The challenges for precision measurements at the LHC

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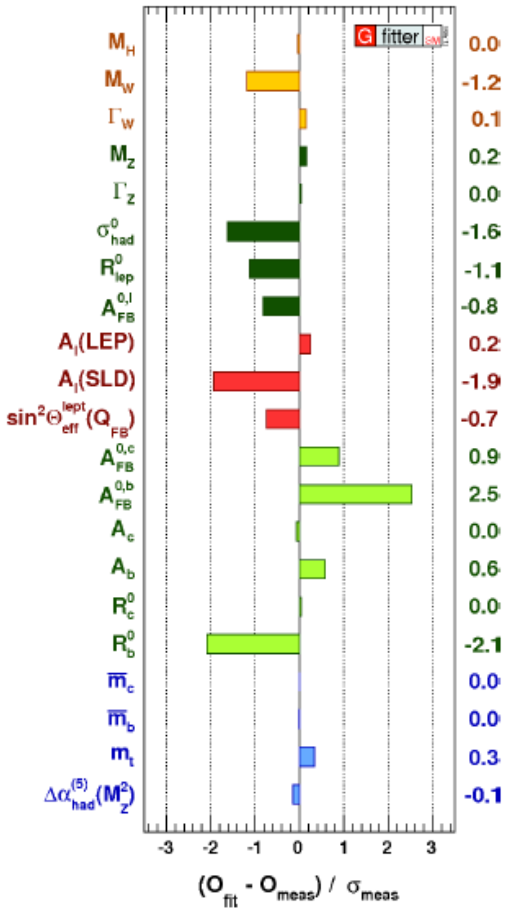
What I mean by "precision measurements"?

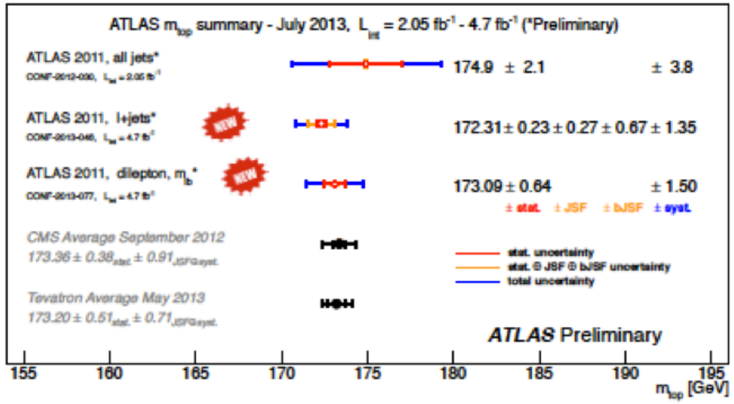
1. *Measurements which test the SM with better precision (with respect to what has been achieved so far)*

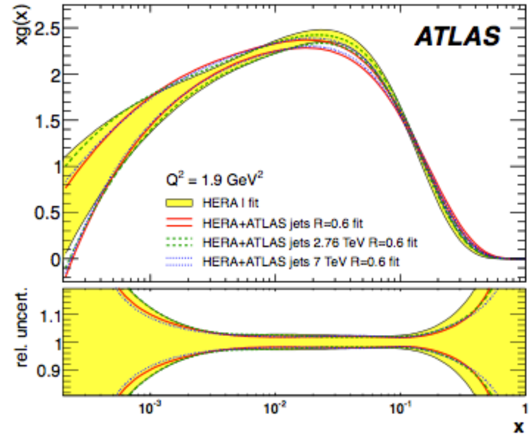
2. *Measurements which improve the precision of the "primary" parameters of the Standard Model*

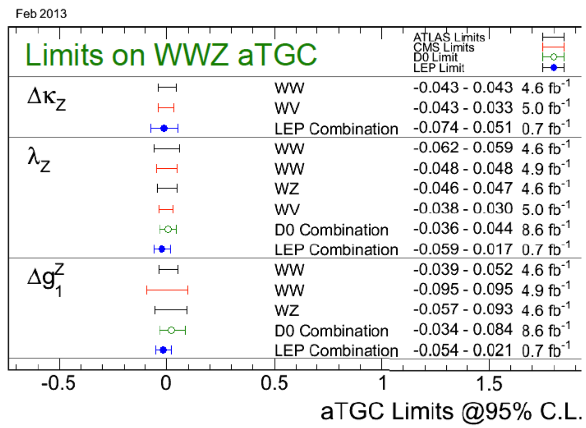
3. *(This talk)Measurements which are not limited by the statistical precision but rather by the systematic measurement accuracy and/or by the present accuracy of the theory calculations (order of perturbative expansion, the theory input parameters, including the PDFs parameters)*

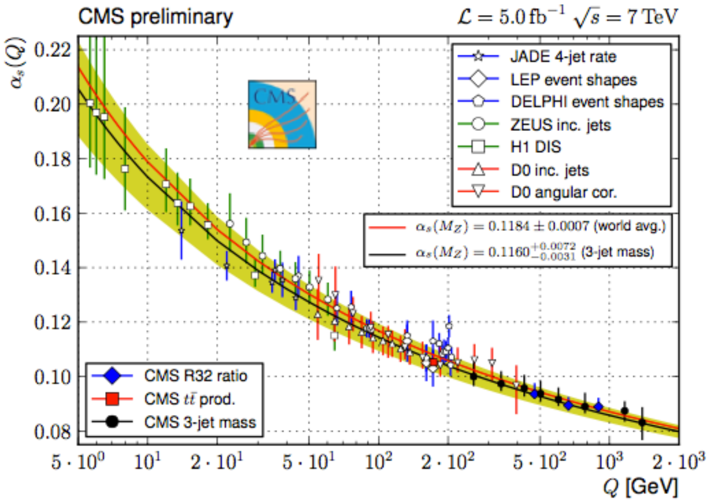
Examples:











Up to now the LHC has not (yet?) contributed significantly to the domain of precision measurements. Why?

Challenges for precision physics **at the LHC**

At the LHC we collide pp not $p\bar{p}$ like at the Tevatron

- Symmetry relations not at work! (e.g .need to understand the charge and polarization asymmetries in W and Z production (valence/sea separation)
- Collisions at much higher energy! (e.g. need to understand heavy flavours with much better precision)
- W and Z bosons are produced at the LHC by the low-x partons! (need to understand precisely not only the x dependence of their distributions but also their correlations and the flavour dependent k_T distributions)

The gain in the collected luminosity is at the cost of the large pp collision pileup

The departure point this talk is the following statement:

If the Monte-Carlo tools and the measurement procedures developed for the Tevatron programme are used at the LHC, and if no LHC-specific effort is undertaken, then the precision of majority of the Standard Model parameters, will not be improved at the LHC - ***no matter what level of the understanding of the LHC detectors performance will eventually be achieved….***

How to move forward?

1.Use flexibilities of the operation modes of the LHC

- *Full use of the variability of the CM-energy settings of the LHC* (see e.g M.W. Krasny et al. Eur.Phys.J. C51 (2007) 607;M.W. Krasny, Acta Phys.Polon. B42 (2011) 2133; M. Mangano, J.Rojo, JHEP1208 (2012) 10.)

- *Exploit the potential of the pA collisions at the LHC*
  (see e.g. M.W Krasny et al. Eur.Phys.J. C44 (2005) 333.)

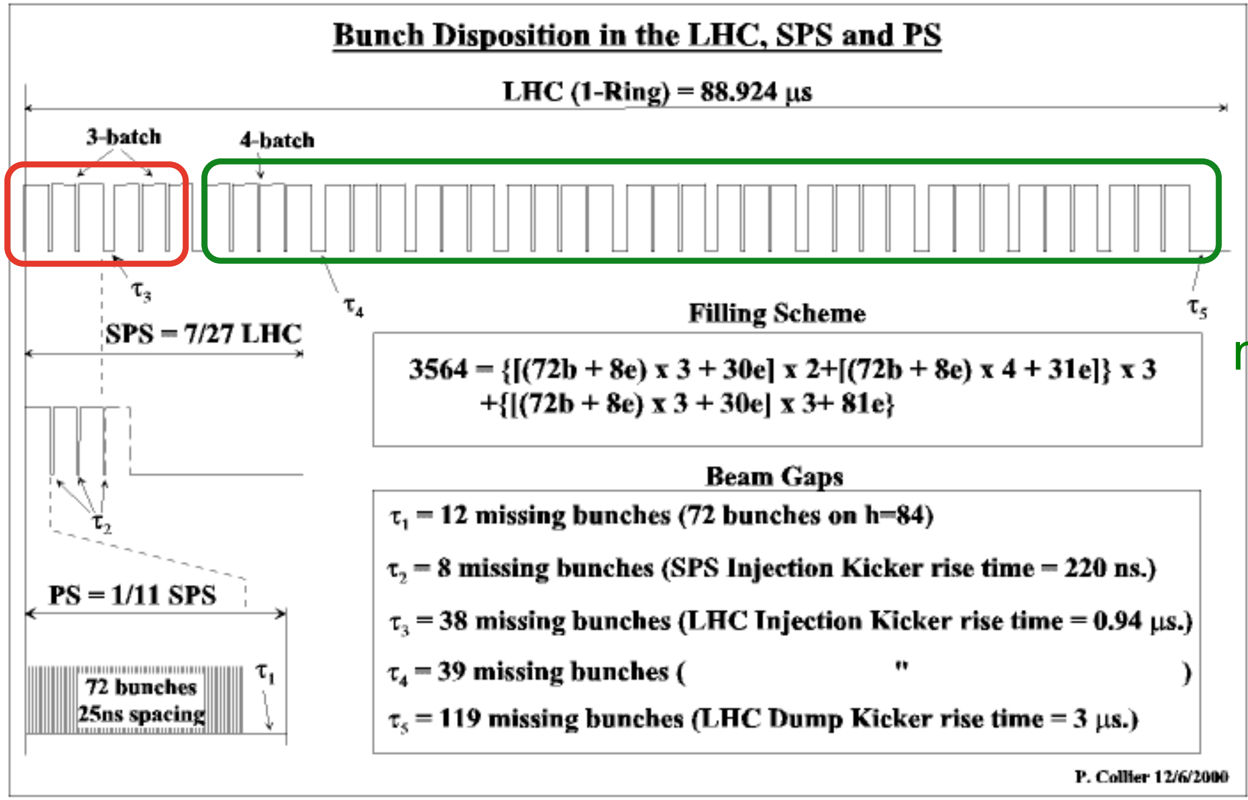
- *Collisions of isoscalar beams for precision EW physics*
  (see e.g. M.W Krasny et al. Eur.Phys.J. C69 (2010) 379.)

- *Use partially stripped ion beams to deliver the monochromatic electron beam to the Interaction Points of the LHC experiments*
  (see e.g. M.W Krasny, Nucl.Instrum.Meth. A540 (2005) 222.)

- *Use the LHC bunch filling scheme which allows for the precise control of the pile-up effects* M.W Krasny, Proposal for the 2012 running scheme.

Integrated luminosity loss: (3+3)/39 = 0.15 Negligible

Pile-up monitoring Bunches: $\mu = 1$



Nominal Bunches used in the precision measurements: $\mu = 50$

Use the first two "3-batch" bunch crossings, for which the proton number is set to assure $\mu \sim 1$, for "in phase" monitoring of the pile-up effects (the proposed running scenario is, in the long term, indispensable for the precision measurements. It is considered by S.Myers as feasible.)

2. Create the "precision support" LHC-auxiliary exp. programme

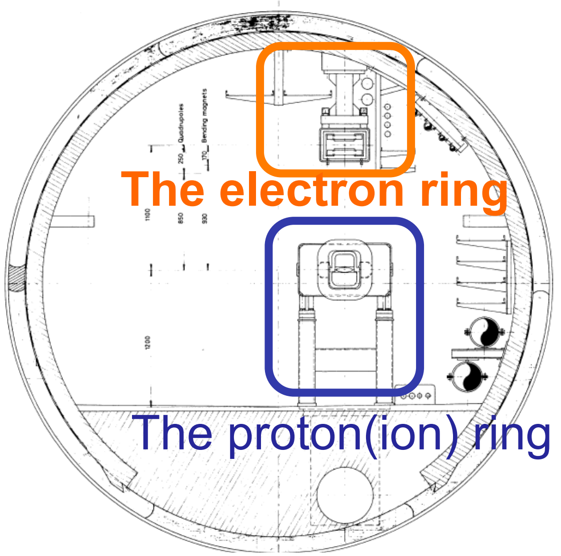
- *The SPS fixed target, precision support programme (understanding of the W and Z polarisation at the LHC)*

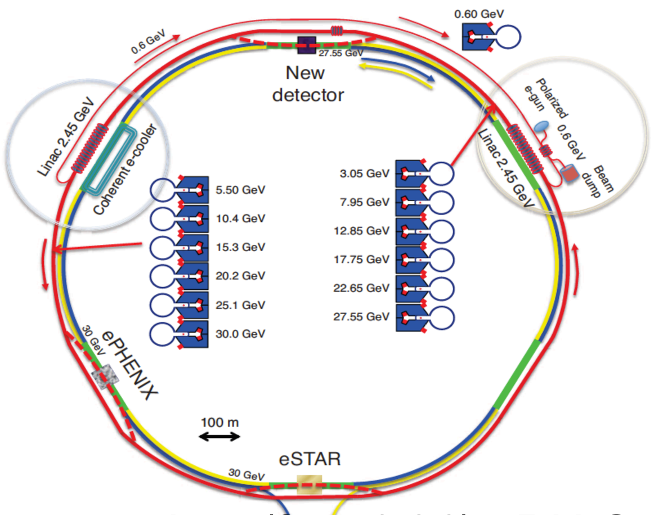
  (see e.g F. Dydak. M.W. Krasny, R. Voss CERN-SPSC-2009-028 / SPSC-I-239 Letter of Intent)

- *The ep (eA) collider in the SPS tunnel*

  (see e.g. M.W Krasny: Exploring Confinement, contribution to the European Strategy process, arXiv: 1208.3764 [physics.acc-ph]. See also M.W. Krasny contribution to the 2013 DIS workshop, Marseille, April 2013)

iCHEEPx: The ep(eA) collider in the SPS tunnel as the precision support for the LHC





The scaled up (fac. 1.81) eRHIC project

2.45 GeV ERLs

(no bypasses necessary)

6 vertically stacked recirculation passes in the arcs : 5.5, 10.4, 15.3, 20.2, 25.1, 30.0 GeV

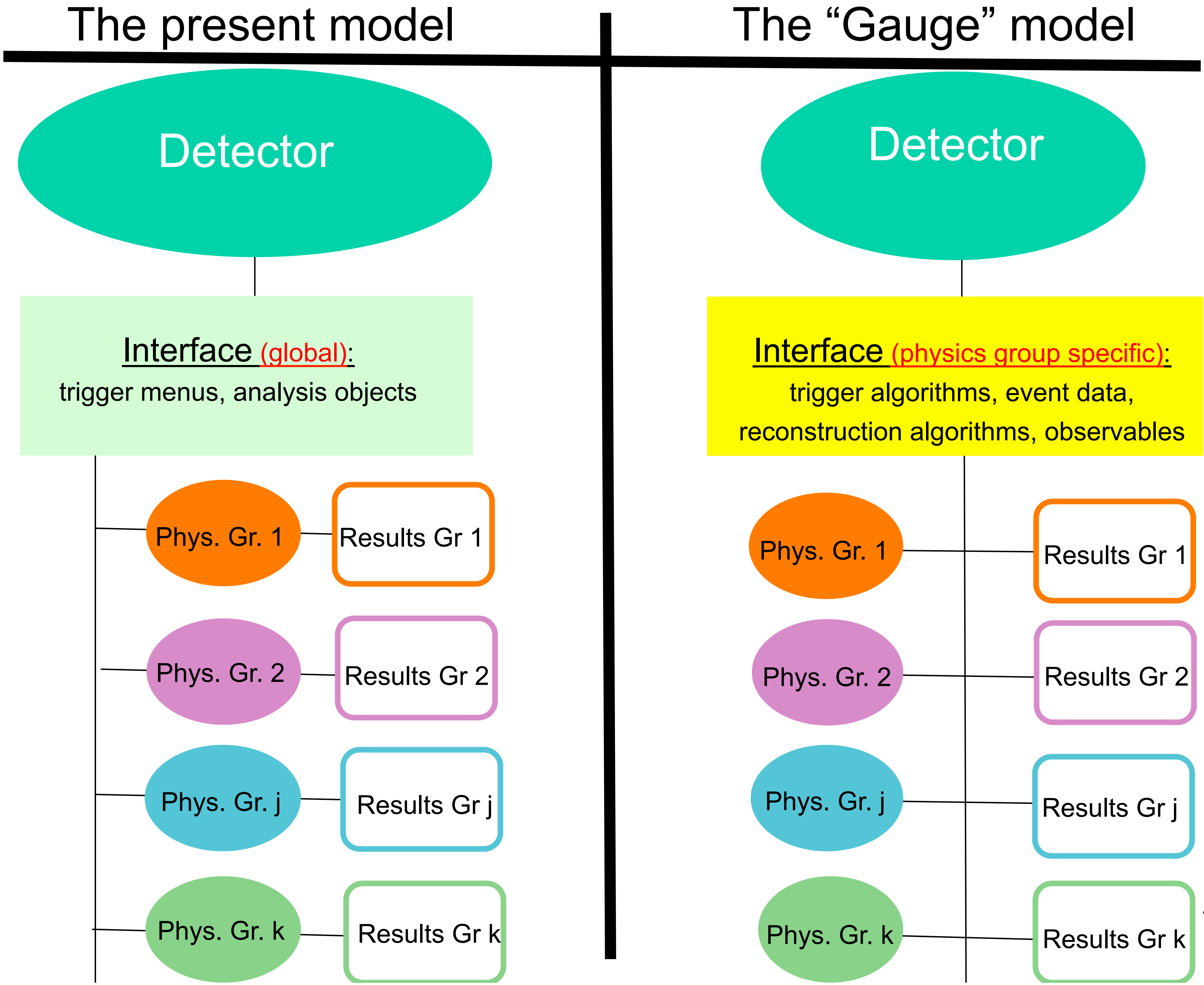
E_{CM}(ep/eA) = 14-230 GeV

(covers the energy range of eRHIC, MEIC and ENC@FAIR, overlap with PIE@LHC – easy cross-normalisation of the iCHEEP and LHC cross-sections)

3. Switch to a new (precision oriented) operation mode of the LHC experiments

- *The "Gauge" model of the Trigger, Data Acquisition and the Data Analysis for the LHC experiments*

  (see e.g. M.W. Krasny, Acta Phys.Polon. B39 (2008) 1613. M.W. Krasny, In Computing in High Energy and Nuclear Physics, VOL 1, Macmillan advanced research series, and references quoted therein)



The present model
The "Gauge" model
Detector
Detector
Interface (global):
trigger menus, analysis objects
Interface (physics group specific):
trigger algorithms, event data,
reconstruction algorithms, observables
Phys. Gr. 1
Results Gr 1
Phys. Gr. 2
Results Gr 2
Phys. Gr. j
Results Gr j
Phys. Gr. k
Results Gr k
Phys. Gr. 1
Results Gr 1
Phys. Gr. 2
Results Gr 2
Phys. Gr. j
Results Gr j
Phys. Gr. k
Results Gr k

4. Upgrade the LHC detectors

- An example: *High precision luminosity measurement for the LHC*
  (see e.g. M.W. Krasny et al. Nucl.Instr.Meth. A584 (2008) 42,Nucl.Instr.Meth.D-11-00978(in print), Nucl.Instr.Meth.D-06-00760 (in print))

Four reasons to measure the ratios of the cross sections to a 0.1% precision

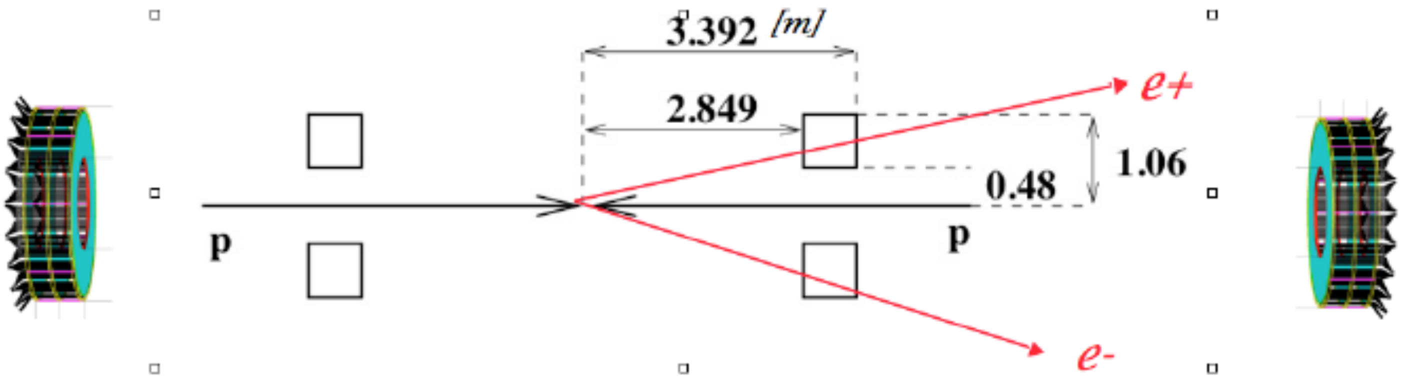
•***Measurement of the cross sections ratios at different CM-energies***
(EW physics, Primakoff processes, Higgs searches, etc…)

• ***Measurement of the cross section ratios with different beam species***
(use ions to modify the medium effects in hard EW and QCD processes)

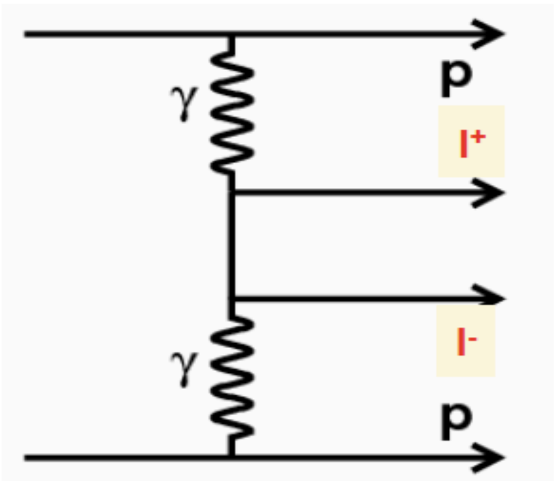
•***Relative normalization of the cross sections measured in different phase-space regions*** *(e.g. ATLAS/CMS versus LHCb in the measurement of $\sin^2\theta_W$)*

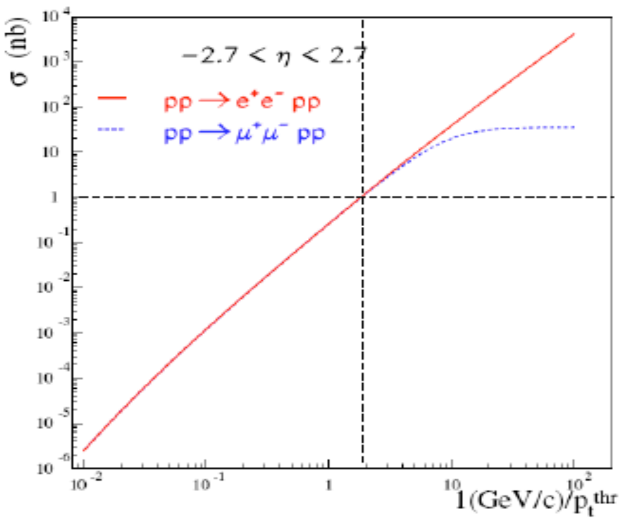
•***Relative normalization of cross sections measured at the LHC and Tevatron***
(precision unfolding of the flavour and sea/valence structure of the proton)

Precision (LEP-like) luminosity measurement for the LHC



$Rate_{ll}(L_{pp}=10^{33}) \sim Rate_{ll}(L_{pPb}=10^{29}) \sim Rate_{ll}(L_{PbPb}=5x10^{24})$





O(1) events/sec for $L=10^{33}$ $s^{-1}cm^{-2}$ and p_t^{thr} >0.5 GeV/c cut
(the transverse momentum of each of the two leptons > 0.5 GeV/c)

5. Define new observables and new, precision measurement procedures (strategies)

- *Example: measurement of the SM EW parameters:* $M_{W,}$ $\sin^2(\theta_W)$, $\Gamma_{W,}\ldots$ *using new observables which profit from the flexibility of the detector and the machine running modes to minimize the impact of the dominant sources of systematic and modeling errors:*

  (discussed in: M.W. Krasny et al. Eur.Phys.J. C51 (2007) 607; M.W. Krasny, Acta Phys.Polon. B42 (2011) 2133;F. Fayette et al., Eur.Phys.J. C63 (2009) 33-56, M.W Krasny et al. Eur.Phys.J. C69 (2010) 379.

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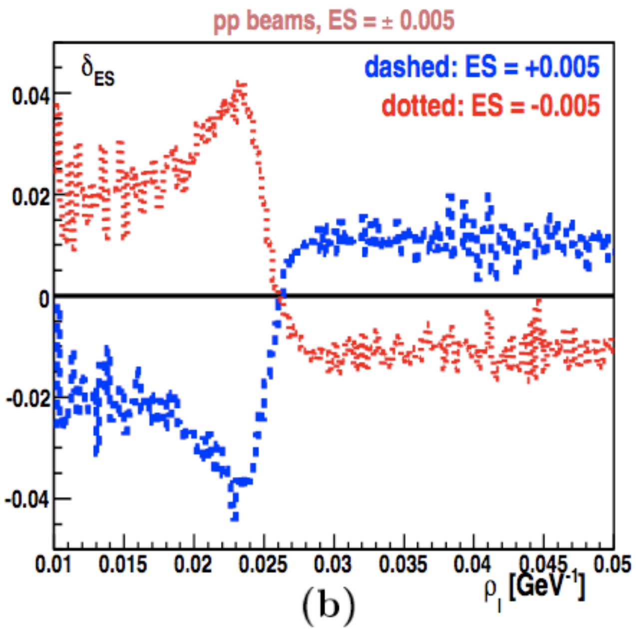
Impact of the lepton energy scale bias on the M_W measurement:

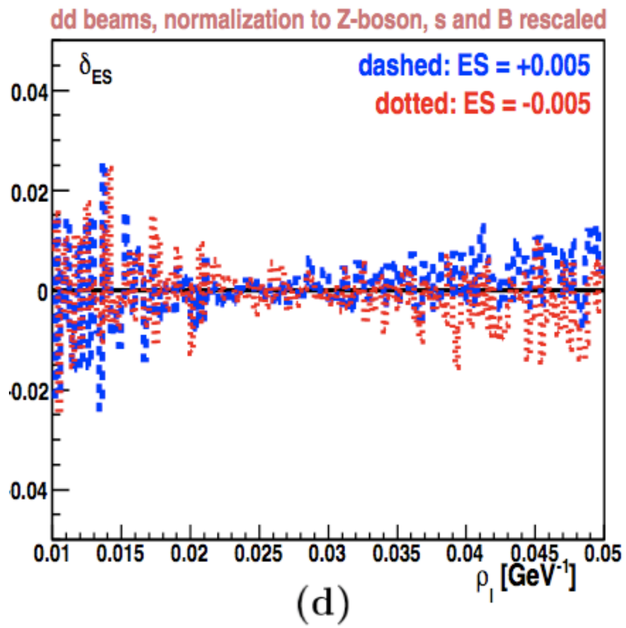
$E_{true} = E_{meas}(1 \pm ES)$ $\delta_{ES} = \frac{d\sigma/d\rho_l(ES\pm) - d\sigma/d\rho_l(ES)}{d\sigma/d\rho_l(ES)}$

$\rho_l = 1/p_{t,l}$

Standard measurement procedure (Tevatron-like)

Special observable and dedicated Measurement procedure





Reduction of biases by a factor of ~ 20 !

Conclusions

The precision measurements at the LHC require a substantial effort to reach the precision limits of the LHC detectors and to reach the matching precision of the Event Generators. ***The basic message of this short talk is that such an effort is necessary but, unfortunately, not sufficient.***

In order to be competitive new measurement strategies exploiting fully the flexibilities of the LHC collider and its detectors (e.g such as sketched in this talk) must be incorporated.

The precision measurements cannot be done in parallel to the program of searches at the luminosity and energy frontier but require a dedicated running time and/or dedicated operation modes of the of the machine and of the detector.

The precision measurement programme is worth an effort – not only for the textbook measurements but also as a complementary search for new physics phenomena.