass = 125 GeV (ZZ Mass= 124.3 GeV; γγ Mass = 126.8 GeV)

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(Englert, Higgs: Nobel Prize, 2013)

** CURRENT STATUS AT LHC (Owen - LP13): BSM Higgs

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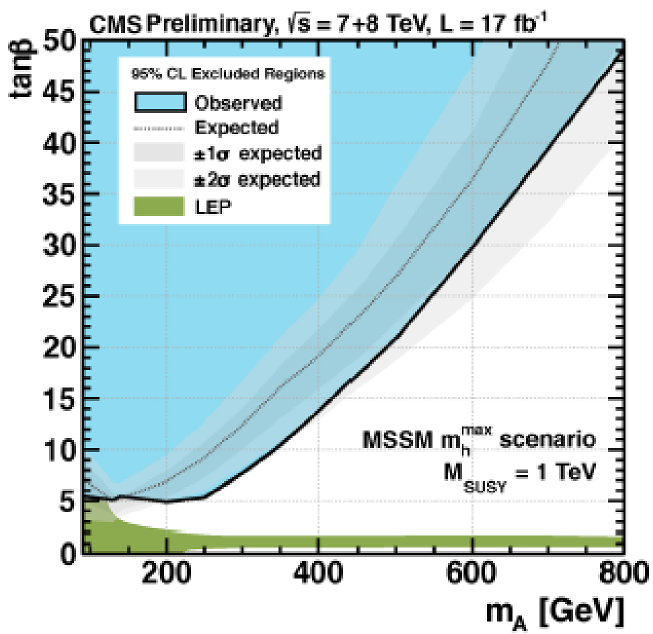
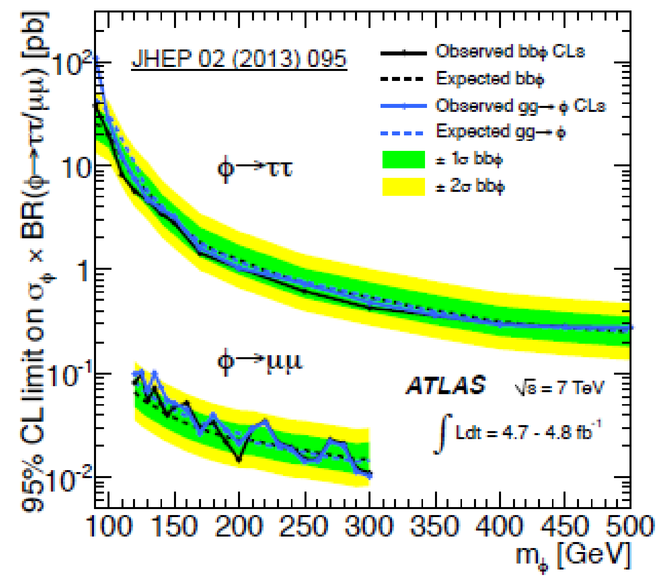
Neutral Higgs to Tau Pairs

CMS, 12 fb^{-1} 8 TeV, 5 fb^{-1} 7 TeV
ATLAS, 5 fb^{-1} 7 TeV

- Stringent limits on MSSM parameter space in a given benchmark model:





- Important to provide also the model independent cross section limits to allow translation into other BSM Higgs models.

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(Still Alive – See Pokorski's Talk!)

** CURRENT STATUS AT LHC (Owen - LP13): BSM Higgs

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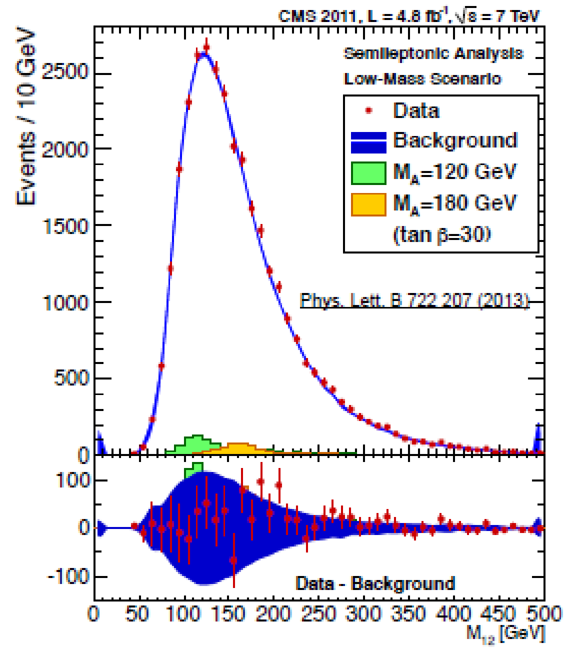
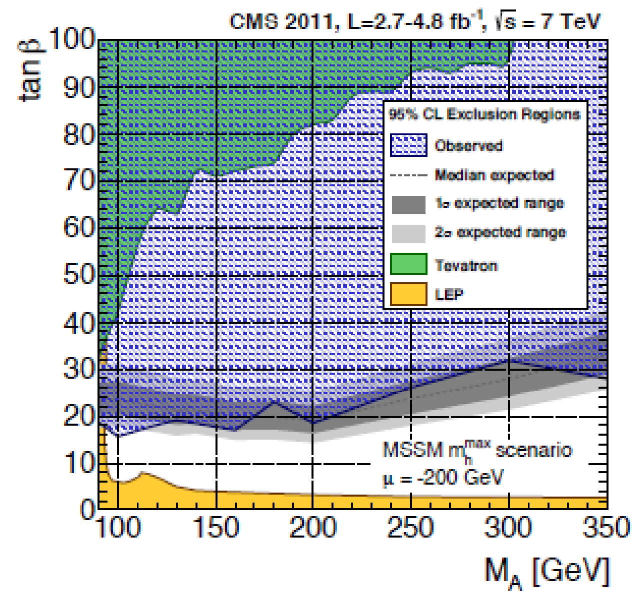
Neutral Higgs to b Quark Pairs

- Recent analysis by CMS in the same final state, using multijet and muon + jet triggers.

CMS 2-5 fb-1 7 TeV





- No significant excess seen - analysis excludes region of MSSM parameter space consistent with Tevatron excess.

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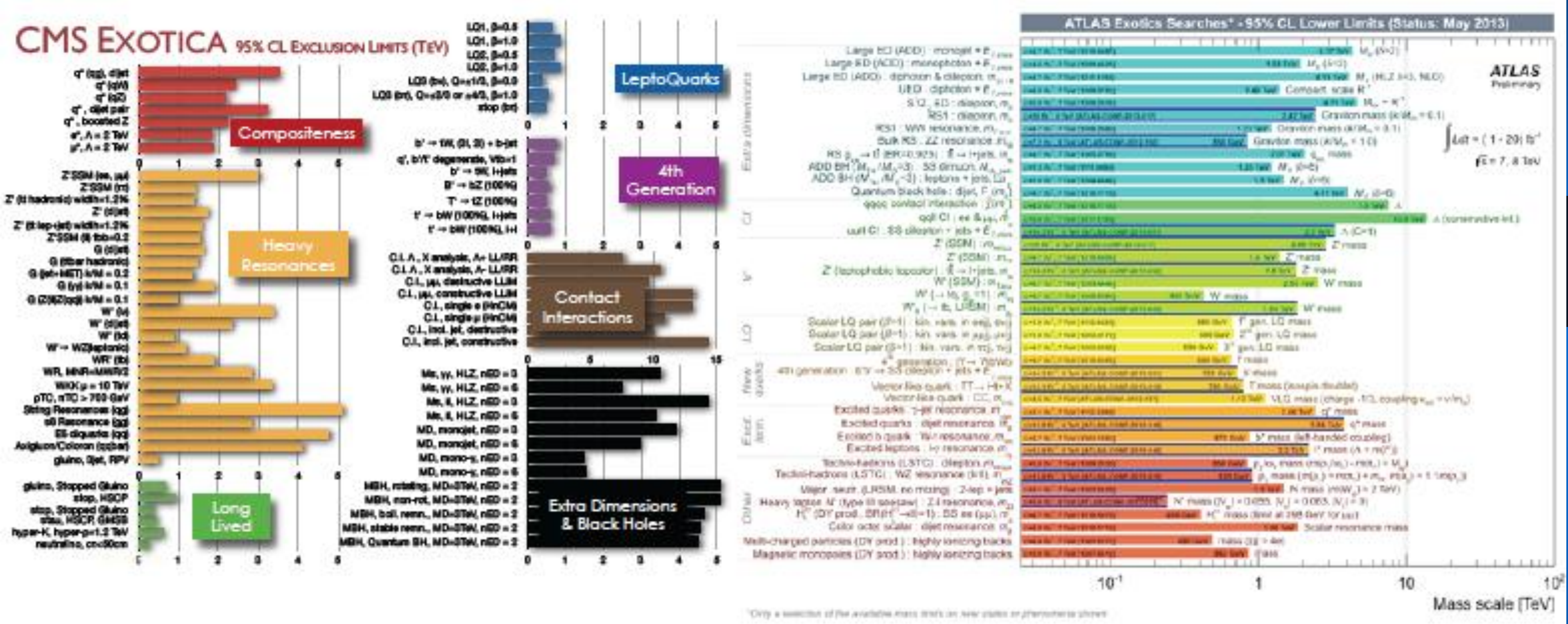
(Still Alive – See Pokorski's talk!)

** CURRENT STATUS AT LHC (Rappoccio - LP13): BSM -- General



(Still Alive – See Pokorski's talk!)

** HOW ARE THESE RESULTS OBTAINED?

COMPARISON OF THEORY AND EXPERIMENT ⇒ FUTURE

1. PRECISE BEH STUDIES
2. PRECISE BSM STUDIES
3. DISCOVERY???

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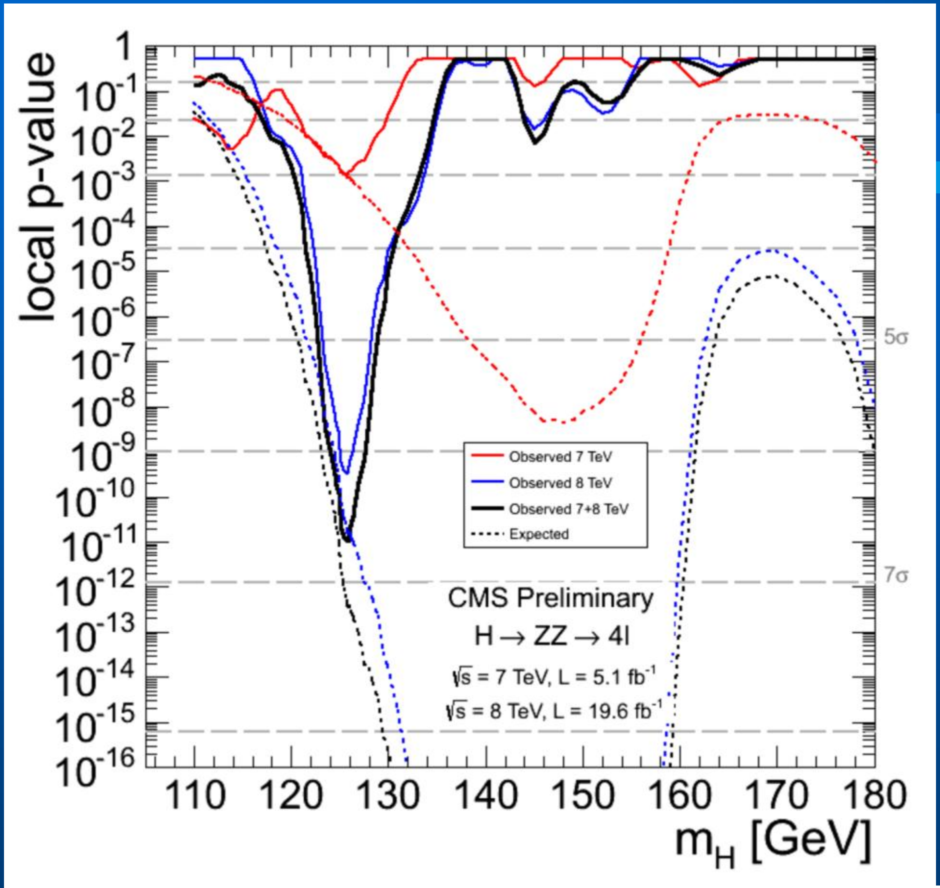
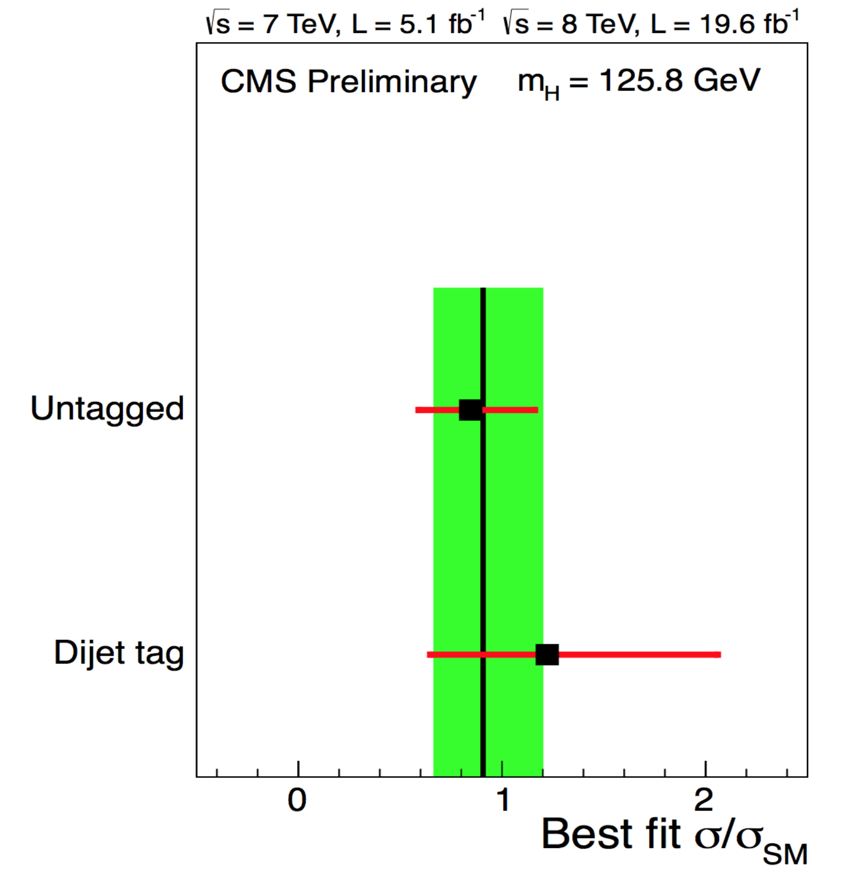
** PRECISE BEH PHYSICS(De Roeck, LP13)

The Decay $H \to ZZ \to 4l$





p-value: Expected: 7.1σ
Observed: 6.7σ

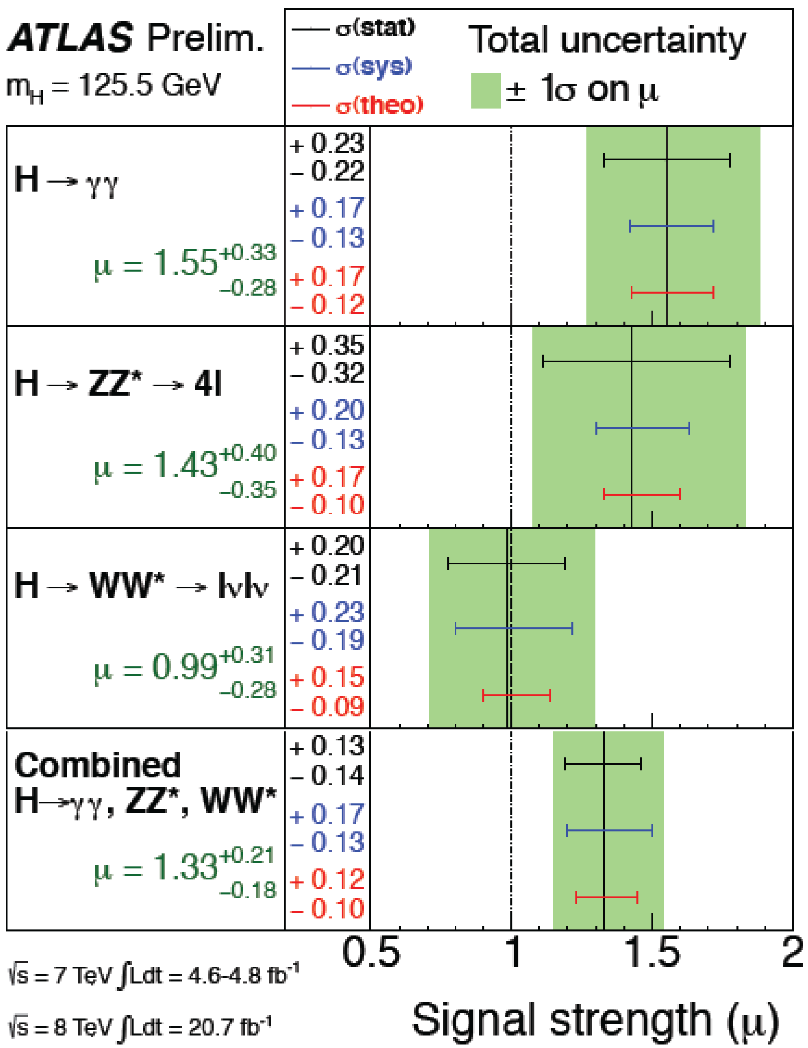
σ/σ_{SM} at 125.7 GeV = 0.92 ± 0.28

Significance is well over 6 standard deviations in this channel

** PRECISE BEH STUDIES(Jakobs-LP13)

Signal strength in di-boson decay modes

-including full data set-



- Data are consistent with the hypothesis of a Standard Model Higgs boson:

$$\mu = 1.33^{+0.21}_{-0.18}$$

- Experimental uncertainties are still too large to get excited about "high" γγ signal strength

- Signal strengths in fermionic decay modes have large uncertainties, but are compatible with SM value of 1;

  If preliminary H → ττ and H → bb results are included:

$$\mu = 1.23 \pm 0.18$$

Ratios of production cross sections for the various processes (ggF, VBF,..) fixed to SM values

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** 10-12% $\Delta\mu_{th}$ vs ~20% $\Delta\mu_{expt}$

- **OK for NOW**
- **BUT, (WELLS, LP 2013) 300 fb^{-1} by 2021**

$\Rightarrow$ $\Delta\mu_{th} \lesssim$ 3.2% NEEDED

1. PRECISION SM THEORY

2. PROVABLE PRECISION TAG, IN ANALOGY WITH WHAT WAS DONE FOR LEP : See H. Anlauf et al., CERN 96-01, v. 2. , eds. G. Altarelli et al., p229; S. Jadach et al., Phys.Lett. B 450 (1999) 262; G. Montagna et al.,ibid. 459 (1999) 649, and references therein.

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THERE ARE MANY!

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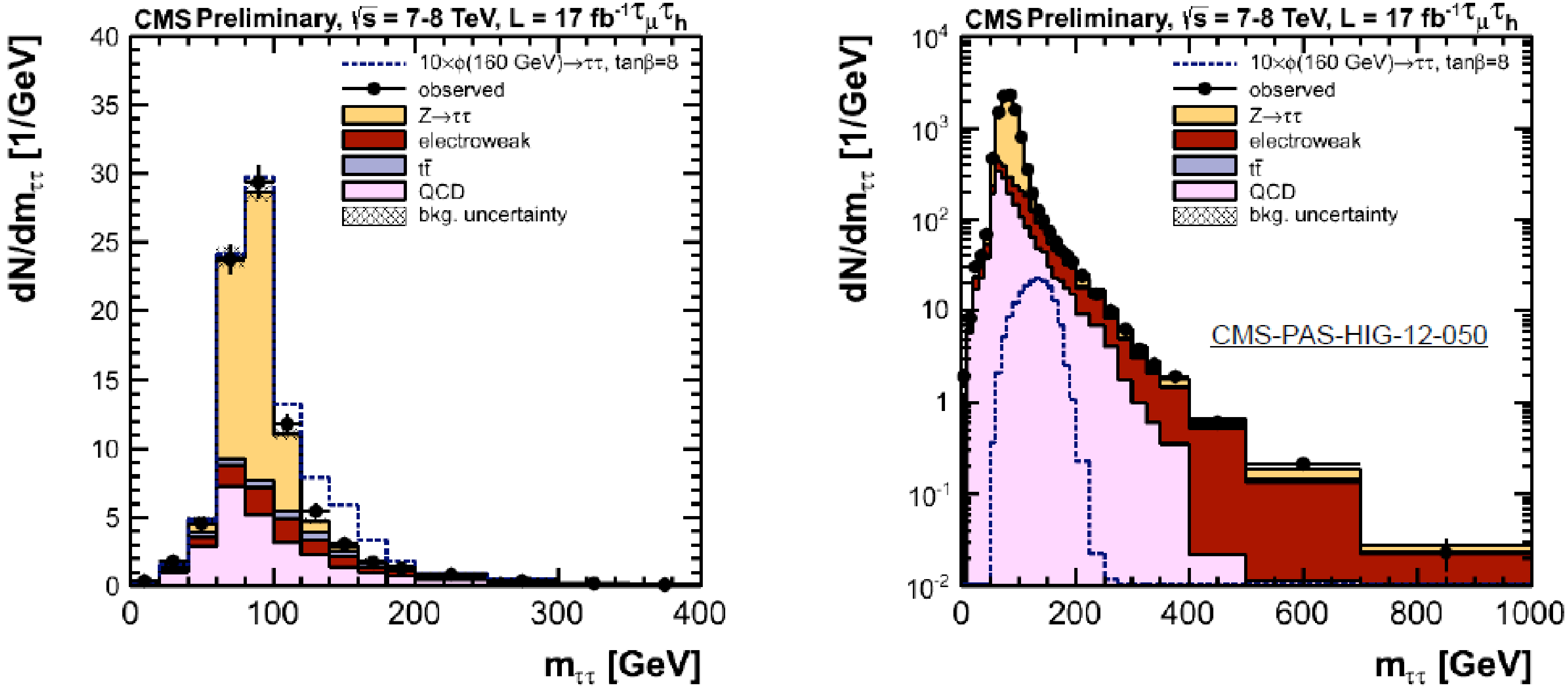
Neutral Higgs to Tau Pairs

CMS, 12 fb^{-1} 8 TeV, 5 fb^{-1} 7 TeV
ATLAS, 5 fb^{-1} 7 TeV

- Main background from $Z \rightarrow \tau\tau$ decays - model using $Z \rightarrow \mu\mu$ from data and replace μ with simulated τ.

- Fit di-tau mass distribution - mass reconstruction is improved by using the measured missing transverse energy.



MANCHESTER 1824

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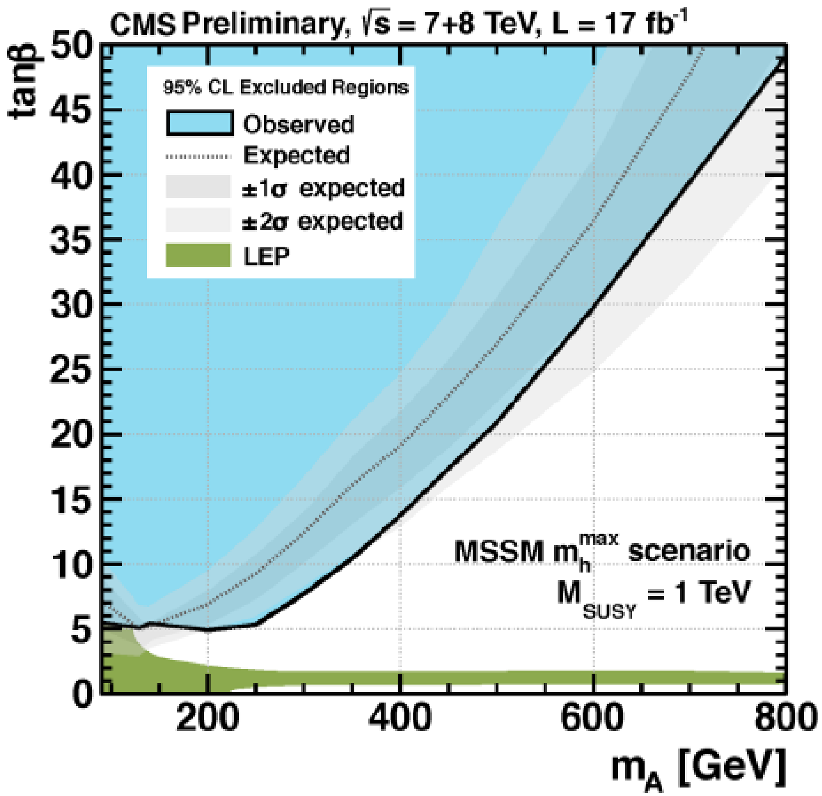

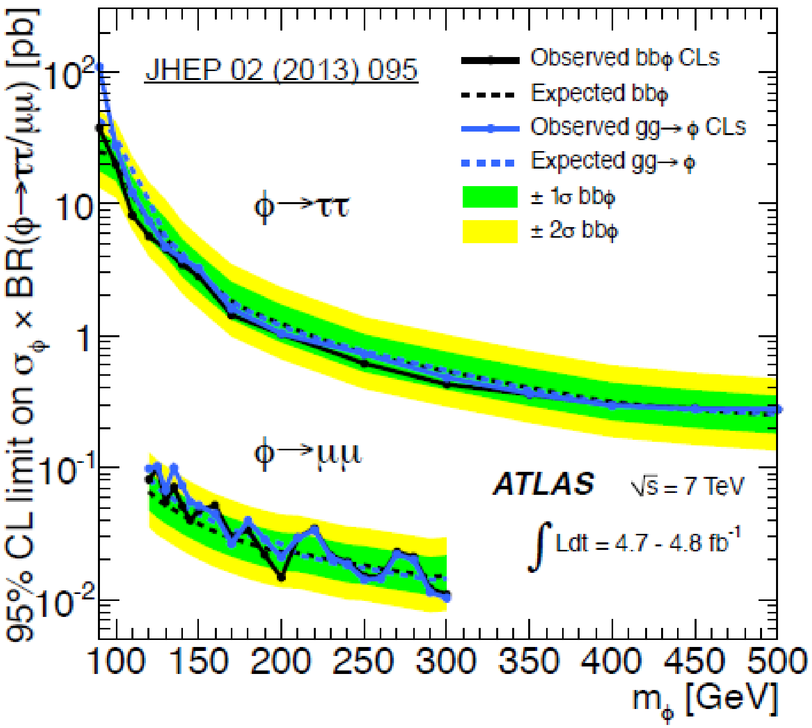

- Important to provide also the model independent cross section limits to allow translation into other BSM Higgs models.

** PRECISE BSM STUDIES

- CURRENTLY,

$$\Delta\sigma_{\mathrm{expt}} \sim 3.4\% \quad \& \; \Delta\sigma_{\mathrm{th}} \sim 2.8\%$$

- With 300 fb^{-1} , to get similar return on data we need

$$\Delta\sigma_{\mathrm{th}} \lesssim 1\%$$

$\Rightarrow$ Precision Theory for both QCD and EW

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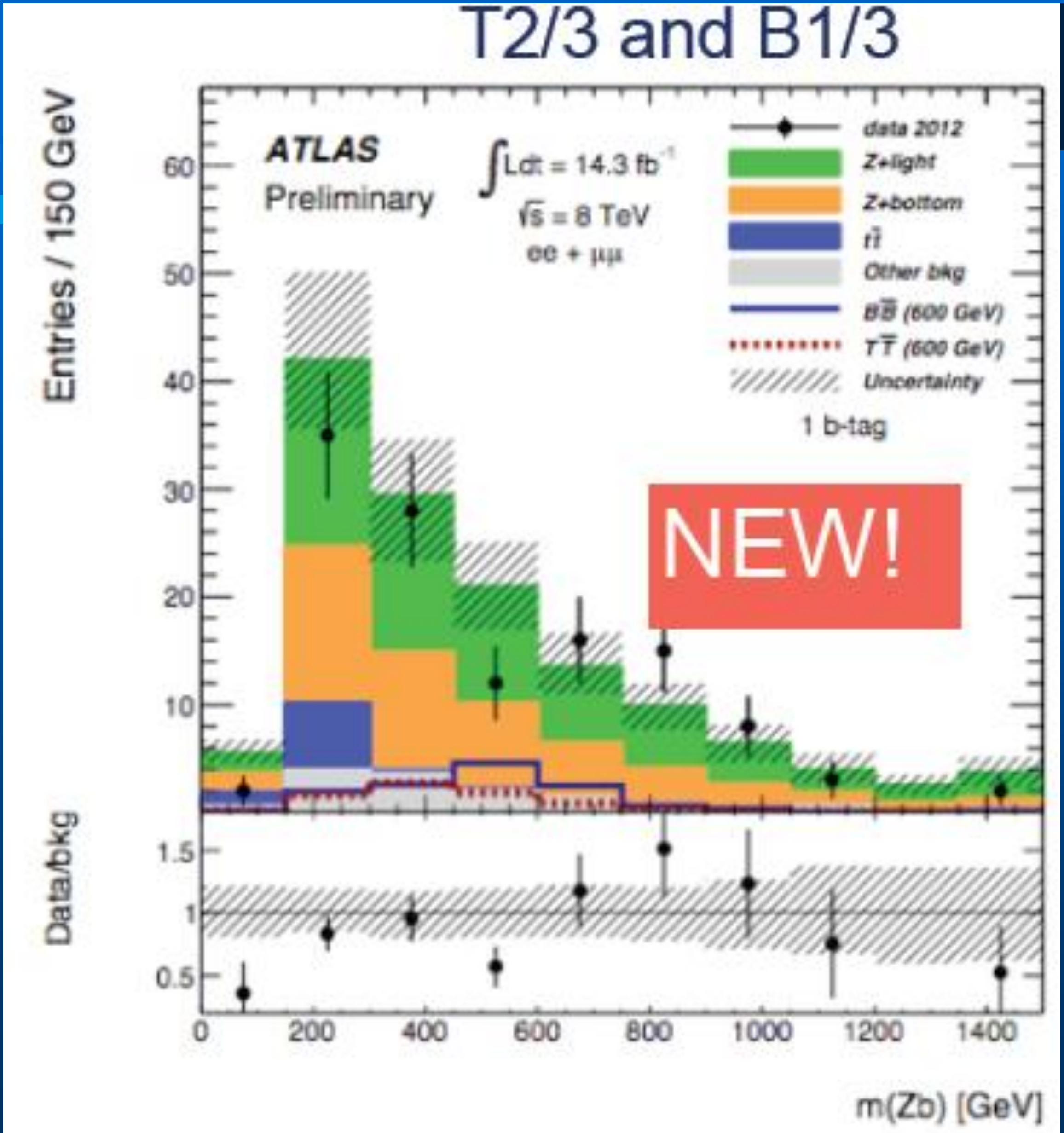
** PRECISE BSM STUDIES(Rappoccio-LP13)

Quark Partners



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** PRECISE BSM STUDIES

- **CURRENTLY,**

  $\Delta\sigma_{expt}$ **~10%** & $\Delta\sigma_{th}$ **~ 10% ,**

  with limits at ~.7TeV

- **With 300 fb^{-1} , to get similar return on data we need**

  $\Delta\sigma_{th} \lesssim$ **2%**

  $\Rightarrow$ **Precision Theory for both QCD and EW**

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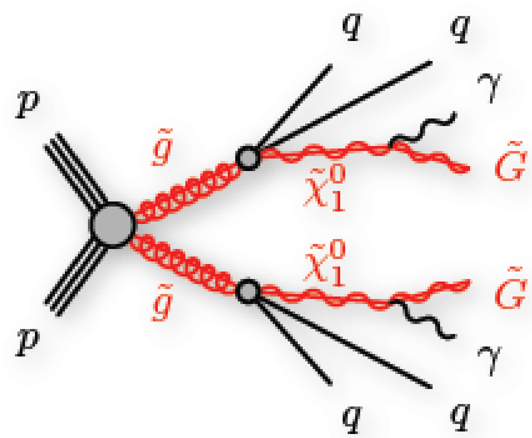
** PRECISE BSM STUDIES(Hoecker-LP13)

Bino NLSP: prod. of photons + jets + MET



MET spectrum of data compared to the QCD and EW background prediction for events with ≥ 1 jet

Strong squark & gluino 95% CL mass limits:

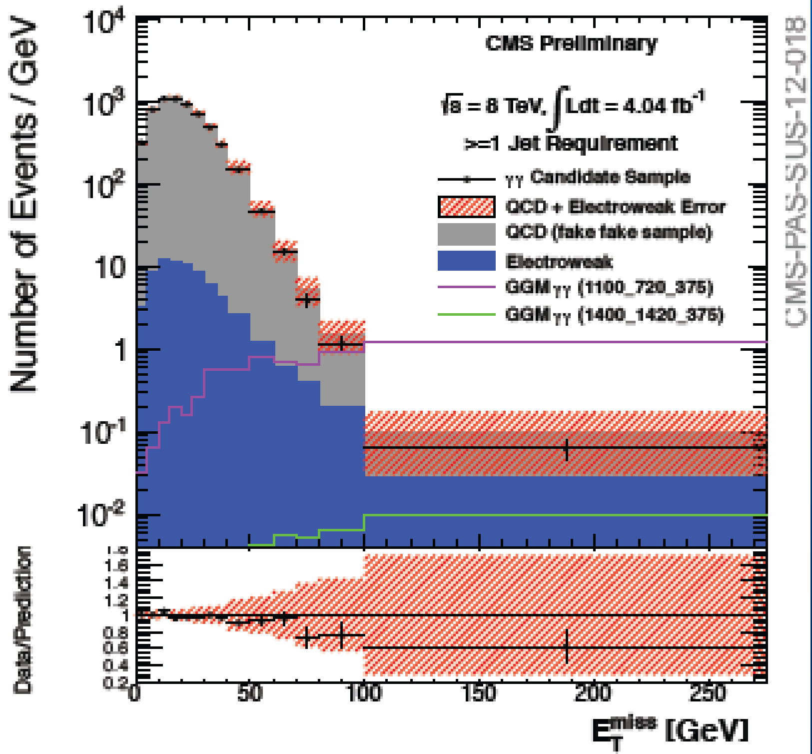
Using GMSB (prompt NLSP decay)

$$m(\tilde{g}) > \begin{cases} 1.2_{\text{low-}\tan\beta} \\ 1.5_{\text{large-}\tan\beta} \end{cases} \text{TeV}$$

Using GGM (bino-like NLSP)

$m(\tilde{q}) > 1.2$ TeV

$m(\tilde{g}) > 1.1$ TeV



** PRECISE BSM STUDIES

- **CURRENTLY, FOR $E^{miss}_T \gtrsim$ 75GeV**

  $\Delta\sigma_{expt}$ ~25% & $\Delta\sigma_{th}$ ~ 40%

- **With 300 fb^{-1} , to get similar return on data we need**

  $\Delta\sigma_{th} \lesssim$ 10%

  ⇒ Precision Theory for both QCD and EW

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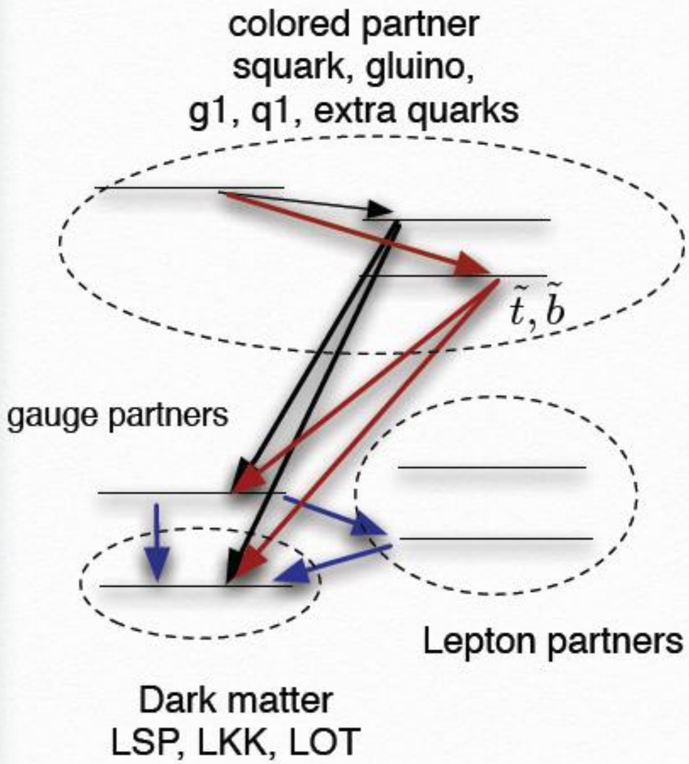
** PRECISE BSM STUDIES(Nojiri-LP13)

dark matter and collider signature



- **"SUSY signature"**
  - "Models with new colored particles decaying into a stable neutral particle--LSP"
- Some of "New physics" are migrated into SUSY category.
- Signal:
  High P_T jets hiph P_T leptons and E_{Tmiss}

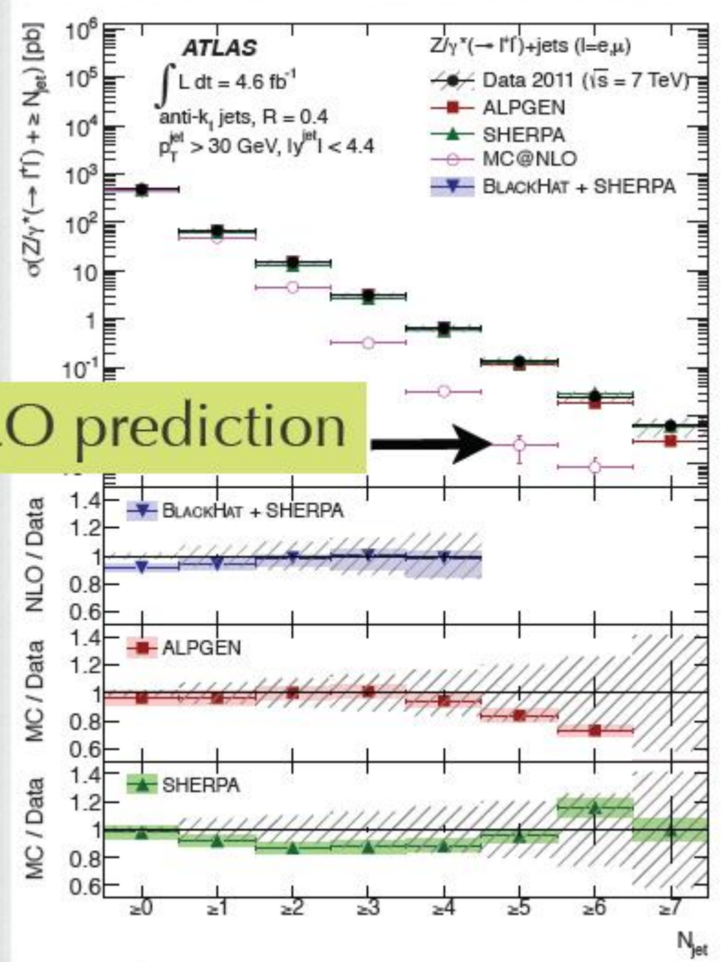
assume mass difference is large

if there are R parity violation, we have additional jets and leptons instead of E_{Tmiss}

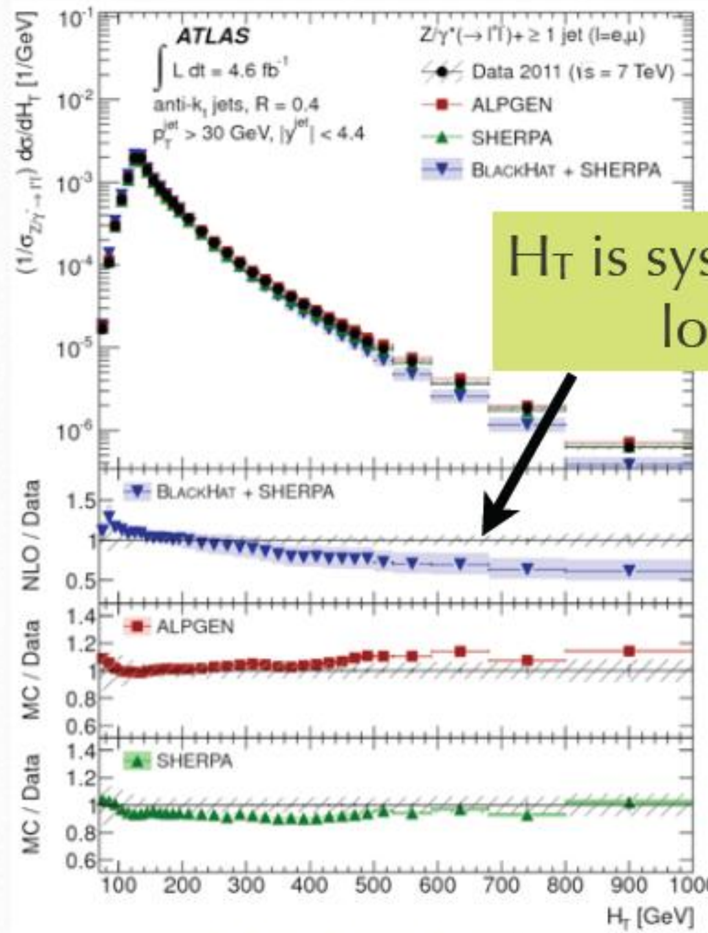
Production of W, Z, and top with additional jets would be significant background

** PRECISE BSM STUDIES(Nojiri-LP13)

reproducing multijet distribution



NLO prediction



H_T is systematically low yet

NLO

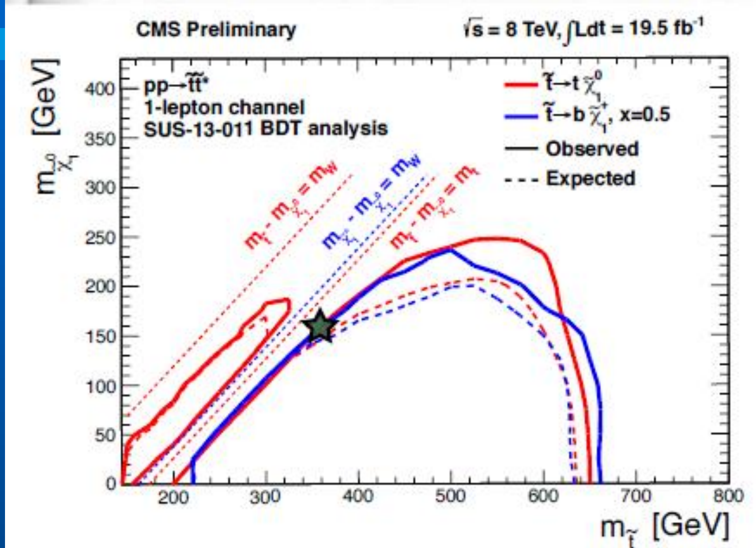
Tree

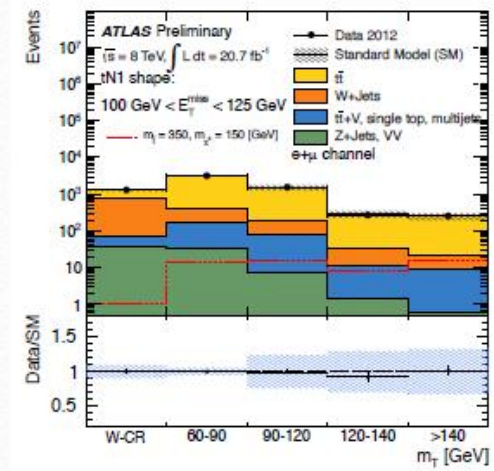
Tree

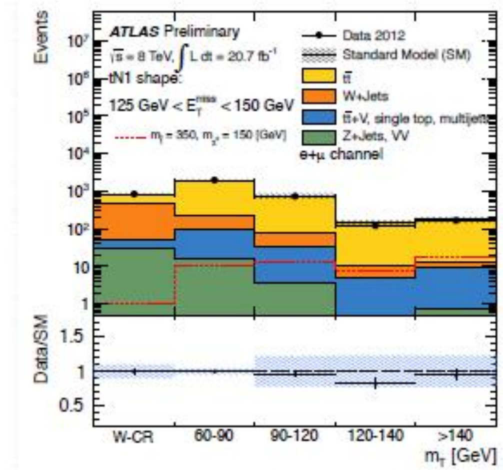
ATLAS 1304.7098

** PRECISE BSM STUDIES(Nojiri-LP13)

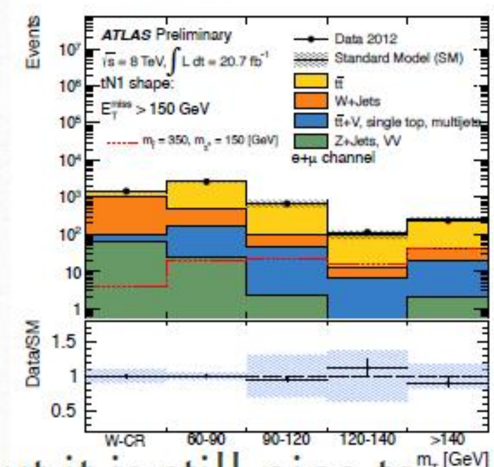
good background prediction = exclusion up to kinematical limit







exclude up to the region
where mstop~mLSP+mt +30GeV



stop 350GeV and LSP 150GeV
There are no region with
S/N>0.1 in this plot!

Nojiri:
I am not sure if I take this as face value but it is still nice to have such efforts from experimental side

** PRECISE BSM STUDIES

1. Conclusive results ⇔ More precise theory

2. Transverse Degrees of Freedom Essential

   a. Precise Predictions

   b. Event-by-event Realization

⇒ Exact Resummation Methods in the MC

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** DISCOVERY?

DISCOVERY ⇒ STRICT CONTROL of

Transverse Degrees of Freedom

⇒ Exact Resummation Methods in the MC, for both QCD and EW Higher Order Effects

WHERE ARE WE (ON THIS)?

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** WHERE ARE WE?

We use the production of $(Z/\gamma^*, W)$ +jets, as the precise data on from AYLAS/CMS on $(Z/\gamma^*, W)$ production and ecay to lepton pairs, more than 10^7 events/experiment, is still not released to the public at this writing.

Let us look at the next plot, made by ATLAS as presented by Hoecker (LP13)

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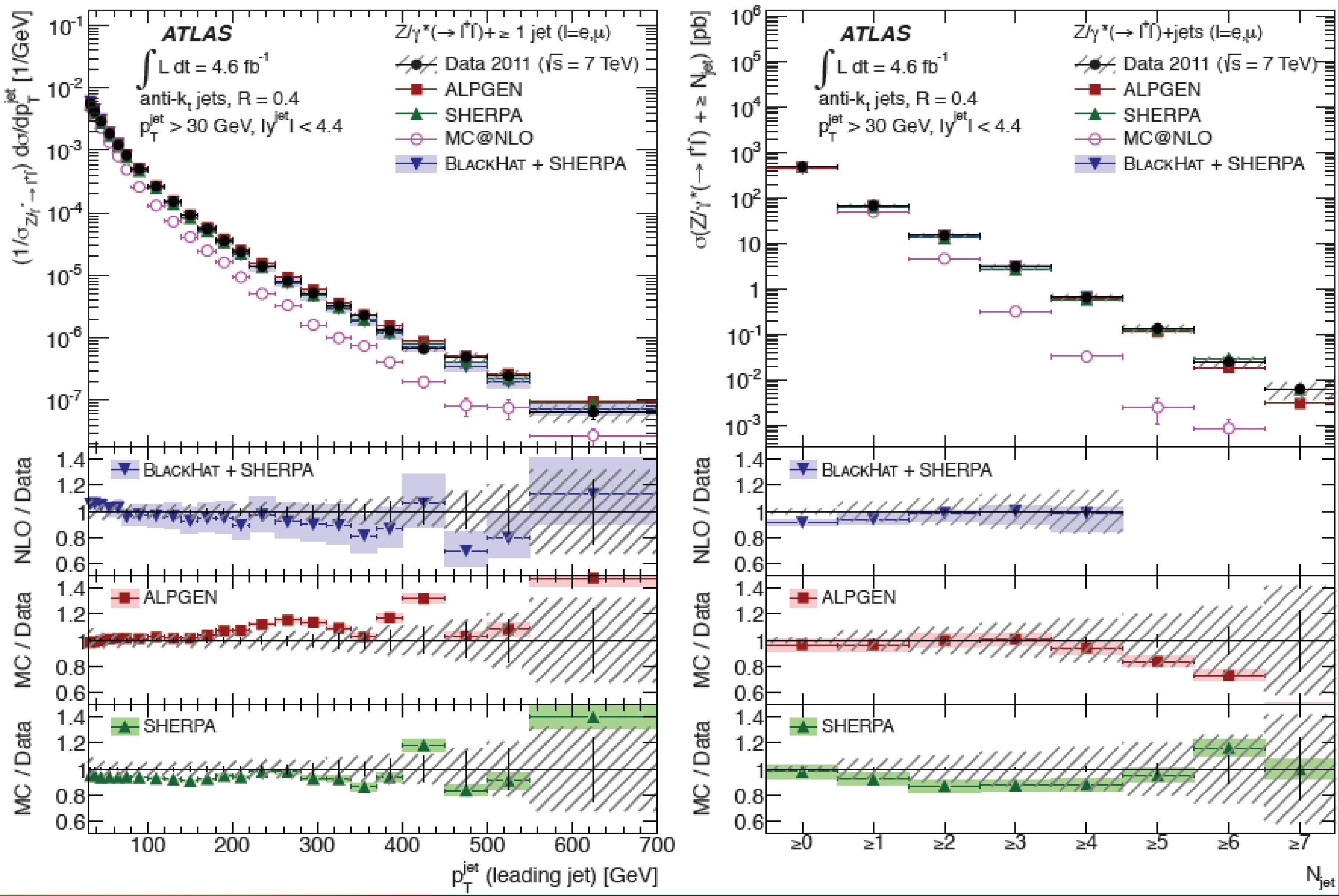
** Precision Studies (Hoecker-LP13)

W and *Z* physics — differential measurements

Large statistics allows precise tests of generators/theory, PDFs and bkg to searches

ATLAS 1304.7098

Measurement of *Z* + jets production



Satisfying agreement for multileg generators.

Improved for MEnloPS.

Insufficient jet emission for MC@NLO + PS (Herwig)

WHERE ARE WE?

SOME OBSERVATIONS

- FOR THIS LEADING p_T, WE NEED HIGHER LEGS IF $p_T > 50$ GeV
- MC@NLO OK for $N_{jet} = 0,1$ in $\sigma(Z/\gamma^{*} + \geq N_{jet}$ jets)
- FOR LARGE FRACTION OF DATA ,

  $p_T < 50$ GeV
- FOR LARGE FRACTION OF DATA ,

  $N_{jet} = 0,1$

$\Rightarrow$ For normalized distributions, we must understand the $\Delta\sigma_{th}$ in the regime $p_T < 50$ GeV, $N_{jet} \geq 0$

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WHERE ARE WE?

TESTING THE THEORY IN THIS REGIME

- The $\geq 10^7$ SAMPLES at ATLAS/CMS NEEDED
- RESUMMATION ESSENTIAL:

  1. PARTON SHOWER/ME MATCHED EXACT NLO(MC@NLO, POWHEG, etc.) , $\Delta\sigma_{phys} \cong$ 10%
  2. CSS RESUMMATION, RESBOS, $\Delta\sigma_{phys} \cong O(Q_T/Q) \cong$ 5%
  3. SCT/SCET RESUMMATION, $\Delta\sigma_{phys} \cong \lambda = \sqrt{\Lambda/Q} \cong$ 5%
  4. EXACT AMPLITUDE-BASED QED$\otimes$QCD RESUMMATION, $\Delta\sigma_{phys} \lesssim$1% POSSIBLE

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WHERE ARE WE?

- **Standard Resummations, CSS– RESBOS, etc.: (see 1305.0023 for details)**

$$\frac{d\sigma}{dQ^2 dy dQ_T^2} \sim \frac{4\pi^2\alpha^2}{9Q^2 s}\left\{\int \frac{d^2 b}{(2\pi)^2} e^{i\vec{Q}_T\cdot\vec{b}} \sum_j e_j^2 \widetilde{W}_j(b^*; Q, x_A, x_B)\right.$$

$$e^{\{-\ln(Q^2/Q_0^2) g_1(b) - g_{j/A}(x_A, b) - g_{j/B}(x_B, b)\}}$$

$$\left. + Y(Q_T; Q, x_A, x_B)\right\}$$

Dropped terms $O(Q_T/Q)$ in all orders of α_s :
at 5GeV, Q=M_Z, 5.5% Physical Precision Error(PPE)
Errors on the NP functions g_l also yield ~1.5% PPE,…

- **SCT/SCET HAVE ANALOGOUS FORMULA**

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WHERE ARE WE?

- **IN**

$$d\sigma = \sum_{i,j} \int dx_1 dx_2 F_i(x_1) F_j(x_2) d\hat{\sigma}_{res}$$

Resummed Collinear Evolution ⇔ $\{F_i\}$

Soft Resummation (non-coll.) ⇔ $d\hat{\sigma}_{res}$

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WHERE ARE WE?

- FOR QED⊗QCD RESMN

$$d\hat{\sigma}_{res} = \sum_n d\hat{\sigma}_n$$

$$= e^{SUM_{IR}(QCED)} \sum_{m,n=0}^{\infty} \frac{1}{m!n!} \int \prod_{j_1=1}^{m} \frac{d^3 k_{j_1}}{k_{j_1}} \prod_{j_2=1}^{n} \frac{d^3 k_{j_2}}{k_{j_2}} \int \frac{d^4 y}{(2\pi)^4} e^{iy(p_1+q_1-p_2-q_2-\sum_{j1} k_{j_1} - \sum_{j2} k'_{j_2}) + D_{QCED}}$$

$$* \tilde{\bar{\beta}}_{m,n}(k_1,\ldots,k_m;k'_1,\ldots,k'_n) \frac{d^3 p_2}{p_2^0} \frac{d^3 q_2}{q_2^0}$$

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WHERE ARE WE?

- **Shower/ME Matching:**

$$\tilde{\bar{\beta}}_{m,n} \rightarrow \hat{\tilde{\bar{\beta}}}_{m,n}, \text{ shower - subtracted residuals}$$

- **IR-Improved DGLAP-CS Theory:**

  New resummed scheme for P_{AB}, reduced cross section --

$\mathrm{F_j}, \hat{\sigma} \rightarrow \mathrm{F_j'}, \hat{\sigma}'$ for

$$\mathrm{P_{qq}} \rightarrow \mathrm{P_{qq}^{exp}} = \mathrm{C_F} F_{YFS}(\gamma_q) e^{\frac{1}{2}\delta_q} \frac{1+z^2}{1-z}(1-z)^{\gamma_q}, \text{ etc.,}$$

giving the same value for σ, with improved MC stability.

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Illustration for Union with MC@NLO:

$$d\sigma_{MC@NLO} = \left[B + V + \int (R_{MC} - C)\, d\Phi_R\right] d\Phi_B$$

$$\left[\Delta_{MC}(0) + \int \left(\frac{R_{MC}}{B}\right) \Delta_{MC}(k_T)\, d\Phi_R\right] + (R - R_{MC})\Delta_{MC}(k_T)\, d\Phi_B\, d\Phi_R$$

$\Longrightarrow$ Sudakov FF

$$\Delta_{MC}(p_T) = e^{\left[-\int d\Phi_R \frac{R_{MC}(\Phi_B,\Phi_R)}{B} \theta(k_T(\Phi_B,\Phi_R) - p_T)\right]}$$

$\Longrightarrow$

$$\frac{1}{2}\hat{\hat{\bar{\beta}}}_0 = \bar{B} + (\bar{B}/\Delta_{MC}(0)) \int (R_{MC}/B)\Delta_{MC}(k_T)\, d\Phi_R$$

$$\frac{1}{2}\hat{\hat{\bar{\beta}}}_1 = R - R_{MC} - B\tilde{S}_{QCD}$$

for

$$\bar{B} = B\left(1 - 2\alpha_s \Re B_{QCD}\right) + V + \int (R_{MC} - C)\, d\Phi_R$$

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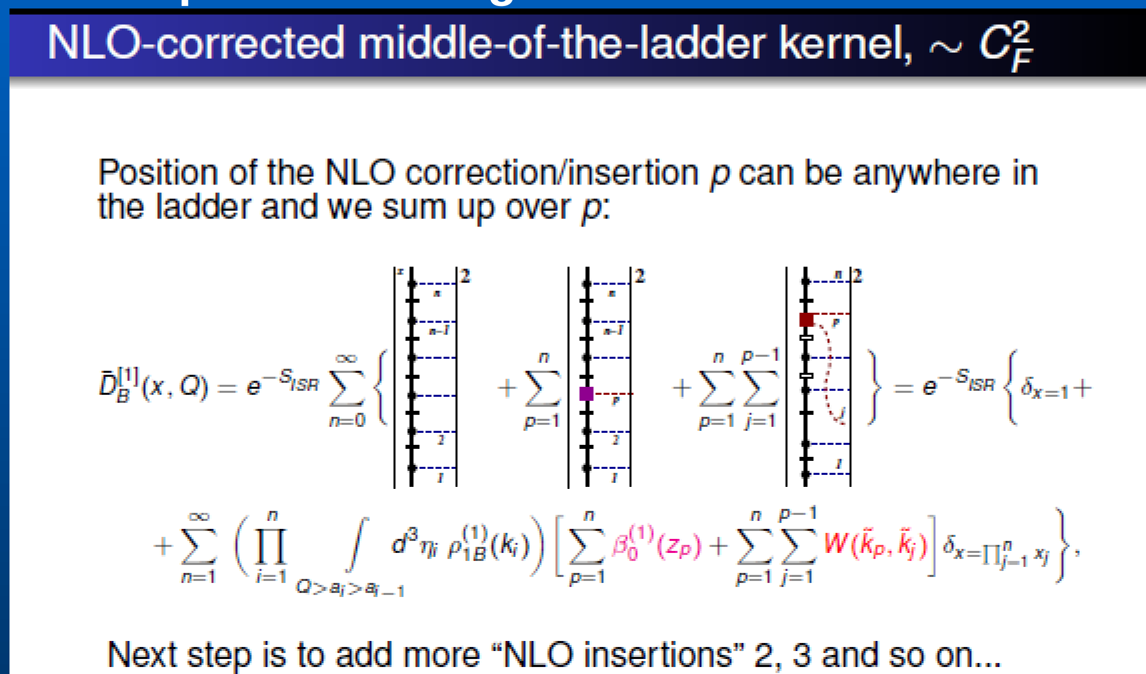
WHERE ARE WE?

- **NLO P_{AB} Exclusively(Jadach et al.):**
  Proof of the concept for non-singlet NLO DGLAP --



WHERE ARE WE?

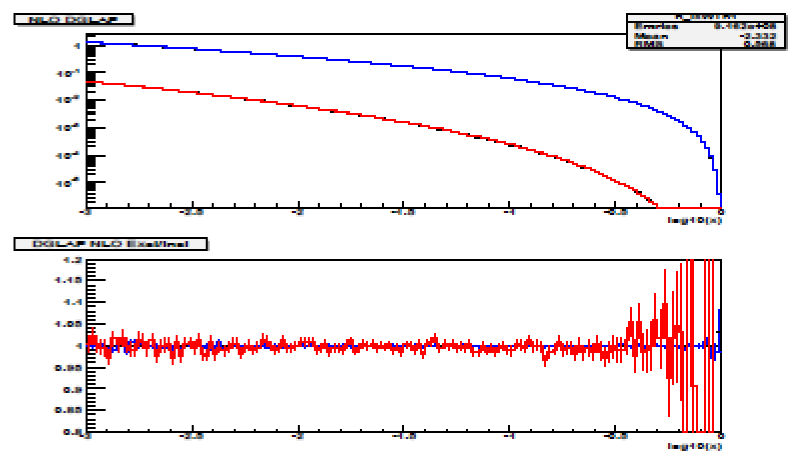
- **NLO P_{AB} Exclusively(Jadach et al.):**

  Proof of the concept for non-singlet NLO DGLAP –

Similar Results for FSR. More insertions & virt. corrections:

see in 1310.6090, 1310.7537

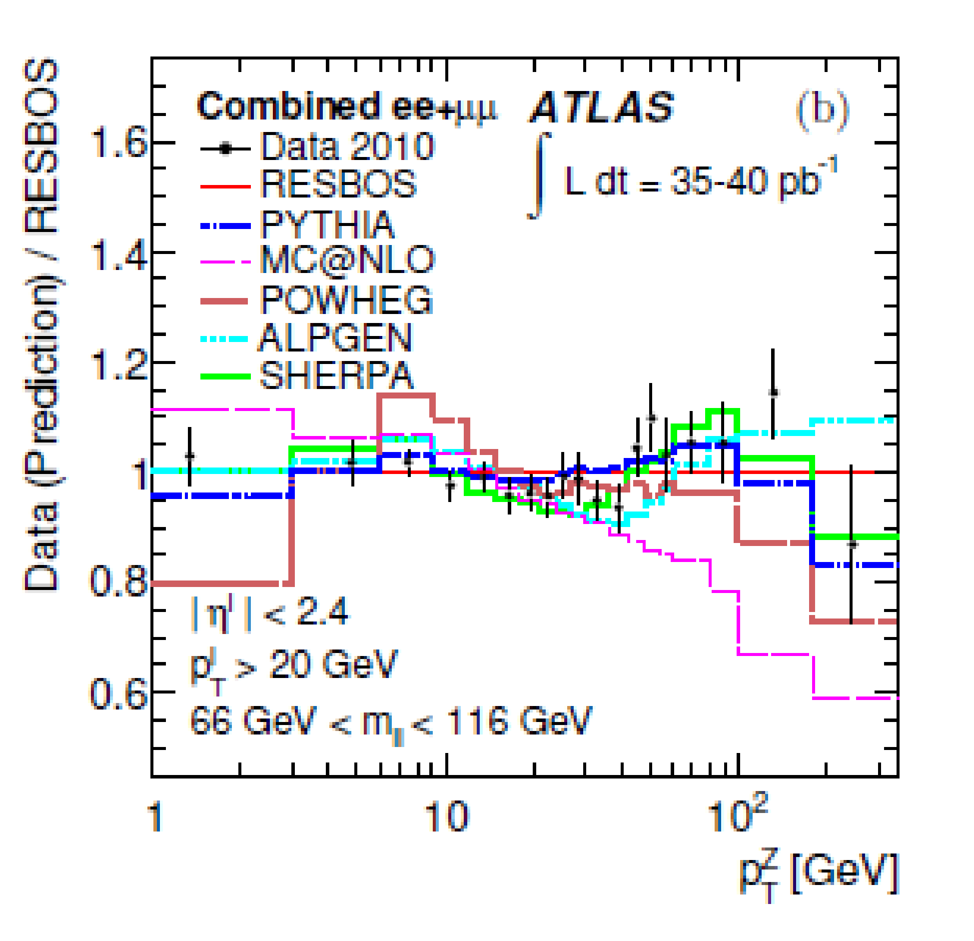
Numerical test of ISR pure C_F^2 NLO MC



Numerical results for $D(x, Q)$ from **two** Monte Carlos inclusive and exclusive.
Blue curve is single NLO insertion, red curve is double insertion component.
Evolution 10GeV→1TeV starting from $\delta(1-x)$.
The ratio demonstrates 3-digit agreement, in units of LO.

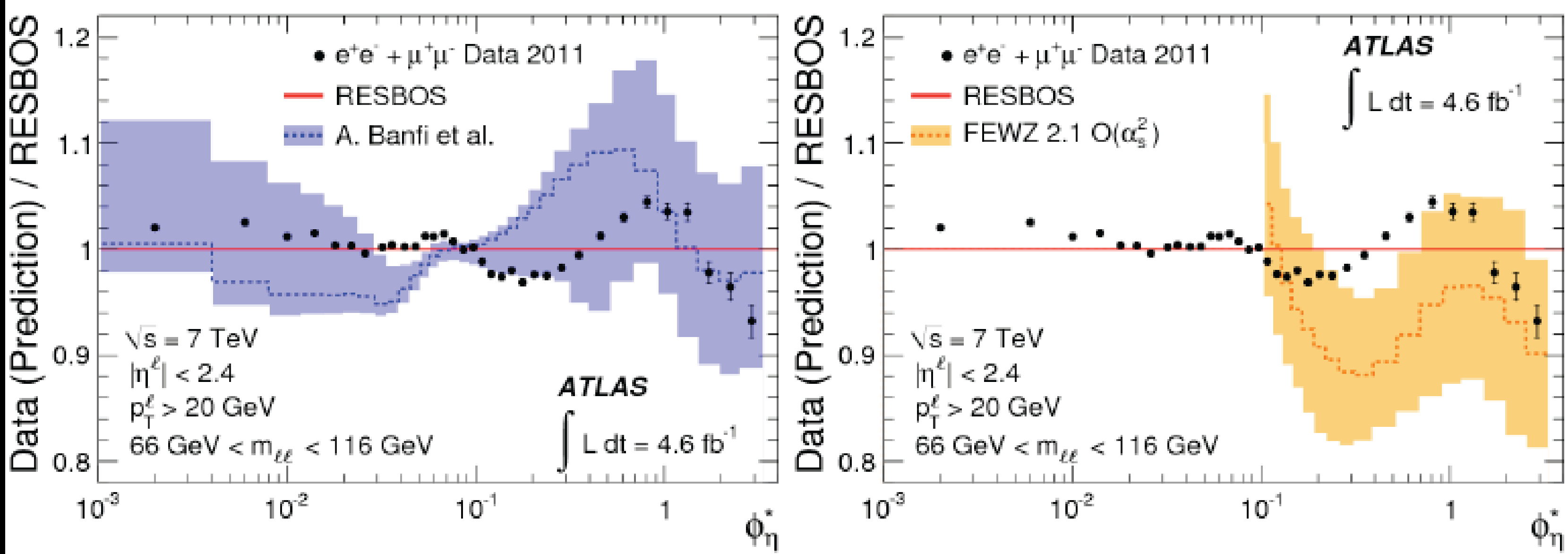
WHERE ARE WE?

- **THEORY COMPARISONS:ATLAS(1107.2381)**



- **THEORY COMPARISONS:Hassani(EW Moriond, 2013) – { $\phi^*_\eta = \tan(\frac{1}{2}(\pi - \Delta\phi))\sin\theta^*$ }**

Z/γ* transverse momentum (dσ/dφ*$_\eta$(ll))



- Calculations from A. Banfi et al. (resummed QCD predictions+fixed-order pQCD) is less good than ResBos
- **Measurement precision about one order of magnitude lower than the present theoretical uncertainties**
- FEWZ predictions undershoot the data by ~10% which confirm previous CDF observation (PRD 86,052010)

WHERE ARE WE?

- LHC DATA: CMS Rapidity & ATLAS PT Spectrum for Z/γ* Production vs ERQCD(IRI-DGLAP-CS in MC Herwiri1.031)

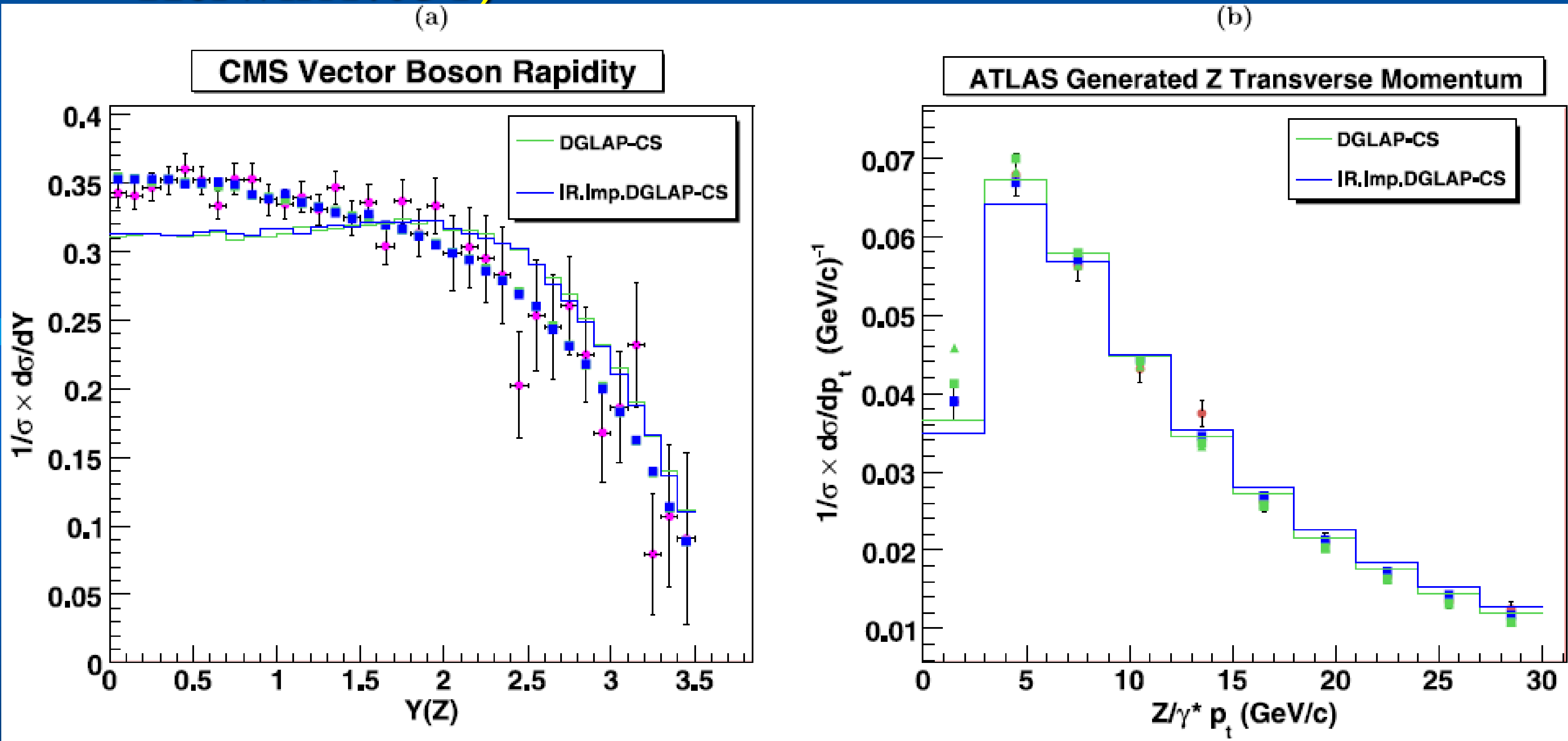


Fig. 2. Comparison with LHC data: (a) CMS rapidity data on (Z/γ^*) production to e^+e^-, $\mu^+\mu^-$ pairs, the circular dots are the data, the green (blue) lines are HERWIG6.510 (HERWIRI1.031); (b) ATLAS p_T spectrum data on (Z/γ^*) production to (bare) e^+e^- pairs, the circular dots are the data, the blue (green) lines are HERWIRI1.031 (HERWIG6.510). In both (a) and (b) the blue (green) squares are MC@NLO/HERWIRI1.031 (HERWIG6.510 (PTRMS = 2.2 GeV)). In (b), the green triangles are MC@NLO/HERWIG6.510 (PTRMS = 0). These are otherwise untuned theoretical results. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this Letter.)

• Observations

1. For the unimproved case, the data suggest that we need a GAUSSIAN (intrinsic) PTRMS ≅ 2.2 GeV
[Herwiri1.031(blue line), Herwig6510(green line(PTRMS=2.2GeV)), MC@NLO/Herwiri1.031(blue squares), MC@NLO/Herwig6510(green squares (PTRMS=2.2GeV), green triangles(PTRMS=0))]
(similar to what holds at FNAL)

2. This same shape is provided from fundamental principles by the MC@NLO/Herwiri1.031 with PTRMS ≅ 0 GeV (similar to what holds at FNAL)

- Observations (Quantitative)

1. Unimproved case, the respective χ^2 /d.o.f.'s are 1.37, 0.70 (MC@NLO/Herwig6510(PTRMS=2.2GeV)) for the p_T and rapidity data
2. IR-improved case, the respective χ^2 /d.o.f.'s are 0.72, 0.72 (MC@NLO/Herwiri1.031) for the p_T and rapidity data
3. Unimproved case, the respective χ^2 /d.o.f.'s are 2.23, 0.70 (MC@NLO/Herwig6510(PTRMS=0)) for the p_T and rapidity data

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- Which is Better for Precision QCD Theory?

1. Precocious Bjorken Scaling in SLAC-MIT Experiments: already at $Q^2 \cong 1_+ \ \mathrm{GeV}^2$

$\Rightarrow$ $PTRMS^2$ small compared to $1_+ \ \mathrm{GeV}^2$

See R.P. Feynman, M. Kislinger and F. Ravndal, Phys. Rev. D**3** (1971) 2706; R. Lipes, *ibid.***5** (1972) 2849; F.K. Diakonas, N.K. Kaplis and X.N. Mawita, *ibid.* **78** (2008) 054023; K. Johnson, Proc. Scottish Summer School Phys. **17** (1976) p. 245; A. Chodos *et al.*, Phys. Rev. D**9** (1974) 3471; *ibid.* **10** (1974) 2599; T. DeGrand *et al.*, *ibid.* **12** (1975) 2060; …. – all have $PTRMS^2 << 1_+ \ \mathrm{GeV}^2$

- Which is Better for Precision QCD Theory?

2. The first principles approach is not subject to arbitrary functional variation to determine its $\Delta\sigma_{\rm th}$

3. Experimentally, in principle, events in the two cases should look different in terms of the properties of the rest of the particles in the events – this is under study.

Here, we show the following.

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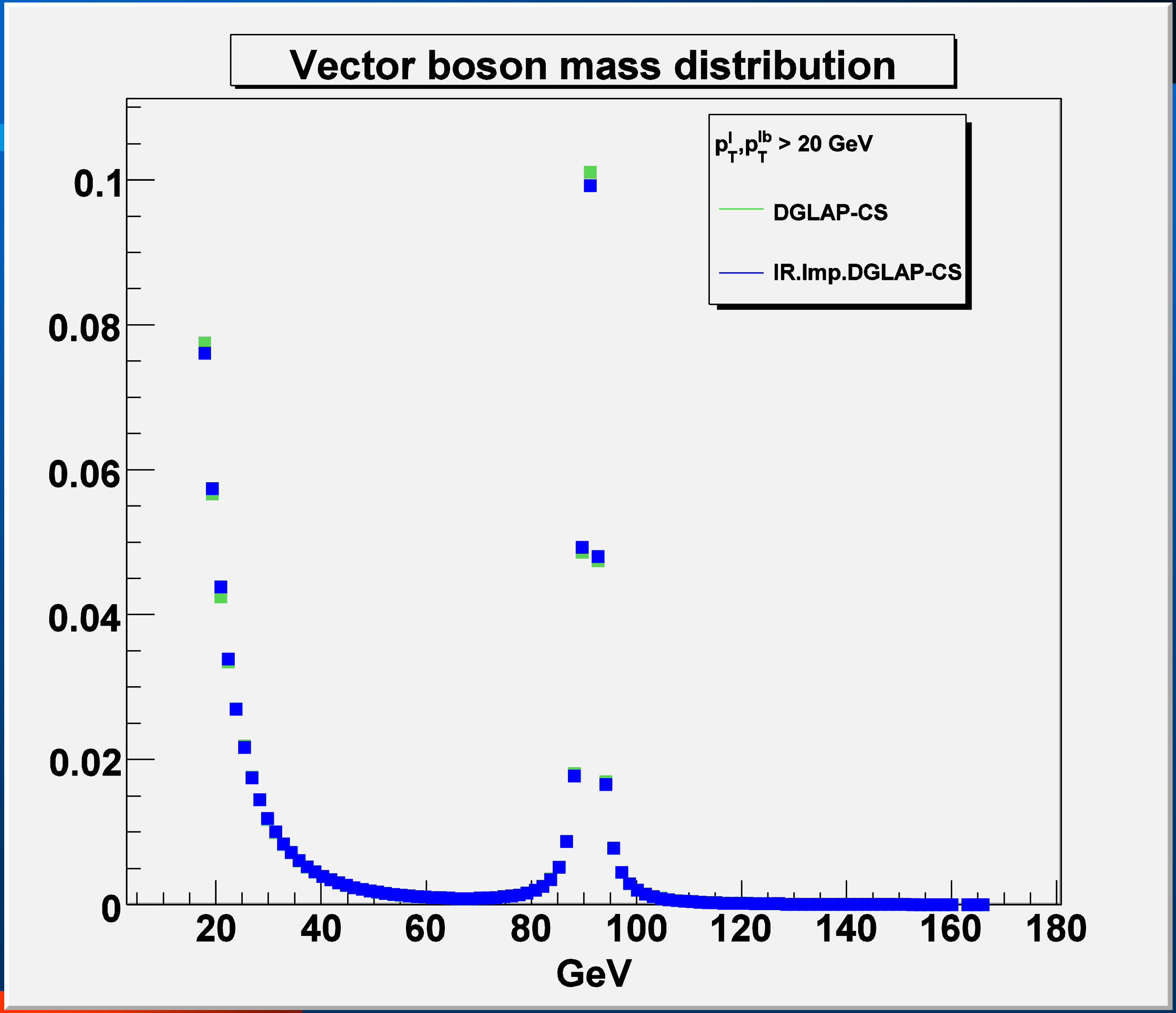
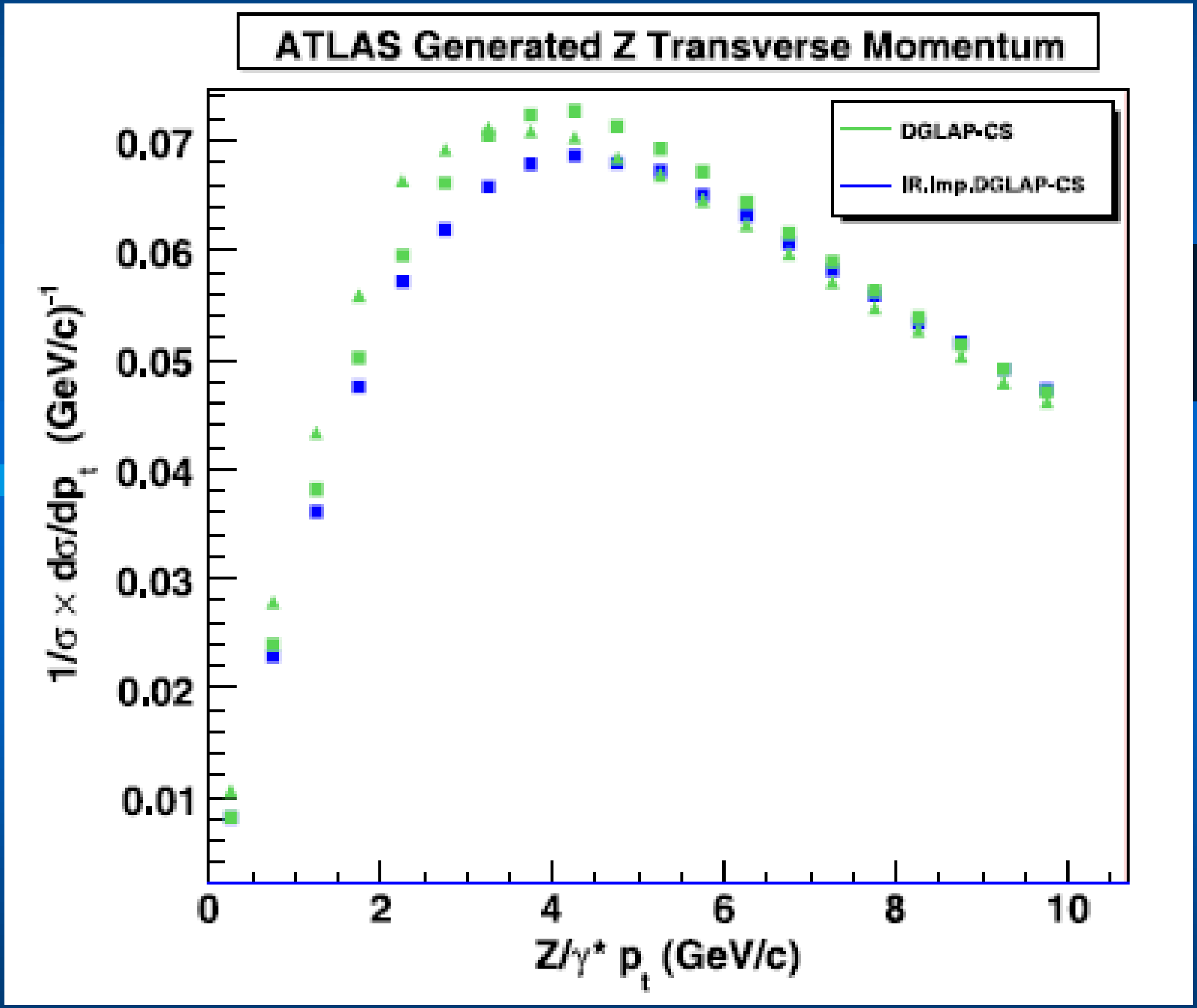
For example: 2.2% Peak Effect



THEORY COMPARISON: FINER BINS -- 0.5GeV vs 3.0GeV



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OBSERVATIONS

* IR-Improved DGLAP-CS Theory Increases Definiteness of Precision Determination of NLO Parton Shower MC’s and Improves Such.
* More Potential Checks Against Experiment Are Being Pursued.

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Near Future

* Herwig++(soon, running , under cross checks)
* Pyhtia 8,6 (w consultation from Peter Skands and Torbjorn Sjostrand
* Sherpa (w consultation from Jan Winter)

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Near Future

*New Observables: ϕ_η^* (w p_T cuts, etc.)

*New Data: ATLAS & CMS,

EACH > 10^7 lepton pairs

$\Longrightarrow$ COMPLETE INTRINSIC P_T TESTS

*HERWIRI2.0 (w S.Yost, M. Hjena, V. Halyo)

HERWIG6.5 $\cup$ KK MC 4.22

KK MC 4.22 (w S. Jadach, Z.Was), 1307.4037

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. . . *MC@NNLO

KK MC 4.22

$v_{\max}$	KKsem Refer.	$\mathcal{O}(\alpha^3)_{\rm EEX3}$	$\mathcal{O}(\alpha^2)_{\rm CEEX}$ intOFF	$\mathcal{O}(\alpha^2)_{\rm CEEX}$
	$\sigma(v_{\max})$ [pb]			
0.01	0.9145 ± 0.0000	0.9150 ± 0.0004	0.9150 ± 0.0004	0.9323 ± 0.0004
0.10	1.0805 ± 0.0000	1.0807 ± 0.0004	1.0808 ± 0.0004	1.0920 ± 0.0004
0.30	1.1612 ± 0.0000	1.1615 ± 0.0004	1.1616 ± 0.0004	1.1691 ± 0.0004
0.50	1.1974 ± 0.0000	1.1977 ± 0.0004	1.1981 ± 0.0004	1.2036 ± 0.0004
0.70	1.2310 ± 0.0000	1.2312 ± 0.0004	1.2317 ± 0.0004	1.2357 ± 0.0004
0.90	1.6104 ± 0.0000	1.6128 ± 0.0003	1.6114 ± 0.0004	1.6148 ± 0.0004
0.99	1.6218 ± 0.0000	1.6254 ± 0.0003	1.6244 ± 0.0004	1.6277 ± 0.0004
	$A_{\rm FB}(v_{\max})$			
0.01	0.5883 ± 0.0000	0.5883 ± 0.0005	0.5883 ± 0.0005	0.6033 ± 0.0005
0.10	0.5882 ± 0.0000	0.5881 ± 0.0004	0.5881 ± 0.0004	0.5966 ± 0.0004
0.30	0.5879 ± 0.0000	0.5879 ± 0.0004	0.5879 ± 0.0004	0.5932 ± 0.0004
0.50	0.5875 ± 0.0000	0.5874 ± 0.0004	0.5875 ± 0.0004	0.5912 ± 0.0004
0.70	0.5848 ± 0.0000	0.5845 ± 0.0004	0.5846 ± 0.0004	0.5868 ± 0.0004
0.90	0.4736 ± 0.0000	0.4722 ± 0.0003	0.4728 ± 0.0003	0.4748 ± 0.0003
0.99	0.4710 ± 0.0000	0.4691 ± 0.0003	0.4697 ± 0.0003	0.4716 ± 0.0003

TABLE II. Study of total cross section $\sigma(v_{\max})$ and charge asymmetry $A_{\rm FB}(v_{\max})$, $d\bar{d} \to \mu^-\mu^+$, at $\sqrt{s}$ =189GeV. See Table I for definition of the energy cut $v_{\max}$, scattering angle and M.E. type.

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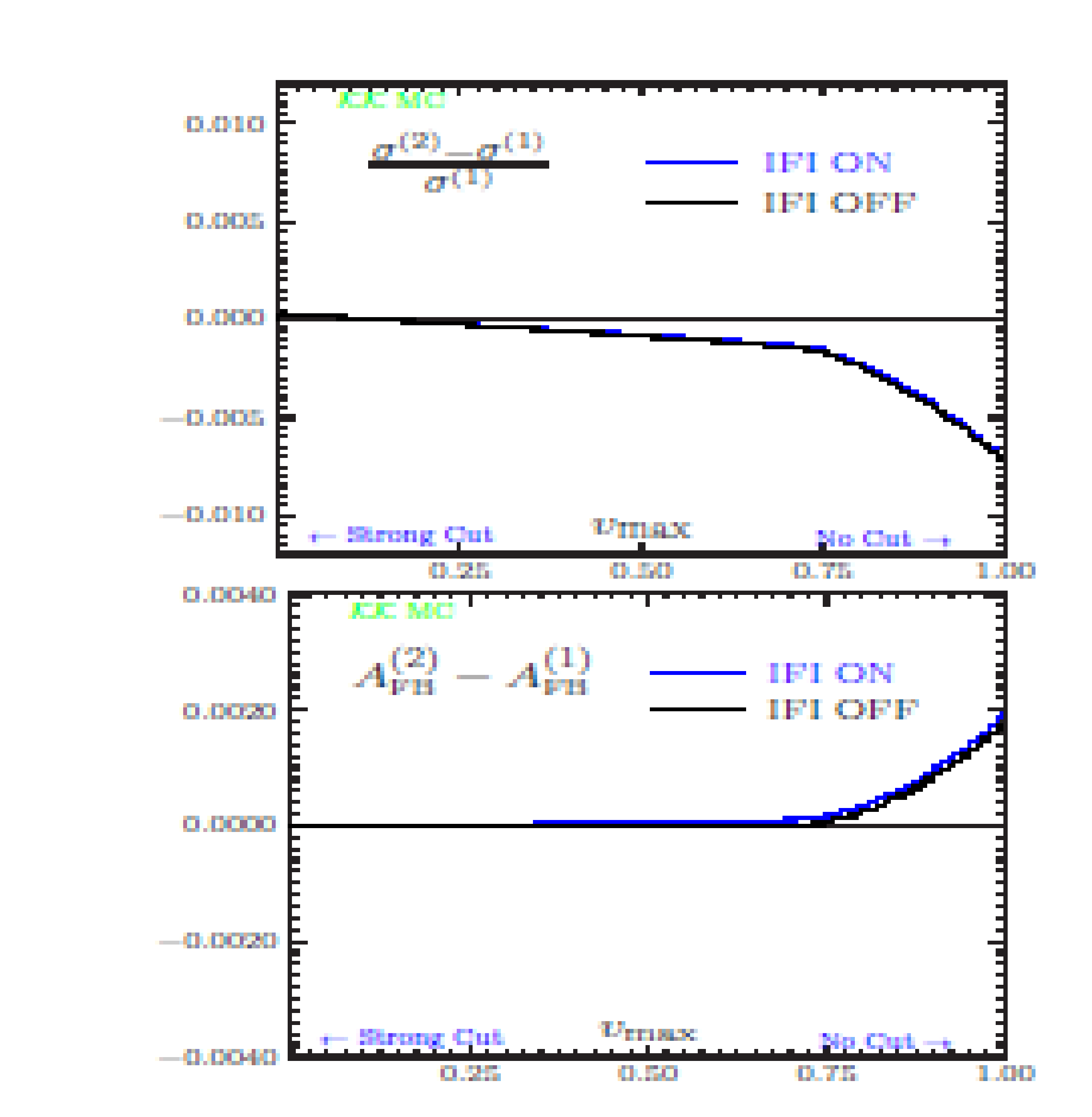
$v=1-s'/s$ (EW lib. = DIZET6.21)

KK MC 4.22($\Delta\sigma_{phys}$ TEST)



$$\frac{\sigma^{(2)} - \sigma^{(1)}}{\sigma^{(1)}}$$

$$A_{FB}^{(2)} - A_{FB}^{(1)}$$

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1/7/2014

KK MC 4.22: physics extensions, PDF's

```
**********************************************************************************
*                               KK Monte Carlo                                   *
*             Version          4.22            May 2013                          *
*      7000.00000000                       CMS energy average        CMSene   a1 *
*         0.00000000                       Beam energy spread        DelEne   a2 *
*                100                       Max. photon mult.         npmax    a3 *
*                  0                       wt-ed or wt=1 evts.       KeyWgt   a4 *
*                  1                       ISR switch                KeyISR   a4 *
*                  1                       FSR switch                KeyFSR   a5 *
*                  2                       ISR/FSR interferenc       KeyINT   a6 *
*                  1                       New exponentiation        KeyGPS   a7 *
*                  0                       Hadroniz.  switch         KeyHad   a7 *
*         0.20000000                       Hadroniz. min. mass       HadMin   a9 *
*         1.00000000                       Maximum weight            WTmax   a10 *
*                100                       Max. photon mult.         npmax   a11 *
*                  2                       Beam ident                KFini   a12 *
*         0.03500000                       Manimum phot. ener.       Ene     a13 *
*     0.10000000E-59                       Phot.mass, IR regul       MasPho  a14 *
*      1.2500000                           Phot. mult. enhanc.       Xenph   a15 *
*         0.00000000                          PolBeam1(1)            Pol1x   a17 *
*         0.00000000                          PolBeam1(2)            Pol1y   a18 *
*         0.00000000                          PolBeam1(3)            Pol1z   a19 *
*         0.00000000                          PolBeam2(1)            Pol2x   a20 *
*         0.00000000                          PolBeam2(2)            Pol2y   a21 *
*         0.00000000                          PolBeam2(3)            Pol2z   a22 *
**********************************************************************************

                             Event listing (summary)
    I particle/jet KS     KF  orig    p_x      p_y      p_z       E        m
    1 !u!          21      2    0    0.000    0.000   22.668   22.668    0.005
    2 !ubar!       21     -2    0    0.000    0.000 -245.458  245.458    0.005
    3 (Z0)         11     23    1   23.016   18.370  -80.068  115.249   77.487
    4 gamma         1     22    1  -30.989   -6.132 -128.905  132.719    0.000
    5 gamma         1     22    1    0.000    0.000    0.031    0.031    0.000
    6 gamma         1     22    1    7.973  -12.238  -13.848   20.127    0.000
    7 gamma         1     22    1    0.000    0.000 3477.332 3477.332    0.000
    8 gamma         1     22    1    0.000    0.000-3254.542 3254.542    0.000
    9 tau-          1     15    3  -24.701   21.657  -20.217   38.613    1.777
   10 tau+          1    -15    3   47.716   -3.287  -59.851   76.635    1.777
                   sum:  0.00        0.000    0.000    0.000 7000.000 7000.000
                             Event listing (summary)
    I particle/jet KS     KF  orig    p_x      p_y      p_z       E        m
    1 !u!          21      2    0    0.000    0.000  271.908  271.908    0.005
    2 !ubar!       21     -2    0    0.000    0.000   -6.542    6.542    0.005
    3 (Z0)         11     23    1    0.047    1.133  244.401  257.454   80.928
    4 gamma         1     22    1   -0.047   -1.133   20.965   20.996    0.000
    5 gamma         1     22    1    0.000    0.000 3228.092 3228.092    0.000
    6 gamma         1     22    1    0.000    0.000-3493.458 3493.458    0.000
    7 mu-           1     13    3    0.601   14.537    2.005   14.687    0.106
    8 mu+           1    -13    3   -0.554  -13.404  242.396  242.767    0.106
                   sum:  0.00        0.000    0.000    0.000 7000.000 7000.000
```

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KK MC 4.22: physics extensions, PDF's

```
*****************************************************************************
*                       KK2f_Finalize  printouts                            *
*   7000.00000000                  cms energy total         cmsene     a0 *
*            5000                  total no of events       nevgen     a1 *
*              ** principal info on x-section **                            *
*    233.95163953  +- 1.04896414  xs_tot MC R-units         xsmc       a1 *
*      0.41468908                  xs_tot    picob.         xSecPb     a3 *
*      0.00185933                  error     picob.         xErrPb     a4 *
*      0.00448368                  relative error           erel       a5 *
*      0.82048782                  WTsup, largest WT        WTsup     a10 *
*                      ** some auxiliary info **                            *
*      0.00219522                  xs_born   picobarns       xborn     a11 *
*      0.73760000                  Raw phot. multipl.                  === *
*      5.00000000                  Highest phot. mult.                 === *
*                        End of KK2f  Finalize                              *
```

- **NON-ZERO P_T H.O. EW CORRECTIONS, .2% = $\Delta\sigma_{th}$**

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OUTLOOK

* OTHER EFFORTS TO IMPROVE RESUMMATION IN PROGRESS: EW COLLINEAR REGIME – BARZE ET AL., …
* NEW NLO and NNLO RESULTS: multi-leg, $t\bar{t}$, …

* WHAT WE CAN SAY IS THIS:

FULL EXPLOITATION OF LHC DISCOVERY POTENTIAL WILL NEED SUCH EFFORTS

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