Selected topics on the precision of luminometry at the LHC (as seen through the theorist's eyes)

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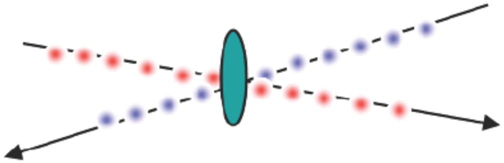
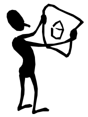
Special thanks to Misha Ryskin for discussions.





PLAN

1. Introduction (10 years on).
2. Two photon production of muon pairs
3. Optical theorem: forward elastic+total inelastic rates.
4. Other methods & Related subjects
5. Overall conclusions

WITH A BIT OF PERSONAL FLAVOUR

Main aims

- to identify the issues which may require further theoretical efforts
- to estimate the size of theoretical uncertainties in different approaches

1. Introduction

$L = \frac{N}{\sigma}$

10 years on

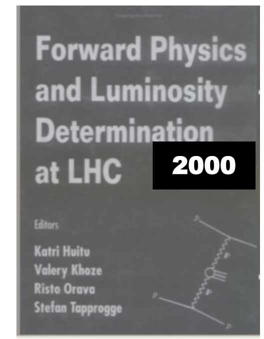
Luminosity measurements-why?

F. Gianotti and M. Pepe-Altarelli, hep-ex/0006016.

KMOR- hep-ph/0010163…..

PRIOR to the LHC START-UP

- Cross sections for "Standard " processes
  - t-tbar production
  - W/Z production
  - …….



- New physics manifesting in deviation of $\sigma \times$ BR relative the Standard Model predictions
- Important precision measurements
  - Higgs production $\sigma \times$ BR
  - tanβ measurement for MSSM Higgs
  - …….

(Michelangelo, this workshop)

Coseners Forum
12^{th}-13^{th} April 2007
Per Grafstrom

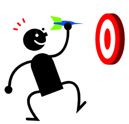
Absolute and relative luminosity measurements

1. Measure the absolute luminosity with a theoretically reliable accurate method at the most optimal conditions.

2. Calibrate luminosity monitor(s) with this measurement, which then can be used at different conditions.

Luminosity monitoring- relative measurements

Use dedicated luminosity monitors either provided by the experiment or by the machine



Target: to illustrate how well calculable could be 'traditional' processes proposed for luminosity calibration (in the real world environment).

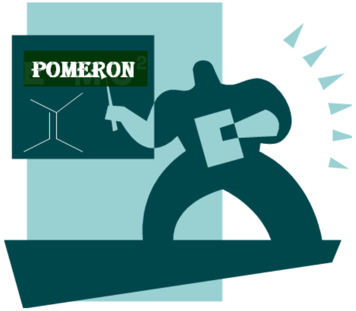
(Excluding W/Z 'standard candles')

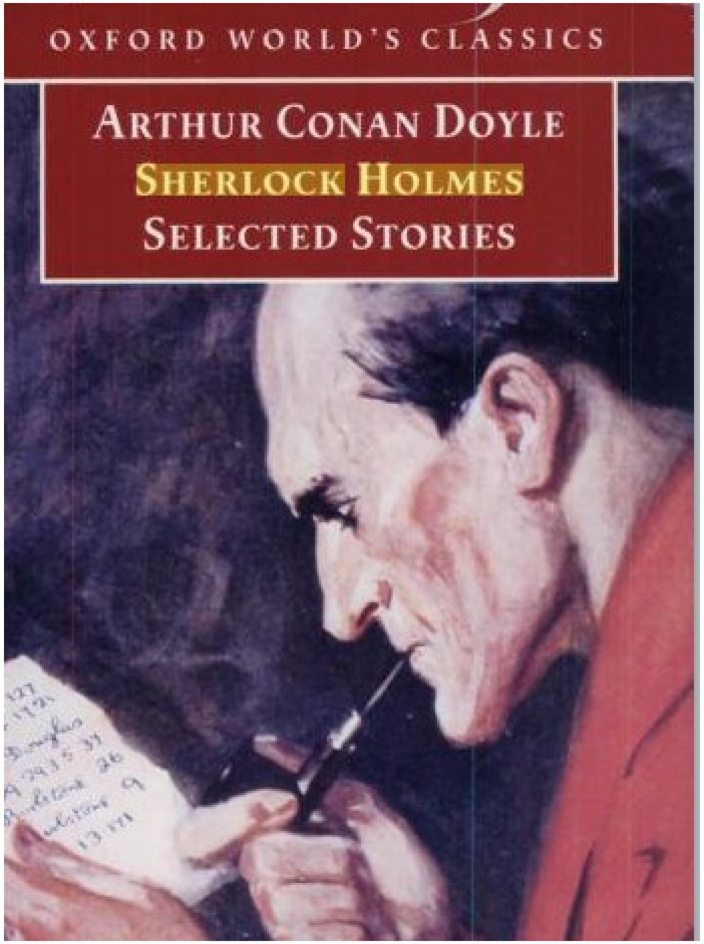
A large variety of theoretical models for soft hadron interactions..

Difference in the predictions for LHC x-sections up to a factor of 2.

(Most) probable models should

- Be theoretically self-consistent
- Allow good description of the available data in the ISR-Tevatron range (+LHC).

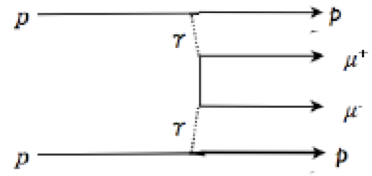




'Well, it is a possible supposition.'
'You think so, too ?'
'I did not say a probable one'

$\mu\mu$

2. Exclusive QED Lepton Pair Production



- First proposed for luminometry by. V. Budnev et al, Nucl. Phys. **B63** (1973) 519.
- First studies of feasibility for the dimuons at the LHC: A.Shamov and V.Telnov-1998 (ATLAS TDR-99).
- Strong-interaction effects- KMOR, Eur.Phys.J.C19:313-322,2001
- First observation of exclusive l^+l^- by CDF: Phys.Rev.Lett.98:112001,2007
- Ongoing studies of exclusive dimuons: CMS and LHCb (this Workshop S. Scnetzer, J. Anderson)

Myth:

- **Pure QED process** –thus, theoretically well understood (higher-order QED effects- reliably calculable).

Reality

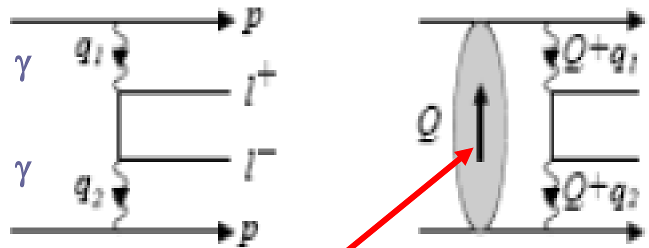
- Strong interaction effects (we collide protons after all).
- **Backgrounds**:
mis-ID, various contributions due to the incomplete exclusivity (lack of full detector coverage), pileup…

$\mu\mu$

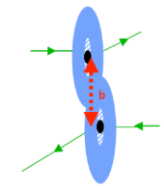
Strong interaction between colliding protons (rescattering or absorptive corrections).

schematically

Even in the fully exclusive case:



Notorious survival factor.



(large impact parameters)

Usually, for photon-photon central production $S^2_{\gamma\gamma}(LHC) \simeq 0.9$

However, in the case of $pp \to p + \ell^+\ell^- + p$ absorption effects could be very small.

In particular, for low $p_t(\mu\mu) \sim 10\text{–}50$ MeV absorpt. correction $2\delta < 0.3\%$.
Will be additionally suppressed by the muon acoplanarity cuts.

$$\delta \approx \frac{\sigma_{\rm inel}}{8\pi}\, p_t^2\, C$$ with C~0.1, KMOR, Eur.Phys.J.C19:313 (2001).

($\ell^+\ell^-$-pair production : K. Pietrzkowsi et al., A. Shamov and V. Telnov, M. Krasny et al…)

$\mu\mu$

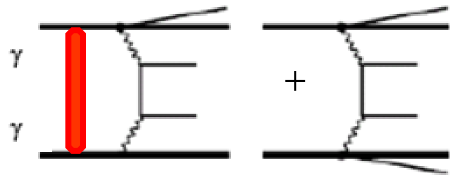
Main Backgrounds

- **Proton dissociation. accompanied by diphoton fusion**

  $P_t(\mu\mu)$ distribution is much wider (slope ~ 0.5-1.5 GeV^2)

  Usually generated with LPAIR (ZEUS version).

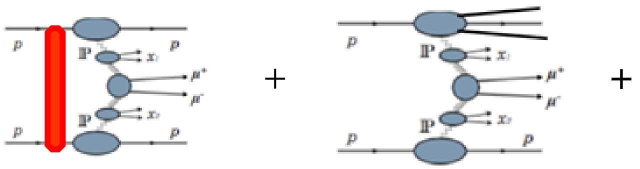
  For P_t >> $P_t(\mu\mu)$ the strong interaction effects are less than 1%.



- **Dimuons from Double Pomeron Exchange (DPE)**

  Usually evaluated using POMWIG (or DPEMC) MC.

  Caveat ☞ survival factor S^2_{PP} (should be calculated theoretically).



  Without proton dissociation $S^2_{PP} \simeq 0.1$, but , in reality, some particles accompanying dimuons could go undetected, thus some increase of the effective survival factor.

  Strong dependence on experimental conditions.

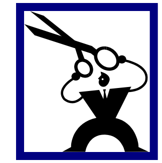
- K/pion mis-ID , muons from b,c- pair decays (the experts say these are manageable).
- $J/\psi, \psi'$ - decays could be removed by proper mass cuts.
- CMS: inel. bgds could be further suppressed by veto on HF,ZDC,Castor, (T1/T2) and FSC.

  Even in the presence of (moderate) pileup. (M.Albrow et al)

  (dielectrons@Alice with FSC -looks promising)

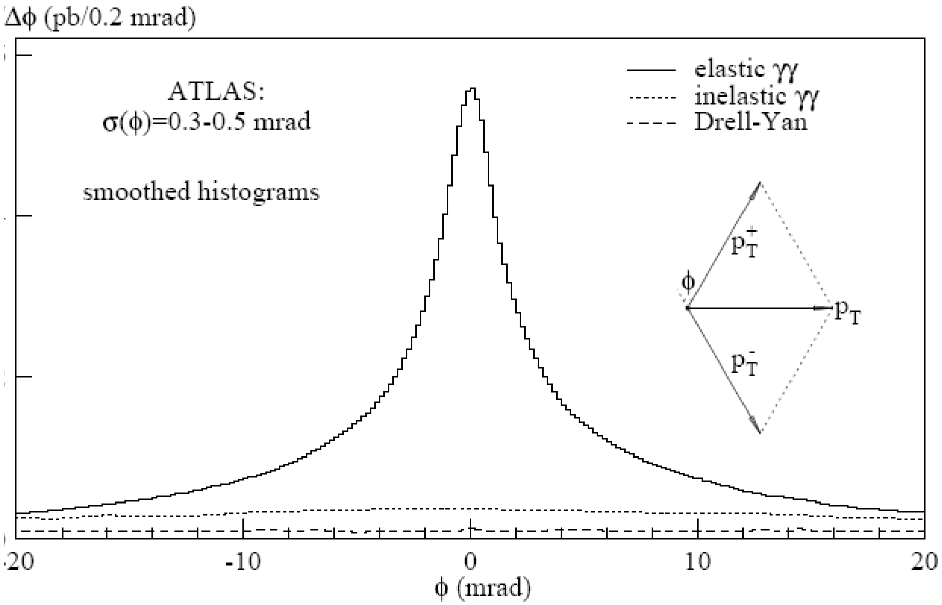
$\mu\mu$

Old recipe: cut, cut and fit.



Tight cuts on $P_t(\mu\mu)$, muon acoplanarity $\Delta\phi$ and fitting of the distributions..
.

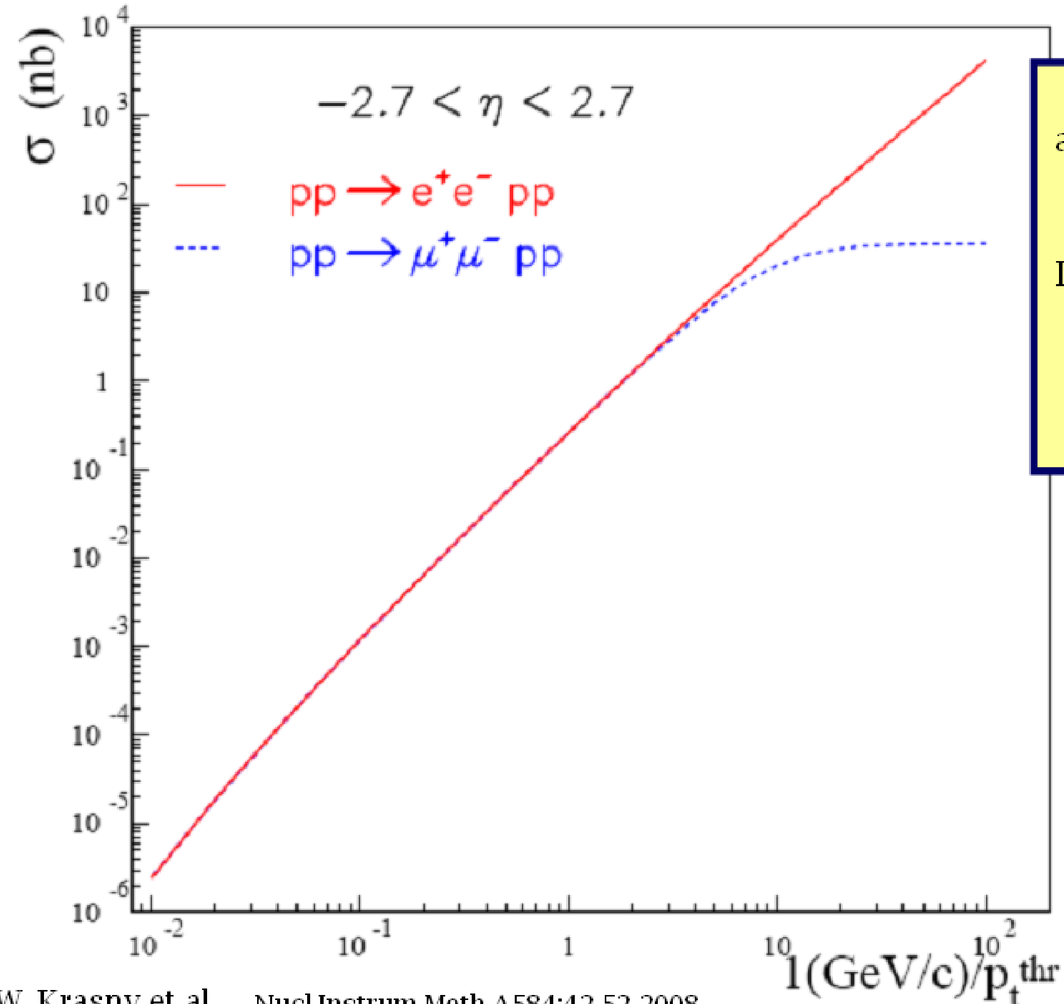
P_t of muons are equal within 2.5 σ of the measurement uncertainty



A. Shamov and V. Telnov, Nucl.Instrum.Meth.A494:51-56,2002

- Efficient suppression of proton dissociation and DPE background.
Reduction of the absorptive correction.
- With good vertex fit
Suppression of hadron decays and pileup.
- However a price to pay- event rate !
- An addition of Forward Shower Counters will allow to reduce inelastic backgrounds.

Lowering lepton detection threshold p_t^{thr} is crucial for statistical accuracy



ATLAS studies:
at p_T >6 GeV , |η|<2.2, M<60 GeV
+isolation requir. → σ ~1.33 pb.

LHCb at M>2.5 GeV → σ ~90 pb.

$P_t(\mu\mu)$ <50 MeV,

(HERA-LHC Worksp. 2008)

M.W. Krasny et al Nucl.Instrum.Meth.A584:42-52,2008

$\mu\mu$

Problems ?

The rate: $d\sigma_{QED} / dp_t^2 \sim \alpha^4 * 1 / p_t^4$

$$\sigma_{QED}(pp \to p + \mu\mu + p) \simeq 8\,pb * 2\Delta M / M (6GeV / M)^2$$

with P_t >6 GeV (e.g. ATLAS to maintain trigger eff.) the x-section is on the 1 pb level.

Pile-up: Running at $10^{34}/cm^2/sec$ ⇒ "vertex cut" and "no other charged track cut" will eliminate many good events (Per Grafstrom).

D.Moran, DIS-2010

- Advantages of LHCb: lower muon P_t (studies for P_t > 1 GeV and $P_t(\mu\mu)$ <50 MeV) and low-pile-up data

(J. Anderson's talk)

SUMMARY I

- Exclusive dimuon cross section is very reliably calculable, and this approach is potentially very promising.
- However there should be well optimized tradeoff between the experimental cuts and event rates. (Alice+ FSC – potential for ee)
- LHCb has good potential to provide a precise luminosity calibration.

3. Elastic Scattering and Optical theorem

A well established and potentially powerful method for Luminosity Calibration

(Mario Deile)

- $\frac{d\sigma_{el}}{dt} = \frac{\pi}{sp^2}|F_{el}(t)|^2$
- optical theorem: $\sigma_{tot} = \frac{4\pi}{p\sqrt{s}} \operatorname{Im} F_{el}(s, t = 0)$
- $L\sigma_{tot} = N_{el} + N_{inel}$
- Need to separate the Coulomb and hadron scattering

$$\sigma_{tot} = \frac{16\pi}{1+\rho^2} \frac{\left.\frac{dN_{el}}{dt}\right|_{t=0}}{N_{el} + N_{inel}}; \qquad L = \frac{1+\rho^2}{16\pi} \frac{(N_{el} + N_{inel})^2}{\left.\frac{dN_{el}}{dt}\right|_{t=0}}$$

To be measured

- Elastic rate N_{el}
- Differential elastic rate $\frac{dN_{el}}{dt}$ for small $-t$
- Inelastic rate N_{inel}

External input

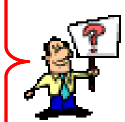
- $\rho = \frac{\operatorname{Re} F_{el}(s, t=0)}{\operatorname{Im} F_{el}(s, t=0)}$

Model	ρ
Islam et al.	0.123
Petrov et al. 2P	0.0968
Petrov et al. 3P	0.111
BSW	0.121
Block-Halzen	0.114
COMPETE	0.1316

Combined uncertainty in σ_{tot} (and L)

$$\sigma_{tot} = \frac{16\pi}{1+\rho^2} \frac{\left.\frac{dN_{el}}{dt}\right|_{t=0}}{N_{el}+N_{inel}}; \qquad L = \frac{1+\rho^2}{16\pi} \frac{(N_{el}+N_{inel})^2}{\left.\frac{dN_{el}}{dt}\right|_{t=0}}$$

	β^*	90 m	1535 m
$\left.\frac{dN_{el}}{dt}\right\|_{t=0}$ (str. interaction)	Extrapolation of elastic cross-section to $t=0$ (Smearing effect due to beam divergence, statistical errors, uncertainty of effective length L_{eff}, RP alignment, model dependent deviation)	$\pm 4\%$	$\pm 0.2\%$
N_{el}	Total elastic rate (strongly correlated with extrapolation)	$\pm 2\%$	$\pm 0.1\%$
N_{inel}	Total inelastic rate (error dominated by single diffractive losses)	$\pm 1\%$	$\pm 0.8\%$
ρ	Error contribution from $(1+\rho^2)$ (using full COMPETE error band $\frac{\delta\rho}{\rho} = 33\%$)	$\pm 1.2\%$	
	Total uncertainty in σ_{tot}	$\pm 5\%$	$\pm 1-2\%$
	Total uncertainty in L	$\pm 7\%$	$\pm 2\%$



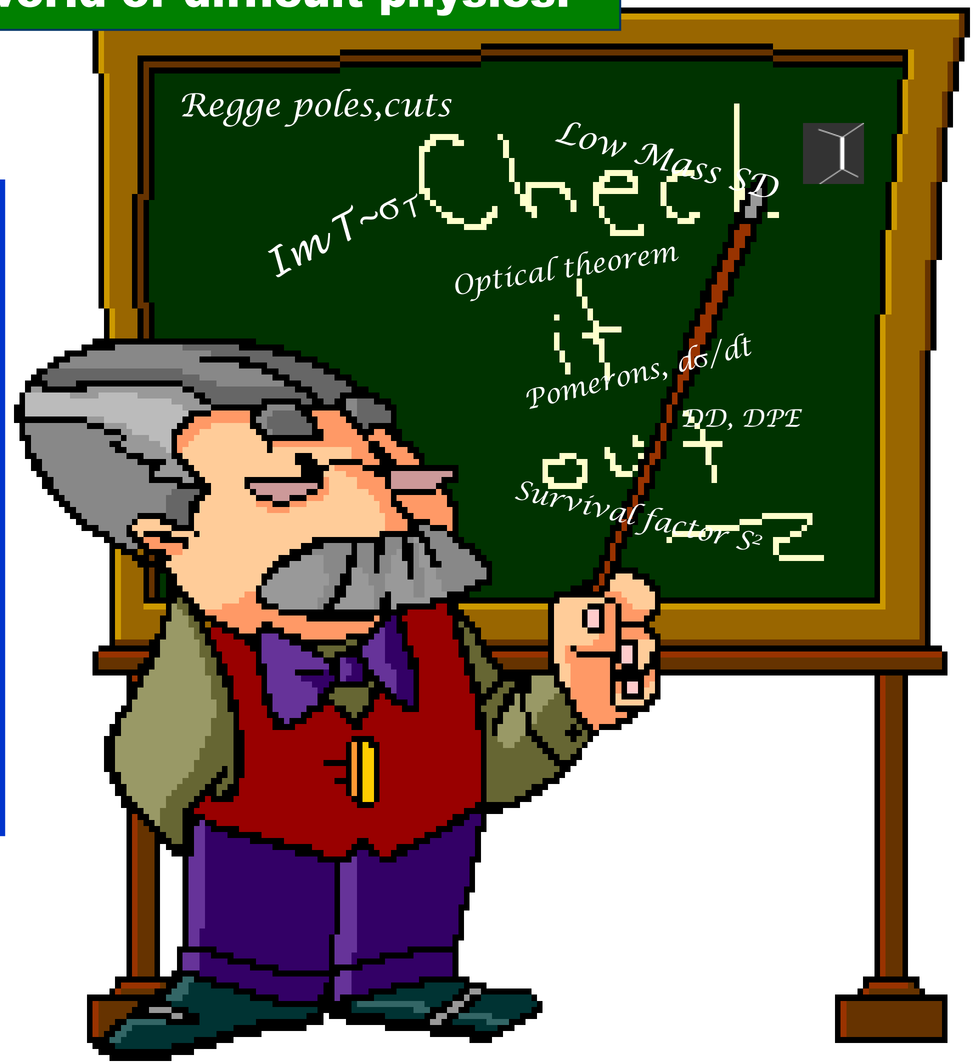
t-dependence of elastic cross section is under control, including pion loop effects, safe extrapolation to the low - t region (KMOR-2000). Recent MP studies + compilation by Totem.

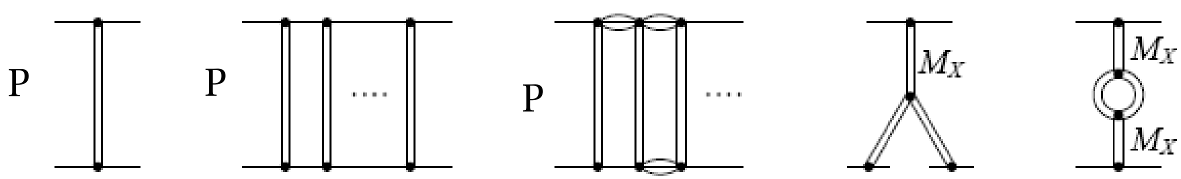
Welcome to the world of difficult physics!

- Current theoretical models for soft hadron interactions are still incomplete, and their parameters are not fixed, in particular, due to lack of HE data on Low-Mass diffraction.

- For illustration purposes only three recent (ideologically close) MP- models are used, which allow good description of the data in the ISR-Tevatron range: KMR-09-10,GLMM-09 and Ostapchenko-10.

- The differences between the results of other existing models wildly fluctuate.





Optical theorem

ILLUSTRATION I: INELASTIC EVENT RATE N_{inel}

THEORETICAL UNCERTAINTIES in the T1+T2 RUNNING SCENARIO

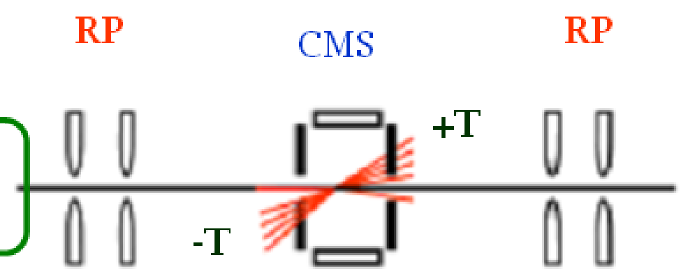
T1+T2=T, $3.1 < |\eta| < 6.5.$

Maximally (**+T** OR **–T**), expected signal σ_{signal} ~ 0.85-0.95 of σ_{inel}
(depending on the MP- model)

$$\sigma_{inel} = \sigma_{tot} - \sigma_{el}.$$

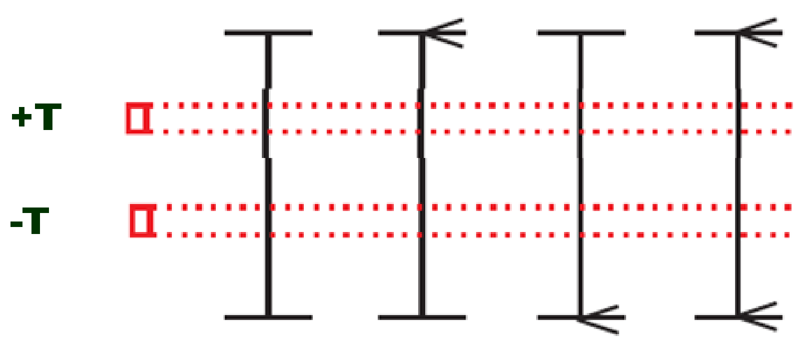
- N_{inel} measured by inelastic detectors T1 and T2
- to suppress background:
  - primary vertex reconstruction with T1 and T2

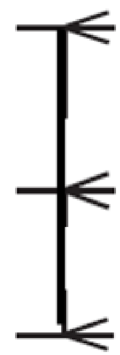
'Double Diffractive' Trigger:



Inelastic (at least 1 'trigger .track' in +T or -T, no RP info)

What is missed then?





multi-gap (DPE)- (very) small

To illustrate the size of uncertainties we compare two models.

$\sqrt{s} = 7$ TeV.

(mb)	σ_{tot}	σ_{inel}	+T	(+T OR –T)	(+T & –T)
SO-2010	95.8	71.0	62.8	66.1	59.3
KMR-2009	88.6	68	50.2 (51.8)	58.7 (61.0)	41.8 (42.6)

$\sqrt{s} = 14$ TeV.

	σ_{tot}	σ_{inel}	+ T	(+T or –T)	(+T & –T)
SO-2010	108	78.5	69.1	72.0	66.0
KMR-2009	91.5	70.0	50.7	59.0	42.4

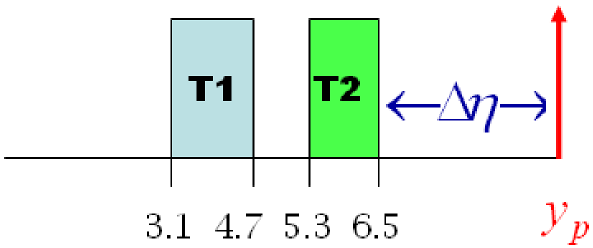
V. A. Khoze, A. D. Martin and M. G. Ryskin, Phys. Lett. B **679**, 56 (2009).
Eur. Phys. J. C60, 249 (2009). KMR-2009

S. Ostapchenko : **arXiv:1010.1869** [hep-ph] SO-2010

Achilles' Heel of 'inelastic' measurements : low mass SD

N_{inel}

Low mass Single Diffraction region: M_X < 2.5 -3.5 GeV → un-instrumented (4-5 GeV conserv.)

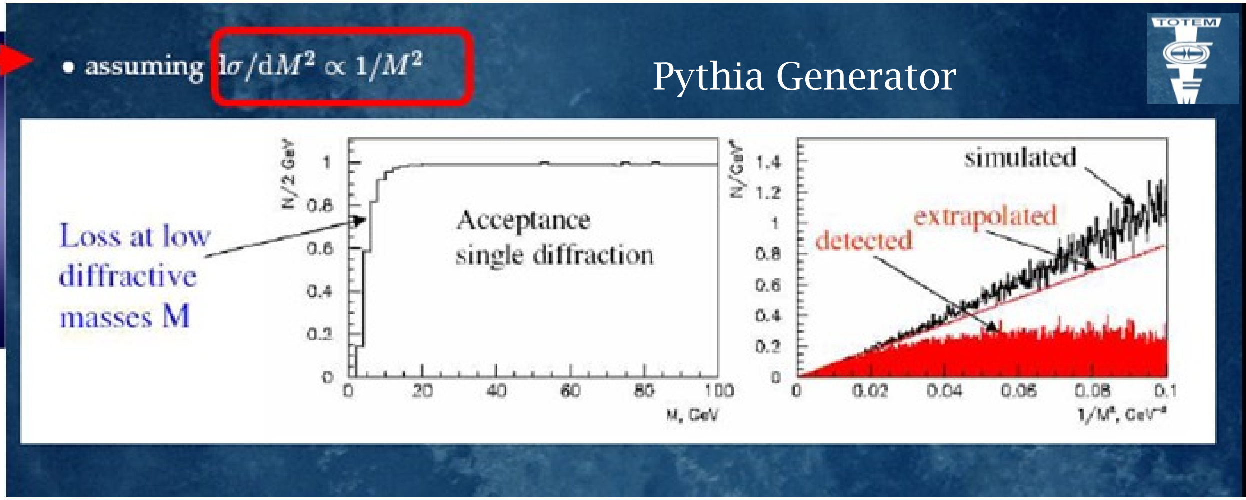


$$\eta = -\ln\tan\frac{\vartheta}{2}$$

$$y_p = \ln(\sqrt{s}/m_p), \Delta\eta \simeq (2.4-3.1)$$

Can we extrapolate from HM SD ?

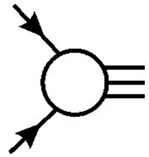
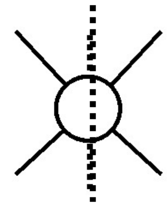
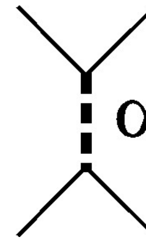
- Theoretically unjustified
- Currently **NO** theoretically solid way to extrapolate HM to LM single diffraction



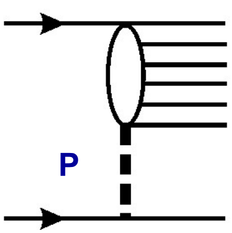
(UA4-experience ☞ factor of 2 for M<4 GeV)

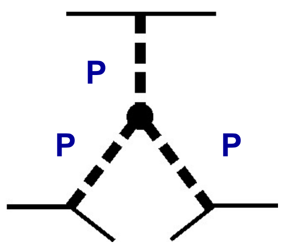
Optical theorem

A diffractive process is characterized by a large rapidity gap (LRG), which is caused by t-channel Pomeron exch.

$\sigma_{total} = \sum_X \Big|$  $X \Big|^2 = \mathrm{Im}$  $=$  $\alpha_{I\!P}(0)$

High mass diffractive dissociation

$\Big|$ 

$M \Big|^2 =$ 

PPP-diagram

$$d^2\sigma/dM^2dt|_{t=0} \sim \frac{s^{2\epsilon}}{(M^2)^{1+\epsilon}} \quad S^2 \quad \sim 1/M^2$$

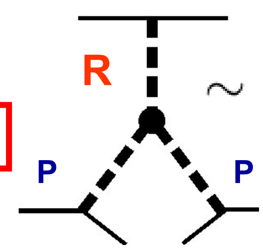
Screening is very important.
(semi) enhanced absorption …

(t-dependence !?)

Low mass diffractive dissociation

introduce diff^{ve} estates ϕ_i, ϕ_k (comb^{ns} of p,p*,..) which only undergo "elastic" scattering (Good-Walker)

dual to



$$\sim \frac{s^{2\epsilon}}{(M^2)^{1.5+2\epsilon}} \quad S^2 \quad \sim 1/M^3$$

PPR-diagram

Optical theorem

ILLUSTRATION II: SCALE OF UNCERTAINTIES

(A,B,C) S. Ostapchenko, Phys.Rev.D81:114028,2010.
KMR-08: KMR, EPJ C54,199(2008); ibid C60,249 (2009).
GLMM-08: GLMM,EPJ C57,689 (2008).

$\sqrt{s} = 14$ TeV.

	σ^{tot}	σ^{el}	σ^{SD}	σ^{DD}	σ^{SD}_{LM}	σ^{SD}_{HM}	σ^{DD}_{LM}	σ^{DD}_{HM}
Set (A)	128	37.5	12.1	4.61	8.48	3.62 (3.54)	1.15	2.06
Set (B)	126	37.3	12.4	5.18	8.22	4.24 (4.14)	1.08	2.50
Set (C)	114	33.0	11.0	4.83	5.76	5.22 (5.12)	0.47	3.15
KMR-08	91.7	21.5	19.0		4.9	14.1		
GLMM-08	92.1	20.9	11.8	6.08	10.5	1.28		

Cross sections (in mb) versus collider energy (in TeV)

energy	σ_{tot}	σ_{el}	$\sigma_{SD}^{\mathrm{low}M}$	$\sigma_{SD}^{\mathrm{high}M}$	σ_{SD}^{tot}
1.8	72.8/72.5	16.3/16.8	4.4/5.2	8.3/11.1	12.7/16.3
14	98.3/94.6	25.1/24.2	6.1/7.5	14.0/15.9	20.1/23.4
100	127.1/117.4	35.2/31.8	8.0/9.9	20.6/20.0	28.6/29.9

KMR-2010, preliminary results

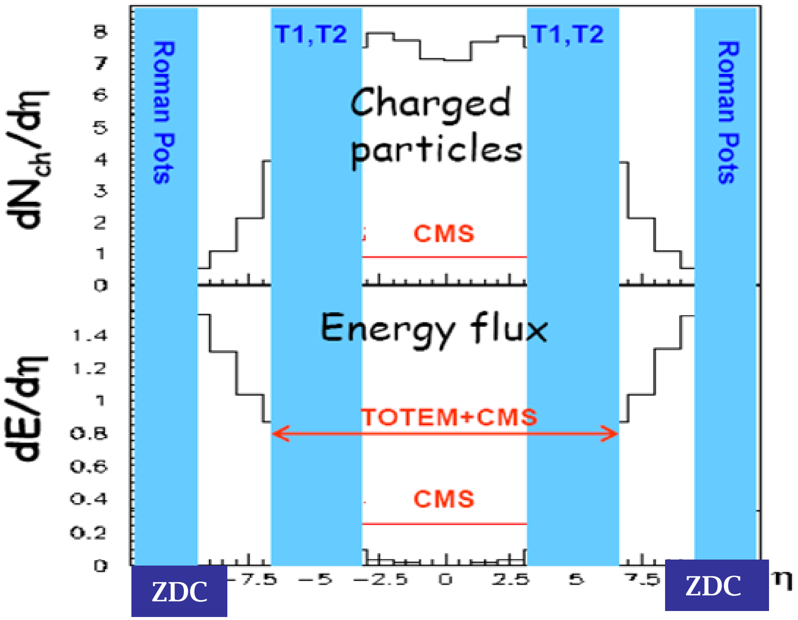
Large variation of σ^{SD}_{LM} in the range 5- 10.5mb

CMS + TOTEM ⇒ largest acceptance detector ever built at a hadron collider

BUT

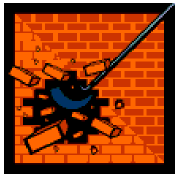
- CMS is currently 'blind' between =6.4(CASTOR) and beam rapidity y_p except ZDC (neutrals).
- T1+T2 detectors do not cover low-mass diffraction.

Even with common DAQ, we miss a few mb in inelastic cross section (without RPs).

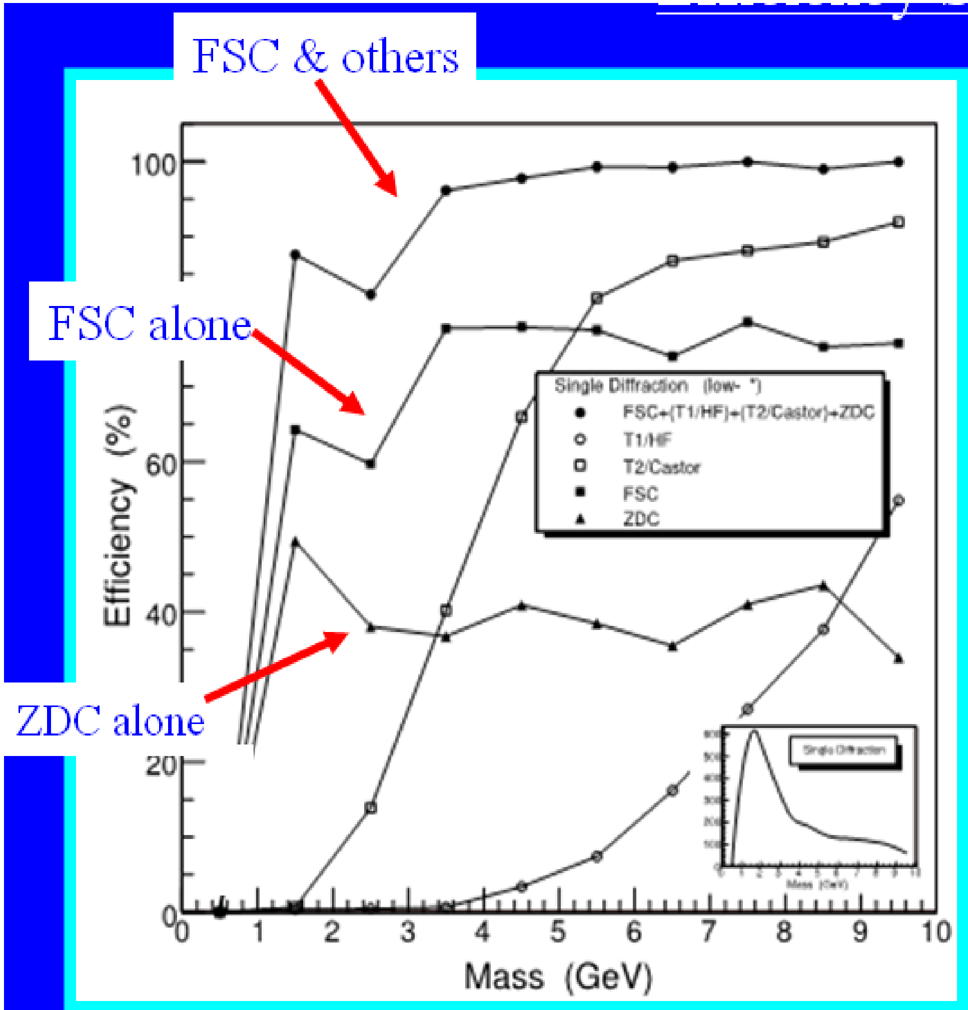


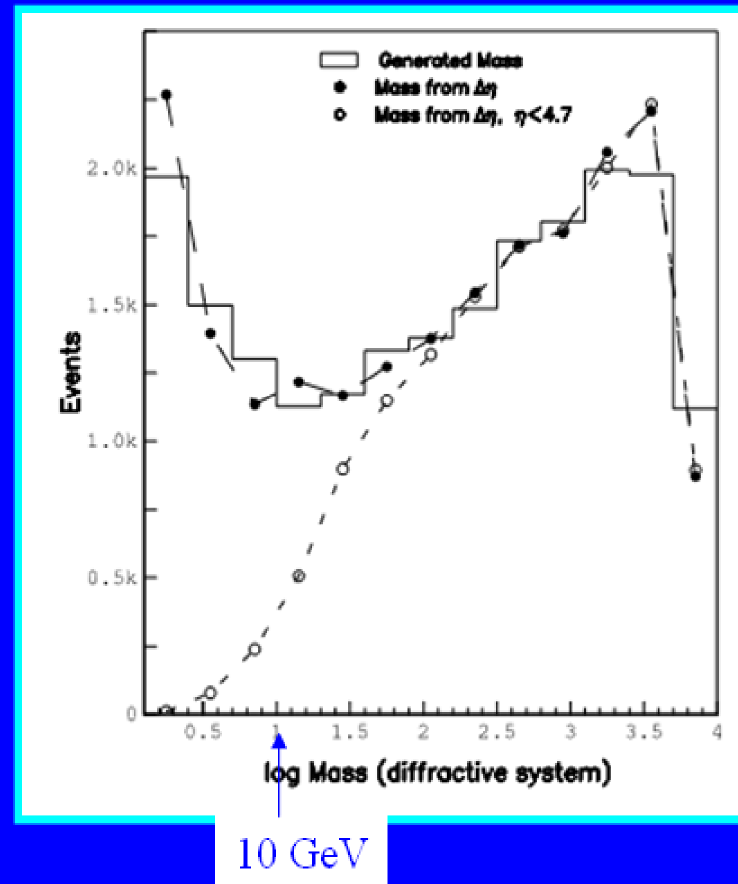
IS THERE A WAY OUT ?

Yes, an addition of Forward Shower Counters around beam pipes at CMS!



(Mike)





>4 hits in FSC or > 1 track in HF or CASTOR or ZDC(min)

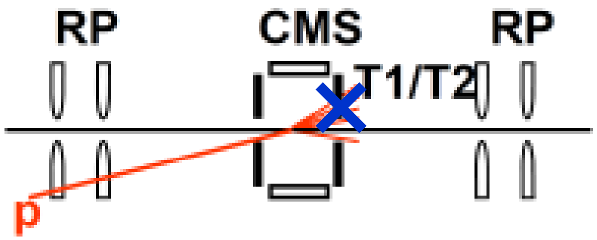
M. Albrow et al, JINST 4:P10001,2009.

Generated diffractive mass (PYTHIA/PHOJET) as log(M_X), M_X in GeV/c2, cf to calculated from rapidity gap edge:
(a) full η coverage
(b) η < 4.7 (no FSC)

Below 10 GeV/c² FSC contain most particles

If without FSC....

A possibility to probe low-mass SD : proton one side + T/1+T2- silent (+ ZDC)



(resonance decays..)

Without ZDC : missed channels: $p + p \rightarrow p + (n + \pi 's)$, $pp \rightarrow p + (p + \pi^0 's), p + (p + \pi^+ + \pi^- (+\pi^0 's)....)$

With ZDC –at least 40-50% (or more) of low-mass SD could be covered

missed $p + \pi^+ + \pi^- (+\pi^0 's)....$

Still – Low-Mass Double Diffraction is not covered (however, expected < 1-2 mb)

Backgrounds (double counting..) ??

More studies needed.

There are known unknowns.

- When the common CMS/ATLAS data taking will happen?
- When the dedicated runs with special optics (90m, 1500 m..) will take place ?
- When/if the FSC will be installed\ fully operational ?

But there may be also unknown unknowns.

N_{inel}

SUMMARY II

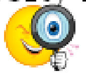
Optical theorem

- In the ideal world we would need full coverage detectors to make precise measurement.
- T1+T2 detectors **could** allow to detect about 0.8-0.9 of inelastic events.
- Because of un-instrumented region of low-mass diffraction we miss about 5-11 mb in $\sigma_{\rm inel}$

  We cannot relay on current MC models when attempting to achieve precise extrapolation to the uncovered regions.
- With beam energy increasing the un-instrumented region rises, and, thus, the uncertainties.
- Running scenarios with Roman Pot triggers might be beneficial but this requires comprehensive studies. Recall $\bar{\xi}_p = (1 - \bar{x}_p) = (M_{SD}^{LM})^2 / s \leq 2*10^{-7}$, while $\delta\ \xi_b \sim 10^{-4}$.

  Beam optics ?, Neutrons at x<0.95?

- Common data taking by CMS and TOTEM + FSC (especially T1/T2 + ZDC+FCS) will allow to measure (first time after the ISR) the low-mass SD, and thus, hopefully, to reduce the uncertainties in the inelastic rate to 1% level.
- FSC could serve as an additional luminosity monitor.



$\sigma_{\rm tot}$, $\sigma_{\rm inel}$, $\sigma^{\rm SD}$ ... ☞ very important physics quantities. Let's measure them at the LHC slides from Per Grafstrom

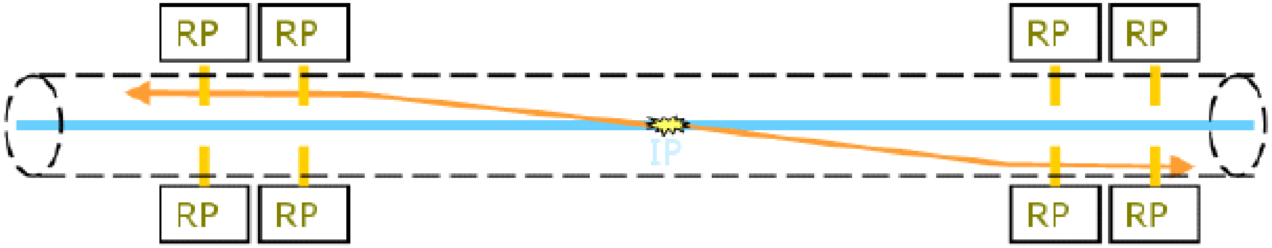
Coulomb

ALFA = Absolute Luminosity For ATLAS

(K. Hiller)

Elastic scattering at very small angles

- Measure elastic scattering at such small t-values that the cross section becomes sensitive to the Coulomb amplitude
- Effectively a normalization of the luminosity to the exactly calculable Coulomb amplitude
- No total rate measurement and thus no additional detectors near IP necessary
- UA4 used this method to determine the luminosity to 2-3 %

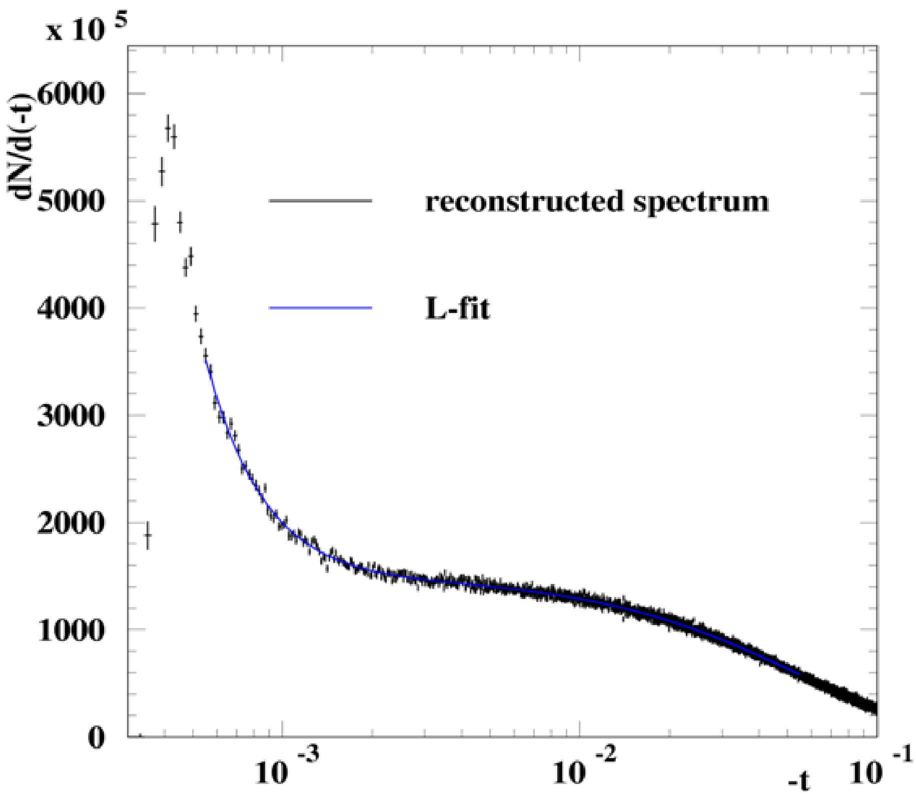


ALFA can also measure the absolute luminosity using optical theorem method if/when σ_{tot} is known

L from a fit to the t-spectrum

$$\frac{dN}{dt} = L\pi\left|F_C + F_N\right|^2$$

$$= L\left(\frac{4\pi\alpha^2(\hbar c)^2}{|t|^2} - \frac{\alpha\rho\sigma_{tot}e^{-B|t|/2}}{|t|} + \frac{\sigma_{tot}^2\left(1+\rho^2\right)e^{-B|t|}}{16\pi(\hbar c)^2}\right)$$



Simulating 10 M events,
running 100 hrs
fit range 0.00055-0.055

	input	fit	error	correlation
L	8.10 10^{26}	8.151 10^{26}	1.77 %	
σ_{tot}	101.5 mb	101.14 mb	0.9%	-99%
B	18 Gev^{-2}	17.93 Gev^{-2}	0.3%	57%
ρ	0.15	0.143	4.3%	89%

large stat.correlation between
L and other parameters

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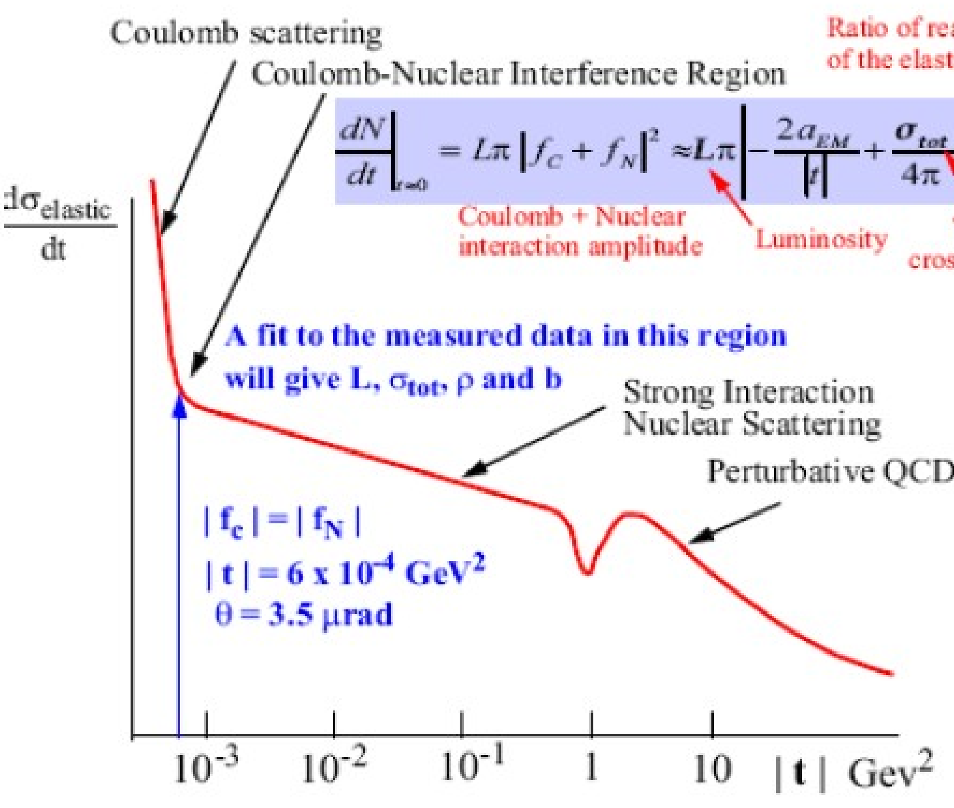
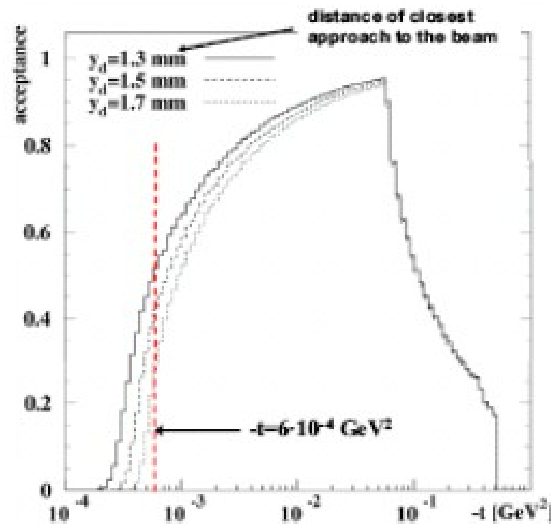
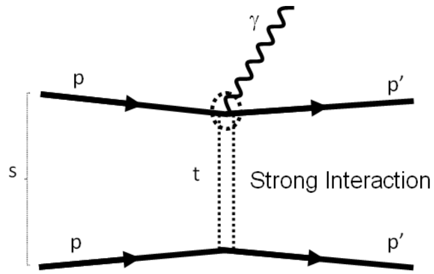
Elastic scattering at very small angles





Commissioning starting after Christmas shut down.

Soft photon radiation accompanying elastic pp- scattering.



R.Orava et al, arXiv:1007.3721 ;
H.Gronquist et al, arXiv:1007.3721

Detect 50 – 500 GeV photons at ~ 0 degrees

$$\Gamma_\gamma = \frac{2\alpha_{em}}{3\pi}\frac{\langle p_t^2\rangle}{m^2}\frac{dk}{k}.$$

- small t ⇒ theor. uncertainties minimal
- ⇒ direct relation between the photon spectra and $\sigma(pp)_{el}/B$ ~ $(\sigma_{el}/\sigma_{tot})^2$
- bremsstrahlung cross section is large: ~ 0.18 x 10^{-3} of σ_{el}
- theor. uncertaint. in $(\sigma_{el}/\sigma_{tot})^2$ are large: 0.05-0.09 or more (0.45- TT-03).
- $N_{\gamma\gamma}/N_\gamma \sim 1/B$; $\frac{d\sigma_{el}^{pp}}{dt} \longrightarrow \sigma_{el}^{pp} B\exp(-B|t|)$

(in principle, a Lumi inependent way to measure eff. elastic slope B)..

Detection advantages, but rate low.

- **Bremsstrahlung photons close to 0 degrees – can be used for alignment (RP's, ZDC), luminosity monitoring.**

BFK-1966

Experience at ee colliders (VEP-I,VEPP-II, ACO, ADONE) and at HERA

ROAD MAP

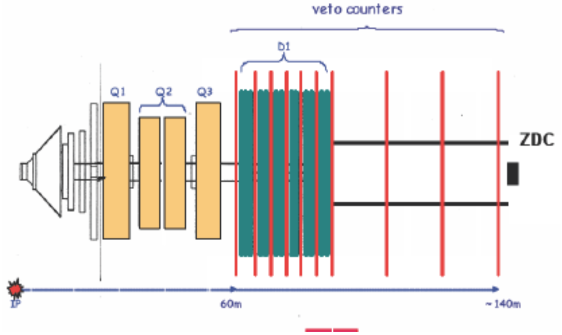
- Use luminosity from the W/Z standard candle measurements or from the beam scan (Van der Meer) $\Rightarrow$ model-independent way to measure $(\sigma_{el} / \sigma_{tot})^2$
- The ZeroDegreeCalorimeter (ZDC) for detecting the bremsstrahlung gammas - the Forward Shower Counters (FSC) to veto backgrounds.
- The set-up of the proposed measurement with k=50-500 GeV and for 3.5 x 3.5 TeV and/or 5 x 5 TeV.

Triggers and Backgound

Slide from H. Gronquist- ISMD-2010

- Main background consists of photons emitted in ineastic diffractive events.
  Non-diffractive events constitute a secondary background.
- For the chosen energy range 50-500 GeV the backgound-to-signal ratio is estimated to be $< 5\%$

- To reduce background further, Forward Shower Counters, FSCs, can be added closely surrounding the beam pipes, at $z \in (60, 120)$m from the interaction point



Luminosity, if $\sigma_{\rm el}$ and B are known

Why measure total and diffractive cross sections?

2 slides from A. Martin (Diffraction 2000)

Intrinsic interest. The LHC should reach, for the first time, sufficiently HE to distinguish between the different theoretical asymptotic scenarios for HE interactions.

(currently available data not decisive)

In HE pp collisions about 40% of σ_{tot} comes from diffractive processes, like elastic scatt., SD, DD. Need to study diffraction to understand the structure of σ_{tot} and the nature of the underlying events which accompany the sought-after rare hard subprocesses. (Note the LHC detectors do not have 4π geometry and do not cover the whole rapidity interval. So minimum-bias events account for only part of total $\sigma_{inelastic}$.)

Study needed to estimate the survival probabilities of LRG to soft rescattering.
Recall "hard" exclusive diffractive processes (e.g., pp → p + Higgs + p) can be New Physics signals

Needed so as to understand the structure of HE cosmic ray phenomena (e.g. Auger experiment).

Finally, the hope is that a study of diffraction may allow the construction of a MC which merges "soft" and "hard" HE hadron interactions in a reliable and consistent way.

Recall that the two Tevatron results for σ_{tot} differ by 12%.

V. Overall conclusions

- We briefly discussed some most popular methods for ‘indirect’ luminosity determination, focussing on potential theoretical uncertainties and the ways how to reduce these.

- On the theory side there seems to be no showstoppers for the dimuon QED production.. Can be performed during the normal collision data taking. However the cross section is small , thus problems with keeping small stat. error on Lumi.

- Optical theorem approach is a potentially very powerful method for Luminosity Calibration. However, for a precise measurement of elastic rate we need special optics, while a very accurate determination of N_{inel} would require a combination of TOTEM with CMS (in particular, ZDC) +FSC. More studies needed.

- $\sigma_{\rm tot}$, $\sigma_{\rm inel}$, $\sigma^{\rm SD}$ are very important physics quantities. **Should be measured at LHC!**

  (TOTEM +CMS, ALFA)

- Further development of theoretical models for HE soft hadron interaction is an important goal as well as creation of “all purpose” Monte Carlo models, tuned to describe various features of elastic and diffractive processes and multi-particle production.


THANK
YOU

BACKUP

(S.Ostapchenko- 2010)

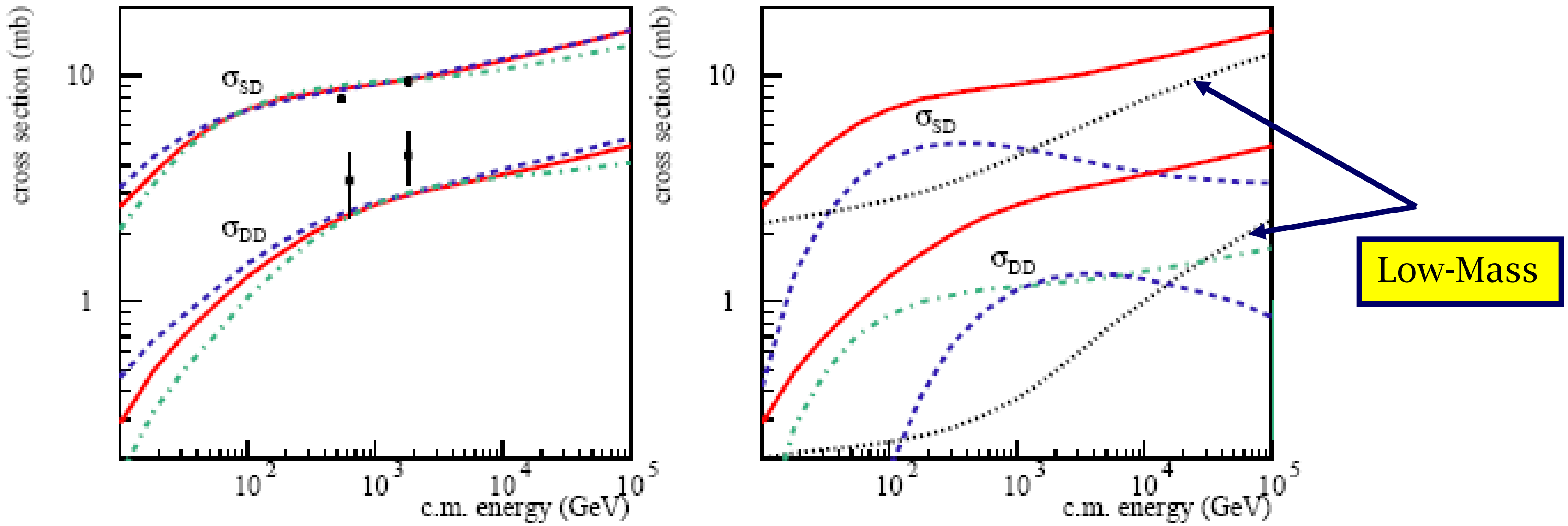


Figure **14**: Left: single and double diffraction proton-proton cross sections ($\sigma^{SD}(M_X^2/s < 0.15)$, $\sigma^{DD}(y_{gap}^{(0)} \geq 3)$), as calculated using the parameter sets (A), (B), and (C) - solid, dashed and dot-dashed lines correspondingly, compared to CDF data [21, 22]. Right: $\sigma^{SD}(M_X^2/s < 0.15)$ and $\sigma^{DD}(y_{gap}^{(0)} \geq 3)$) calculated using the parameter set (A) - solid lines, partial contributions of high and low mass diffraction: $\sigma_{HM}^{SD/DD}$ and $\sigma_{LM}^{SD/DD}$ - dashed and dotted lines correspondingly, σ_{LHM}^{DD} - dot-dashed line.

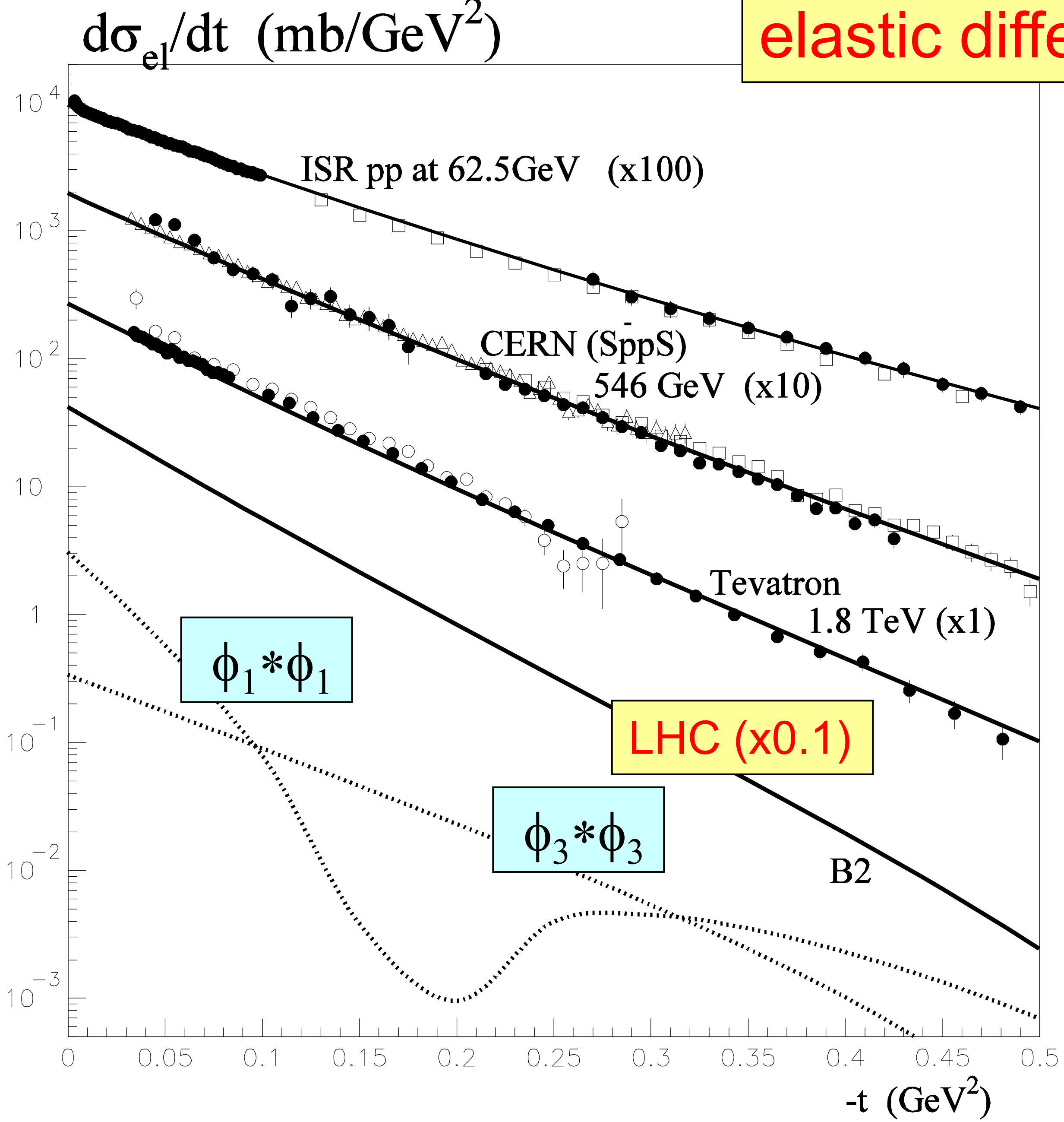
		σ^{tot}	σ^{el}	σ^{SD}	σ^{DD}	σ_{LM}^{SD}	σ_{HM}^{SD}	σ_{LM}^{DD}	σ_{HM}^{DD}	σ_{LHM}^{DD}	σ^{DPE}
	Set (A)	128	37.5	12.1	4.61	8.48	3.62 (3.54)	1.15	2.06	1.40 (1.37)	0.10 (0.05)
	Set (B)	126	37.3	12.4	5.18	8.22	4.24 (4.14)	1.08	2.50	1.60 (1.56)	0.14 (0.07)
	Set (C)	114	33.0	11.0	4.83	5.76	5.22 (5.12)	0.47	3.15	1.22 (1.19)	0.19 (0.09)
KMR-09	Ref. [7]	91.7	21.5	19.0		4.9	14.1				
GLMM-09	Ref. [9]	92.1	20.9	11.8	6.08	10.5	1.28				

For illustration : KMR-2007

(Work currently in progress)

	Tevatron	LHC	$\sqrt{s} = 10^5$ G
σ_{tot}	74.0 (73.9)	88.0 (86.3)	98.0 (94.3
σ_{el}	16.3 (15.1)	20.1 (18.1)	22.9 (20.0
σ_{SD}	10.9 (12.7)	13.3 (16.1)	15.7 (17.7
$\sigma_{\text{SD}}^{\text{low}M}$	4.3 (6.0)	5.1 (7.0)	5.7 (7.9)
$\sigma_{\text{SD}}^{\text{high}M}$	6.5 (6.7)	8.1 (9.1)	10.0 (9.8
σ_{DD}	7.2 (8.7)	13.4 (12.9)	17.3 (21.1
$\sigma_{\text{DD}}^{\text{low}M}$	0.2 (0.5)	0.2 (0.5)	0.2 (0.6)
$\sigma_{\text{DD}}^{\text{high}M}$	4.5 (4.0)	9.3 (5.9)	11.7 (12.9
$\sigma_{\text{DD}}^{(\text{high}M*\text{low}M)}$	2.1 (3.6)	2.9 (5.2)	3.8 (6.0)
$\sigma_{\text{DD}}^{(\text{SD}*\text{SD})}$	0.4 (0.7)	1.0 (1.3)	1.6 (1.6)

elastic differential $d\sigma/dt$



KMR-2009

S. Ostapchenko, Phys.Rev.D81:114028,2010.

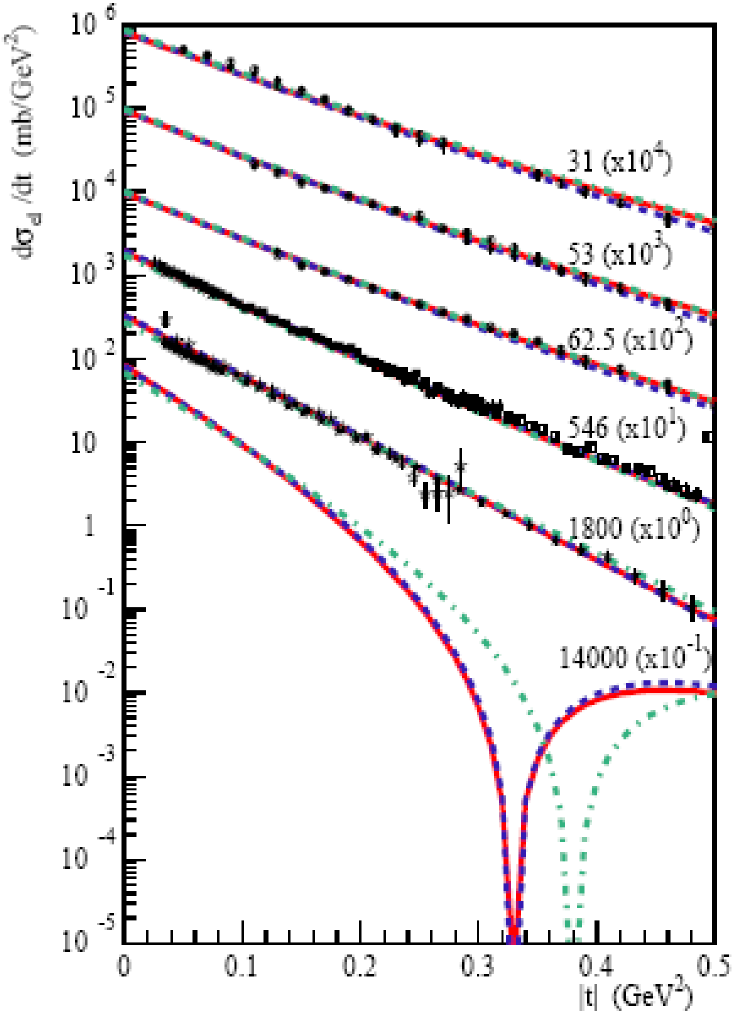


Figure **13**: Calculated differential elastic proton-proton cross section for different $\sqrt{s}$ in GeV (as indicated in the plot) compared to experimental data [23, 24, 25, 26, 27]. The meaning of the lines is the same as in Fig. 12.

SUMMARY

We propose to install a set of scintillation counters around both outgoing beam pipes at CMS, ~ 60m – 100 m

Physics, especially diffractive in no-PileUp interactions

(a) As veto in Level 1 diff. triggers to reduce useless pile-up events.
(b) To detect rapidity gaps in diffractive events (p or no-p).
(c) Measure low mass diffraction and double pomeron exchange.
(d) Measure σ_{INEL} (if luminosity known, e.g. by Van der Meer)
(e) Help establish exclusivity in central exclusive channels

Beam monitoring etc, parallel uses:

(f) To monitor beam halo on incoming and outgoing beams.
(g) To test forward flux simulations (MARS etc.)
(h) Additional Luminosity monitor.
(i) Info on radiation environment for future (?) proton spectrometers

MORE PHYSICS

LOW COST

ZERO RISK*

*Subject to support approval by LHC

The Compact Muon Solenoid Experiment

CMS Note

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

July 19, 2010

Physics and Beam Monitoring with Forward Shower Counters (FSC) in CMS

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[b] Also at Iowa State University

[c] Some authors are not members of CMS, but have contributed to this note.

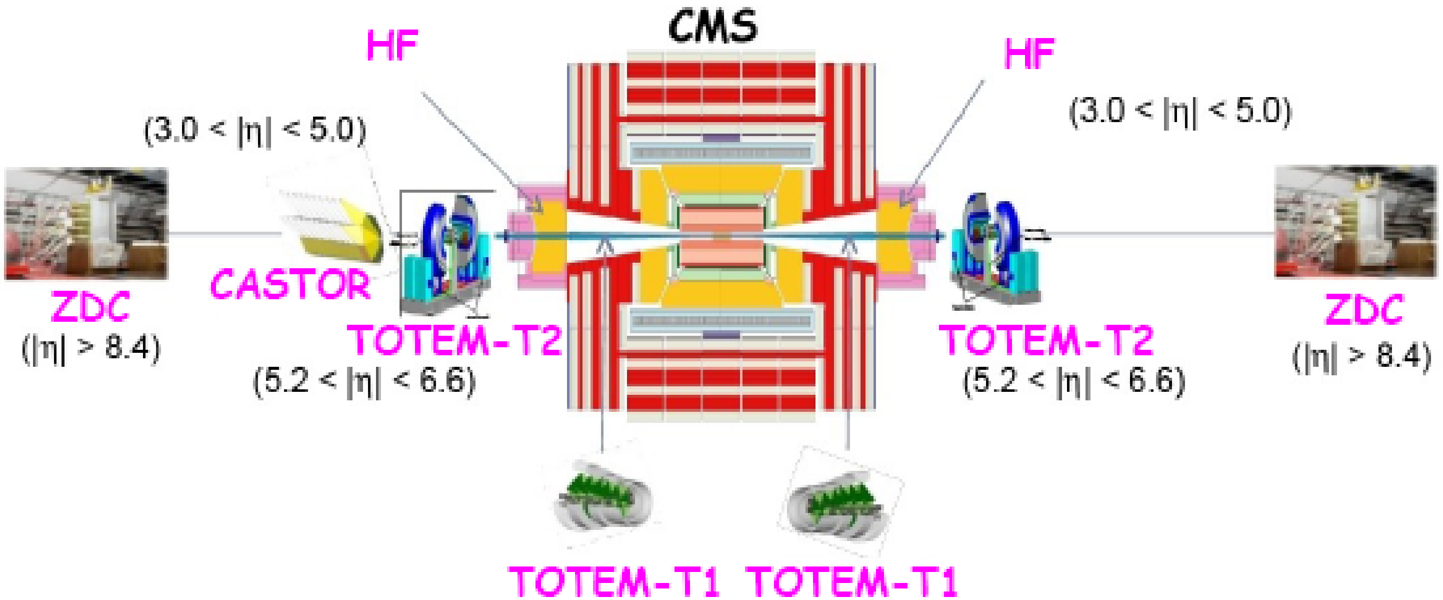
CMS NOTE-2010/015

Approved by CMS MB
for Jan-Feb 2011 installation.

"Limited approval" :
Go ahead without detracting from necessary shutdown work.

Most value is 2011 running
& when <n/x> < ~ 5
(Do not expect to use > 2012)

CMS Forward Detectors

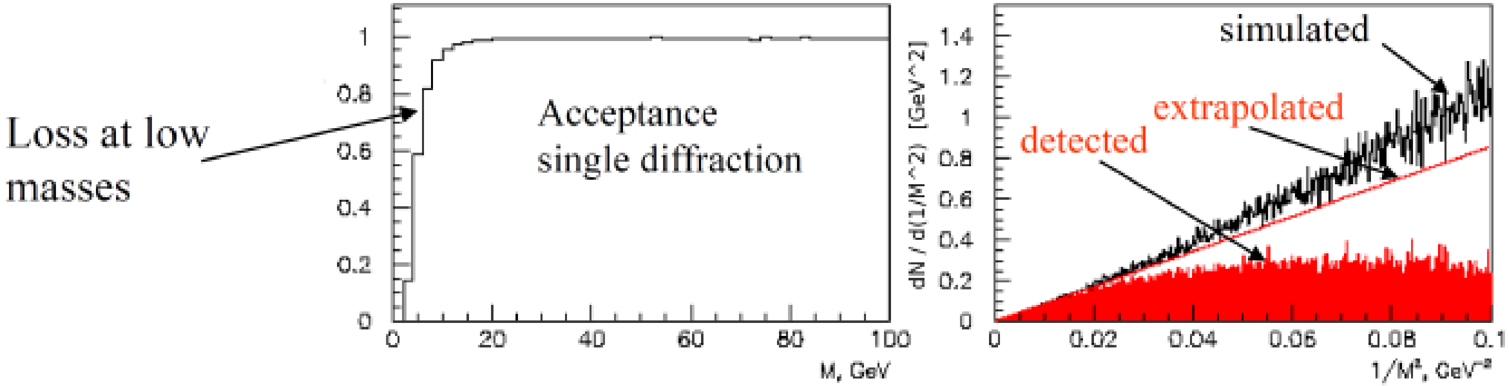


- CMS integrated detector: HF, CASTOR, ZDC
  → Cerenkov sampling calorimeters
- TOTEM + FP420: additional forward detectors around IP5 !

unprecedented calorimetric coverage !

Inelastic event rate N_{inel}

- Extrapolation of diffractive cross-section to large $1/M^2$ assuming $\frac{d\sigma}{dM^2} \approx \frac{1}{M^2}$ to estimate unseen events

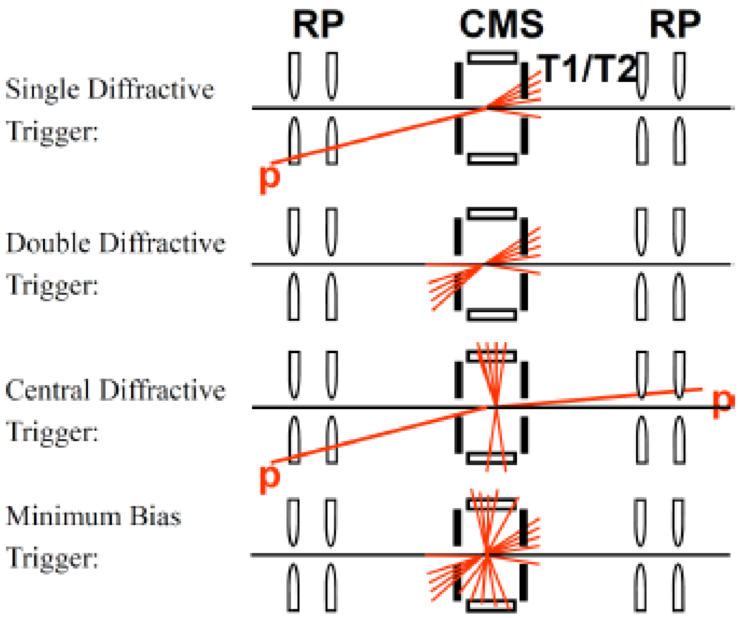


- NB! model+MC+detector simulation needed, simple geometrical acceptance not sufficient!

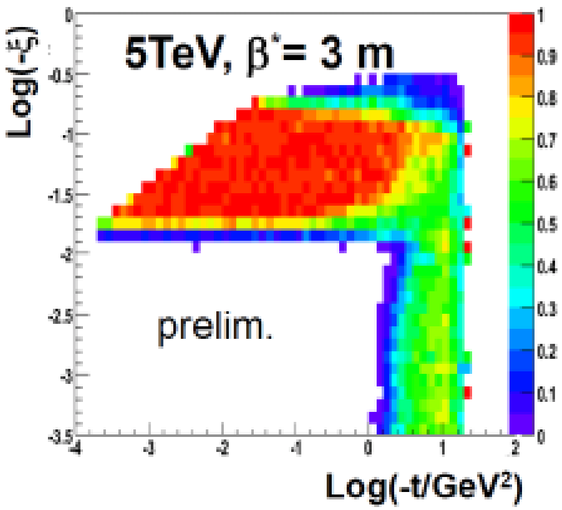
	σ [mb]	trigger loss [mb]	systematic error after extrapolation [mb]
Non-diffractive min bias	58	0.06	0.06
Single diffractive	14	3	0.6
Double diffractive	7	0.3	0.1
Central diffractive	1	0.2	0.02
Total	80	3.6	0.8

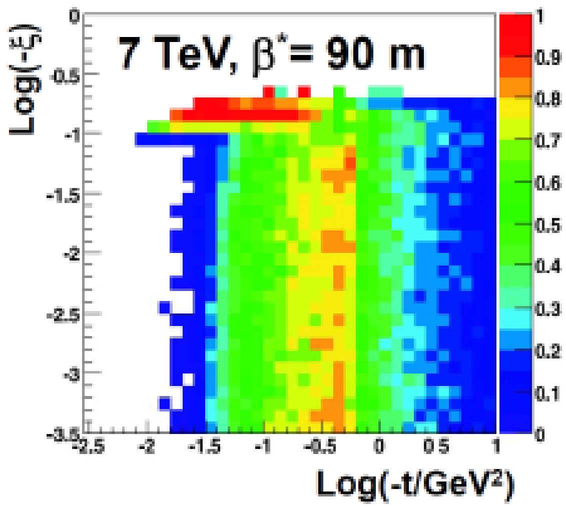
Inelastic event rate N_{inel}

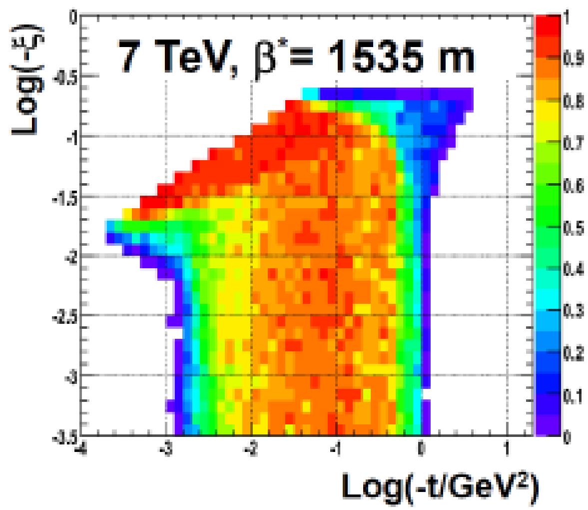
- N_{inel} measured by inelastic detectors T1 and T2
- to suppress background:
  - primary vertex reconstruction with T1 and T2
  - use double arm trigger whenever possible
- trigger on non colliding bunches: to measure beam-gas + halo rates



Diffractive protons' acceptance ($\sqrt{s} = 10, 14, 14$ TeV)







low β^*

low β^* : 0.5 – 2 m, L ≈ 10^{33} cm^{-2}s^{-1}

early running: E = 5TeV, β^* = 3 m

elastic acceptance

2 GeV^2 < -t < 10 GeV^2

resolution

$\sigma(\Theta)$ = 16 – 30 μrad

$\sigma(\xi)$ = 1 – 6 · 10^{-3}

-ξ > 2 % seen

(hard) diffraction, high |t| elastic scattering

β^* = 90 m

L ≈ 10^{30} cm^{-2}s^{-1}

elastic acceptance

3 · 10^{-2} GeV^2 < $-t_y$ < 10 GeV^2

resolution

$\sigma(\Theta)$ = 1.7 μrad

$\sigma(\xi)$ = 6 – 15 · 10^{-3}

all ξ seen, universal optics

diffraction, mid |t| elastic scattering, total cross-section

β^* = 1535 m

L ≈ 10^{28} – 10^{29} cm^{-2}s^{-1}

elastic acceptance

2 · 10^{-3} GeV^2 < $-t_y$ < 0.5 GeV^2

resolution

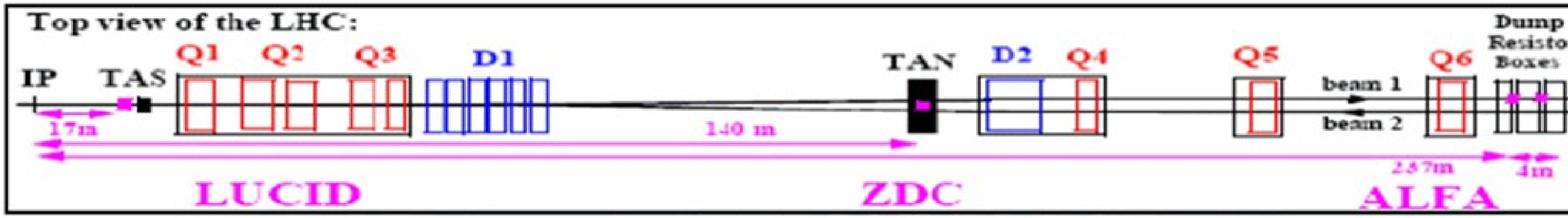
$\sigma(\Theta)$ = 0.3 μrad

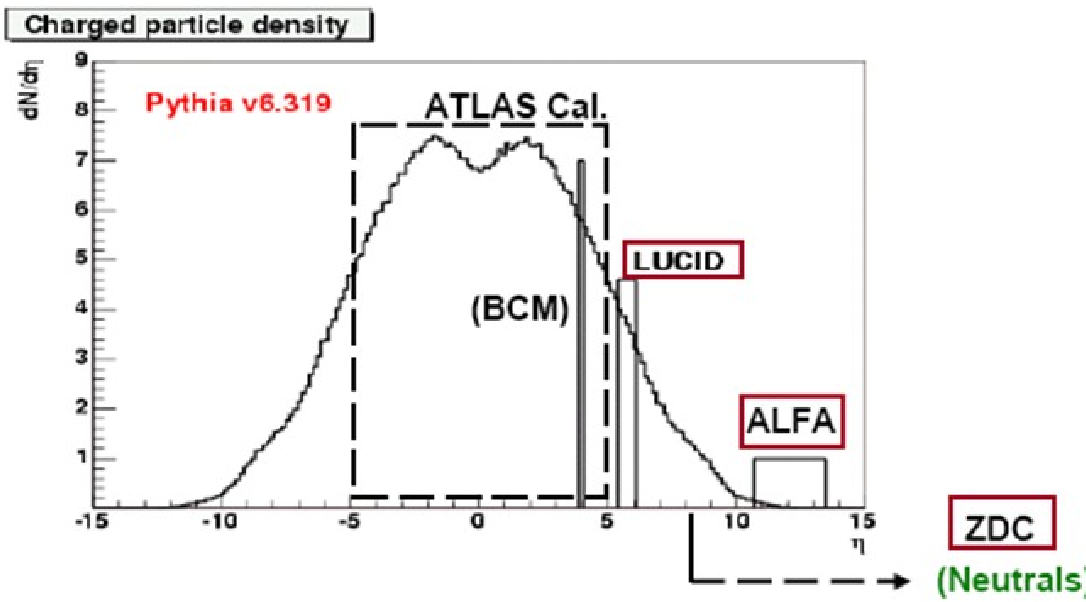
$\sigma(\xi)$ = 2 – 10 · 10^{-3}

all ξ seen

total cross-section, low |t| elastic scattering

ATLAS FORWARD DETECTORS





- LUCID, Cherenkov integrating detector
- ZDC, Zero degree calorimeter
- ALFA, Scintillating fiber tracker (Roman Pot)