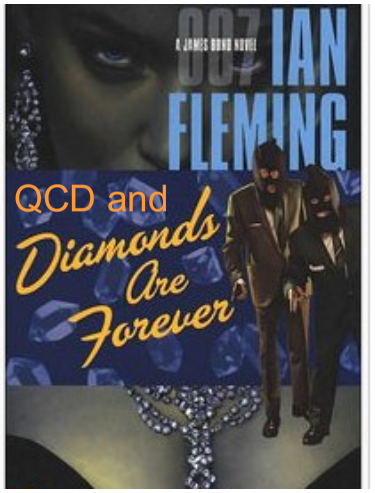
DIFFRACTION AND FORWARD Physics
Today and tomorrow

(spiced with personal flavour)

V.Khoze (Durham)



1.Diffraction as a tool for understanding and developing QCD

Theory/Phenomenology : J.Andersen, S.Brodsky, E.Levin, K.Goulianos.

Experiment: RHIC data W. Guryn, S.White ,S.Klein.

2. Diffraction and forward proton tagging at the LHC as a search tool for new phenomena.

B.Cox, M. Albrow, H.Kowalski, K.Eggert, K. Piotrzkowski, C.Royon

Excellent talks by the world experts, a wealth of new interesting results

QCD Theory

S. Brodsky – Hard Diffraction from parton rescattering
E. Levin, - (mini) review on saturation
J. Andersen - (mini) review on BFKL

Experiments at RHIC

W.Guryn , AN measurement in the CNI region… (pp2pp@ RHIC)

S.White - Recent resullts on inelastic diffraction (PHENIX@RHIC)

S.Klein - Photoproduction at hadron colliders … (STAR@RHIC)

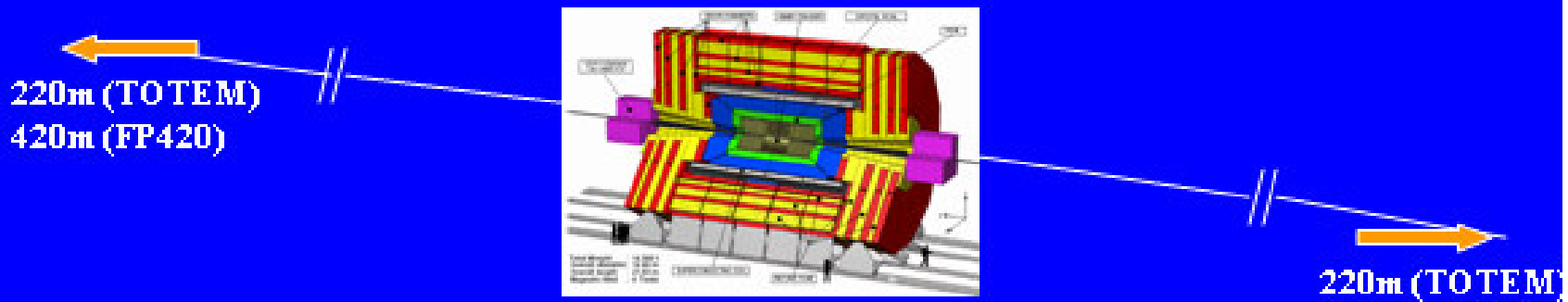
..

Central Exclusive Production in pp (II): LHC

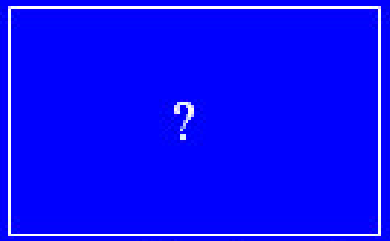
$LHC: \sqrt{s} = 14,000\ GeV$

$pp \rightarrow p \quad W^+W^- \quad p$

$pp \rightarrow p \quad Z^\circ Z^\circ \quad p$



Protons ***coherently*** scattered!
Searching for Higgs
and other structures.
Anomalous EWK-QCD couplings



M.Albrow ⇨ nice introduction to Double Pomeron Physics at the LHC

Several more talks at this meeting about this:

Spencer Klein: Photoproduction at hadron colliders
Brian Cox: Forward proton tagging ...
Henry Kowalski: Hard and soft diffraction
Karsten Eggert: TOTEM
Dino Goulianos, Multigap diffraction at the LHC.
Krzysztof Piotrzkowski: Two photon physics
Christophe Royon: Diffractive production of massive states

This is going to be a very exciting topic at the LHC,
whether or not the Higgs is in reach. If (it exists and) we see it
this will be most important (mass, quantum numbers, properties ...)

$pp \to \{p\pi\ \pi^+\ \pi^-p\}$ at ISR

$pp \to \{p\ W^+W^-\ p\}$ at LHC ?

M. Albrow

Forward Proton Taggers as a gluonic Aladdin's Lamp

(rich Old and New Physics menu)

- Higgs Hunting (the LHC 'core business') B.Cox, M.Albrow, H.Kowalski, C.Royon
- Photon-Photon, Photon - Hadron Physics. S.Klein , K.Piotrzkowski , S. White, C.Royon, KMR-02
- 'Threshold Scan': 'Light' SUSY , tt... KMR-02 , C.Royon
- Various aspects of Diffractive Physics (soft & hard). K.Eggert, H.Kowalski, K Goulianos

(strong interest from cosmic rays people)

- Luminometry KMOR-01 , K.Piotzkowski ,K.Eggert
- High intensity **Gluon Factory**. KMR-00, KMR-01

QCD test reactions, dijet luminosity monitor H. Kowalski, K.Eggert

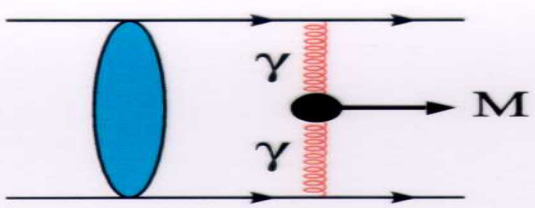
- Searches for new heavy gluophilic states KMR-02

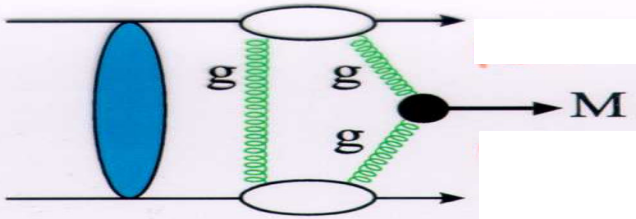
FPT

☞ Would provide a unique additional tool tc complement the conventional strategies at the LHC and ILC.

FPT ▶ an additional physics menu in ILC@LHC

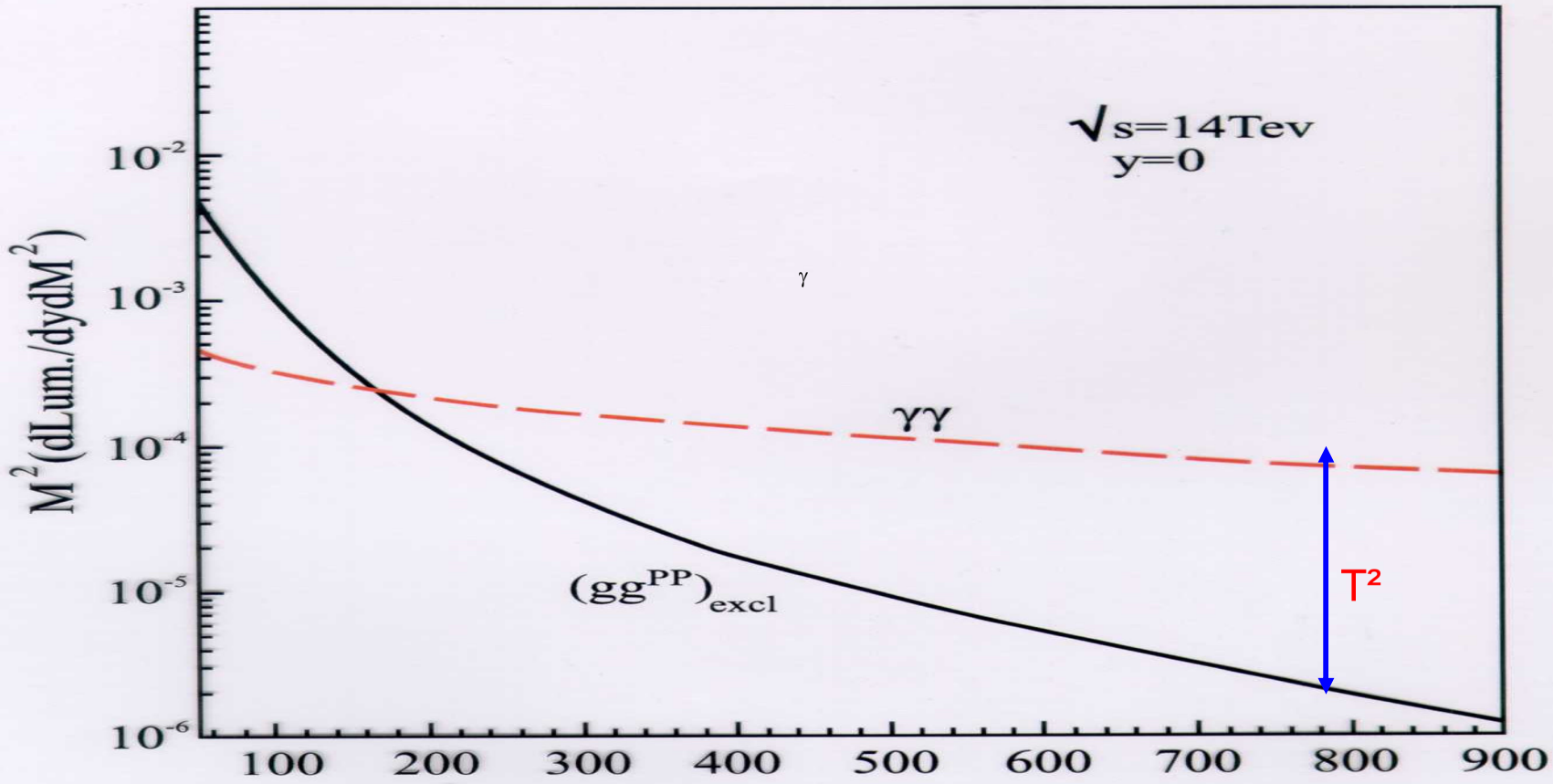
Higgs is only a part of a broad diffractive program@LHC





'New Heavy' States M

$\sigma = L(M^2,y)\ \hat{\sigma}(M^2)$



$(S^2)\ \gamma\ \gamma = 0.86$ (KMR-02)

$\alpha_s^2/8 \longrightarrow \alpha^2$

we should not underestimate photon fusion !

K..Piotrzkowsi, S..White, S.Klein

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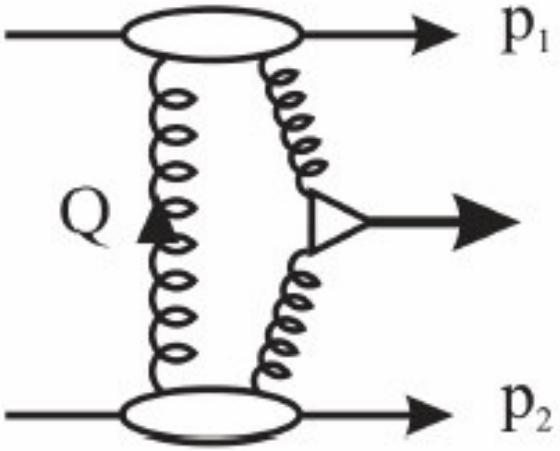
Brian Cox

(the case for FP420)

Forward Physics at the LHC



- Selection rules mean that central system is (to a good approx) 0^{++}
- If you see a new particle produced exclusively with proton tags you know its quantum numbers
- CP violation in the Higgs sector shows up directly as azimuthal asymmetries
- Proton tagging may be the discovery channel in certain regions of the MSSM
- Tagging the protons means excellent mass resolution (~ GeV) irrespective of the decay products of the central system
- Unique access to a host of interesting QCD

Very schematically it's a glue – glue collider where you know the beam energy of the gluons - source of pure gluon jets - and central production of any 0^{++} state which couples strongly to glue is a possibility …

The advantages of CED Higgs production

- Prospects for high accuracy mass measurements
(Γ_H and even lineshape in some MSSM scenarios)
- Valuable quantum number filter/analyzer.

(0++ dominance ;C , P-even)

☹ difficult or even impossible to explore the light Higgs CP at the LHC conventionally. H.Kowalski, B.Cox.

(selection rule - an important ingredient of pQCD approach,
otherwise, large $|J_z|=2$ …effects, $\sim(pt/Qt)^2$ ☝) A. Levy, J. Pumplin -95

- H ->bb 'readily' available

(gg)CED ⊘→ bb LO (NLO,NNLO) BG's -> studied

SM Higgs S/B~3(1GeV/ΔM)

complimentary information to the conventional studies(also ▪ ▪).

For some (troublesome) areas of the MSSM parameter space may become a discovery channel ☝

- **H →WW*/WW - an added value** M.Albrow, B.Cox

especially for SM Higgs with M≥ 135GeV, MSSM at low tan β

- New leverage -proton momentum correlations
(probes of QCD dynamics, pseudoscalar ID,
CP violation effects) KMR-02; J.Ellis et al -05 H.Kowalski, B.Cox

☞ LHC : 'after discovery stage', Higgs ID……

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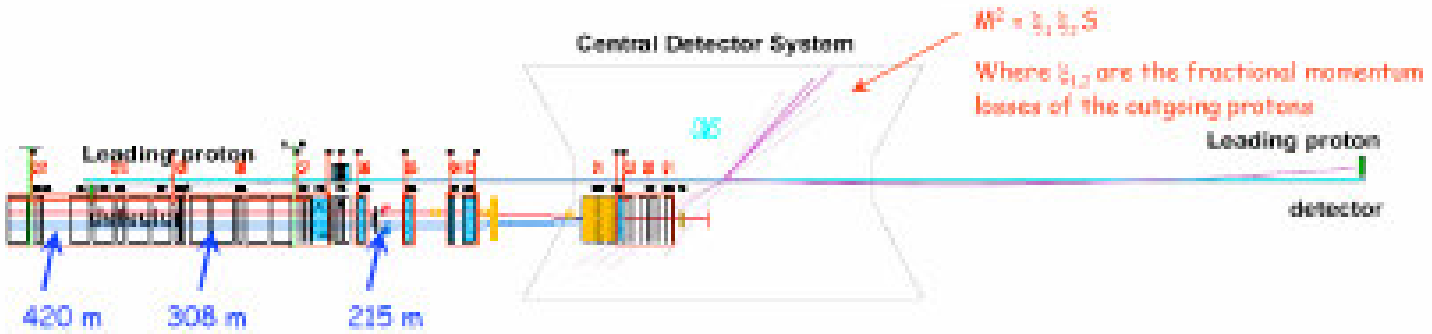
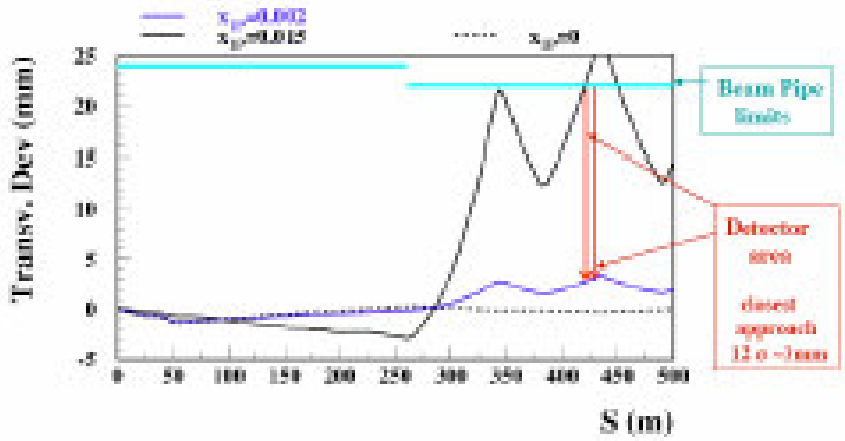
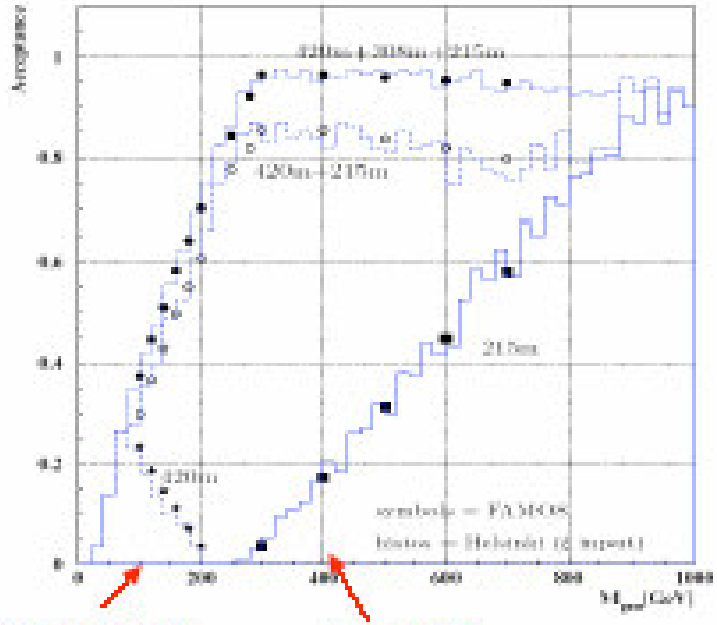
Central Production at LHC







$x_{IP} \sim 0.007$ $x_{IP} \sim 0.03$

Plots from Henri Kowalski and TOTEM (Helsinki group)

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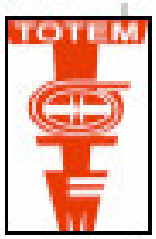
The case for FP420 R&D project

- If you have a sample of Higgs candidates, triggered by any means, accompanied by proton tags, it is a 0^{++} state.
- Standard model Higgs will be seen in WW / WW* modes. b decay mode opens up if mass resolution and trigger acceptable, with S/B > 1
- In certain regions of MSSM parameter space, S/B > 20, and double tagging is THE discovery channel
- In other regions of MSSM parameter space, explicit CP violation in the Higgs sector shows up as e.g. azimuthal asymmetry in the tagged protons -> direct probe of CP structure of Higgs sector at LHC
- "Exclusive double diffraction may offer unique possibilities for exploring Higgs physics in ways that would be difficult or even impossible in inclusive Higgs production" J. Ellis et. al.
- The commissioning phase will produce a wealth of interesting physics, including detailed probe of gap survival / underlying event



TOTEM Physics

- σ tot
- elastic scattering
- diffraction (together with CMS)

Karsten Eggert
CERN, PH Department

on behalf of the

TOTEM Collaboration

http://totem.web.cern.ch/Totem/

Politecnico di Bari and Sezione INFN
Bari, Italy
Case Western Reserve University
Cleveland, Ohio,USA
Institut für Luft- und Kältetechnik,
Dresden, Germany
CERN, Geneva, Switzerland
Università di Genova and Sezione INFN
Genova, Italy
University of Helsinki and HIP,
Helsinki, Finland
Academy of Sciences,
Praha, Czech Republic
Penn State University
University Park, USA
Brunel University, Uxbridge, UK

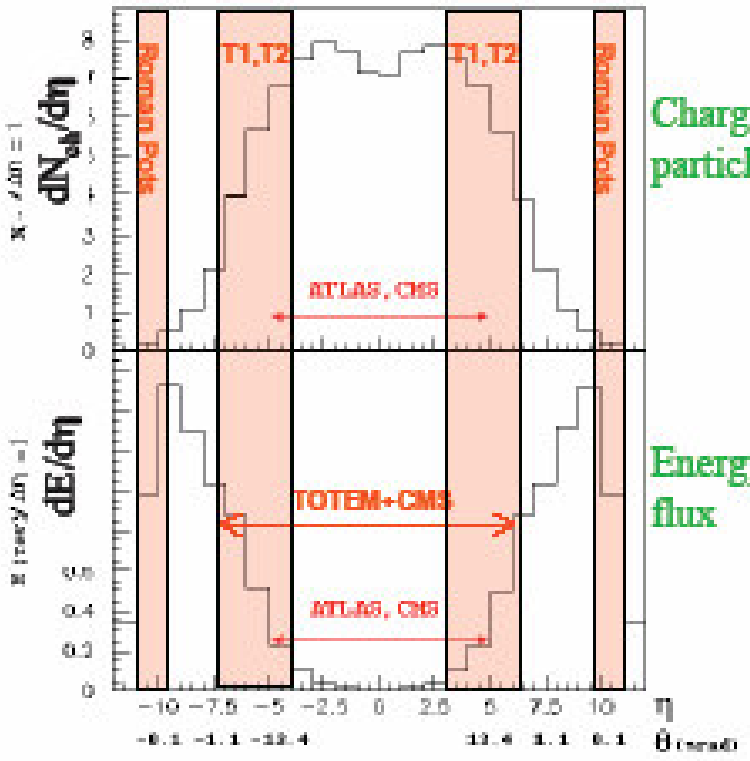
TOTEM TDR is fully approved by the LHCC and the Research Board

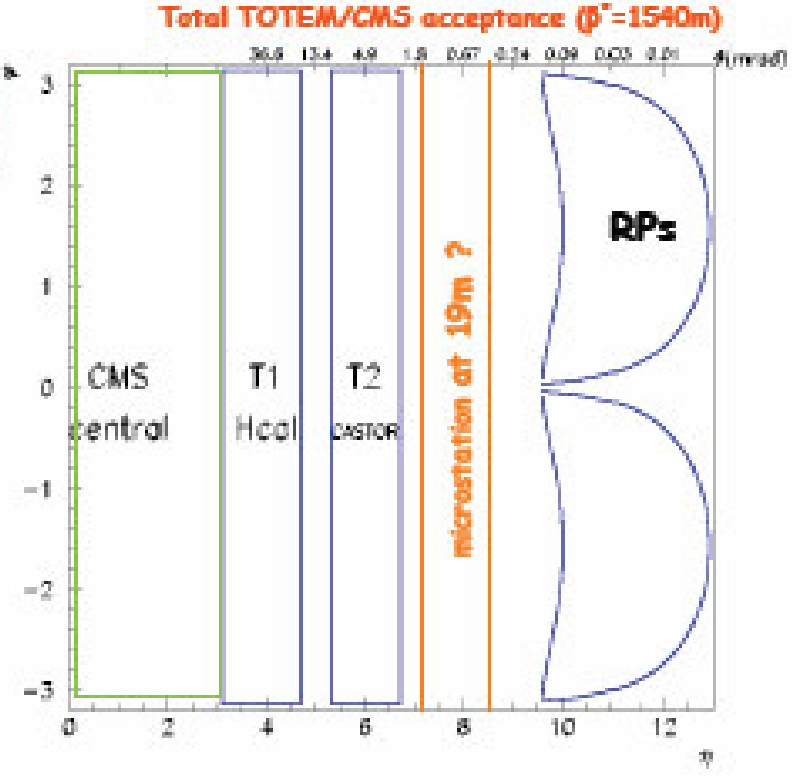
DIS 2005, Madison,Wisconsin,U.S.A.

CMS + TOTEM: Acceptance

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

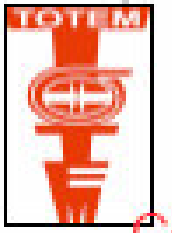
> 90 % of all diffractive protons are detected
10 million min. bias events, including all diffractive processes, in a 1 day run with $\beta^* = 1540$ m





K.Eggert/CERN

⇨ bj's FAD ideas

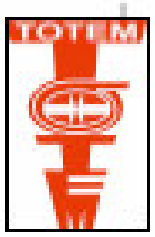


Conclusion on new optics (β^*=172 m) - preliminary

- Luminosity of 0.5 x 10^{32} cm^{-2} s^{-1}
- About 65% of diffractive protons are seen in the RP at 220 m
- ξ resolution of 4 10^{-4}
- θ resolution of few μrad

Future:

- more detailed studies on resolution
- further optimization towards higher luminosities



Conclusions

Measure total cross-section σ_{tot} with a precision of 1 %
$\mathcal{L}$ = ~10^{28} cm^{-2} s^{-1} with β^* = 1540 m

Measure elastic scattering in the range $10^{-3} < t < 8$ GeV^2 (slope is v. important)

With the same data study of soft diffraction and forward physics:
- ~ 10^7 single diffractive events
- ~ 10^6 double Pomeron events

With β^* = 1540 m optics at $\mathcal{L} = 2 \times 10^{29}$ cm^{-2} s^{-1} :
semi-hard diffraction (p_T > 10 GeV)

With β^* = 170 m optics (under study) at $\mathcal{L}$ ~ 0.5 10^{32} cm^{-2} s^{-1}:
hard diffraction and DPE

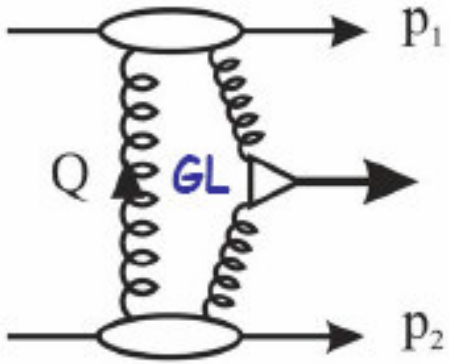
Study of rare events (Higgs, Supersymmetry,...) with β^* = 0.5 m
using eventually detectors in the cold region (420m)

TOTEM and CMS will write a common physics LOI in 2005

Measurement of Hard and Soft Diffraction at the LHC

Towards a DESY LOI

Henri Kowalski



Final state can be fully *controlled* by measurement
→ high measurement precision

Predominant production of *neutral, scalar states*
→ sensitive to new physics

X-sections for new physics in low x region depend on *Gluon Luminosity* which is precisely determined through measurement of *QCD jet-jet* reaction at LHC and HERA data input

K. Eggert

Byproduct: Clean QCD measurements in new, non-trivial, regions

towards the real-life experimental challenges

Challenge of Diffractive DPE Measurement at high luminosity

- acceptance
- calibration and alignment
- stability of measurement conditions
- high resolution in x_{IP}
- backgrounds
- multiple events

Specially designed forward detectors

x_{IP} - 0.2 — 1.5 % t - 0 — O(10) GeV^2

✳ No pile-up measurement scenarios at full lumi

H. Kowalski

SUMMARY

420m counters

pp -> pp jet+jet - $O(10^6)$ events under no pileup conditions are expected
Events are fully contained in the detector ⟹ high measurement precision
⟹ understanding of Gluon Luminosity ⟹ reliable Higgs expectations

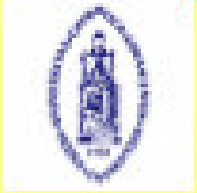
Luminosity for DPE Higgs measurements $O(100)$ fb^{-1}
Higgs x-sections could reach $O(100)$ fb
⟹

Higgs Mass measured with 1.5% precision
Investigations of CP structure of the Higgs sector
-no other detector can do it- new window into physics
⟹

Diffractive LHC ~ pure Gluon Collider => investigations of properties of the gluon cloud in the new region

Gluon Cloud is a fundamental QCD object - SOLVE QCD!!!!

Studies of High Energy Photon Interactions at the LHC



Krzysztof Piotrzkowski
Université Catholique de Louvain

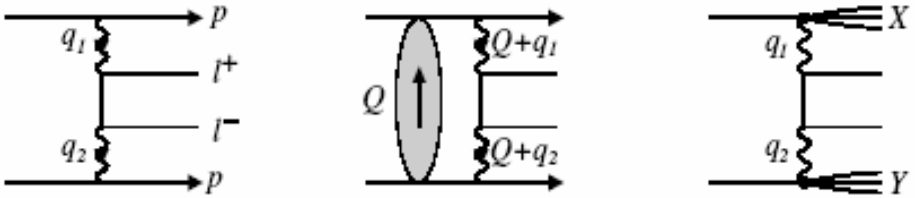
UCL

- Introduction: LHC as a high energy $\gamma\gamma$ and γp collider ($W_{\gamma p}$ ~ 50xHERA)
  (also talks by S.Klein & S.White)
- Photoproduction of WH (M. vander Donckt)
- Luminosity measurement with exclusive lepton pairs at the LHC (Y. Liu)
- Anomalous quartic couplings and WW and ZZ two-photon production (T. Pierzchała)
- Ion case (also talks by S.Klein & S.White).
- Outlook

Introduction : $pp \longrightarrow pe^+e^-p$

- QED process (a) production σ precisely known.

event generator LPAIR based on ME by Vermaseren



- Hadronic corrections [(b) (c)] small. Can suppress with experimental cuts and subtract by fitting final state kinematics.

V. A. Khoze et al Eur. Phys. J **C19**, *313-322 (2001)*

Hadr. Corrects- negligible
(bt +J_z=effects)

- Production rate considerable,

e.g. $\sigma_{(P_T>2\ \mathrm{GeV})} = 0.129\ \mathrm{nb} \pm 0.234\ \mathrm{pb}.$

Infer E_γ at initial state.

- When both leptons are observed, the energy of the $\gamma\gamma$ at initial state can be infered -assumption : their transverse momenta are small

(1) $$M_{l^+l^-} = 4E_{\gamma 1}E_{\gamma 2};$$

(2) $$Y_{l^+l^-} = \frac{1}{2}\log\frac{E_{\gamma 1}}{E_{\gamma 2}} \quad (\text{take } P_{z\gamma 2} < 0)$$

where, $M_{l^+l^-}, Y_{l^+l^-}$ are the invariant mass, rapidity of the l^+l^- two body system respectively.

- This can be used to calibrate forward detectors.

High mass diffraction at the LHC

Christophe Royon
DAPNIA-SPP, CEA Saclay,
Fermilab, Batavia, USA

DIS 2005, April 26- May 1 2005, Madison

Work done in collaboration with
J. Cammin (Rochester), R. Peschanski,
M. Boonekamp, S. Lavignac (Saclay),
A. Kupco (Prague)
Ref: hep-ph/0406061, hep-ph/0504199

Contents:

- Exclusive standard model and SUSY Higgs production: S/B
- W, top and stop production cross section
- W, top and stop mass reconstruction

KMR- 97-02, DKMOR -02, KKMR -04

top, SUSY (KMR-02); WW- K.Piotrzkowski

(assuming the rate is sufficient)

C. Royon

Conclusion

- Study of exclusive Higgs production
- Exclusive events still to be observed in particular at the Tevatron
- Signal over background: ~ 1 if one gets a very good resolution using roman pots (better than 1 GeV), enhanced by a factor up to 50 for SUSY Higgs at high $tan\beta$
- QED WW pair production: cross section known precisely, allow to calibrate prescisely the roman pot detectors
- Diffractive top, stop pair production: possibility to measure top and stop masses by performing a threshold scan with a precision better than 1 GeV (same idea as linear collider, without ISR problem), Caveat: evidence of exclsuive events, cross sections???...

Reservations :

Manchester analysis, B.Cox 's talk

BG ⇨ NLO + NLLO effects are dominant ✵
(DKMOR-02)

NO obvious advantages as compared to the QED dileptons (K.Piotrzkowski's talk)

•threshold scan issues for the P-wave channel, width effects

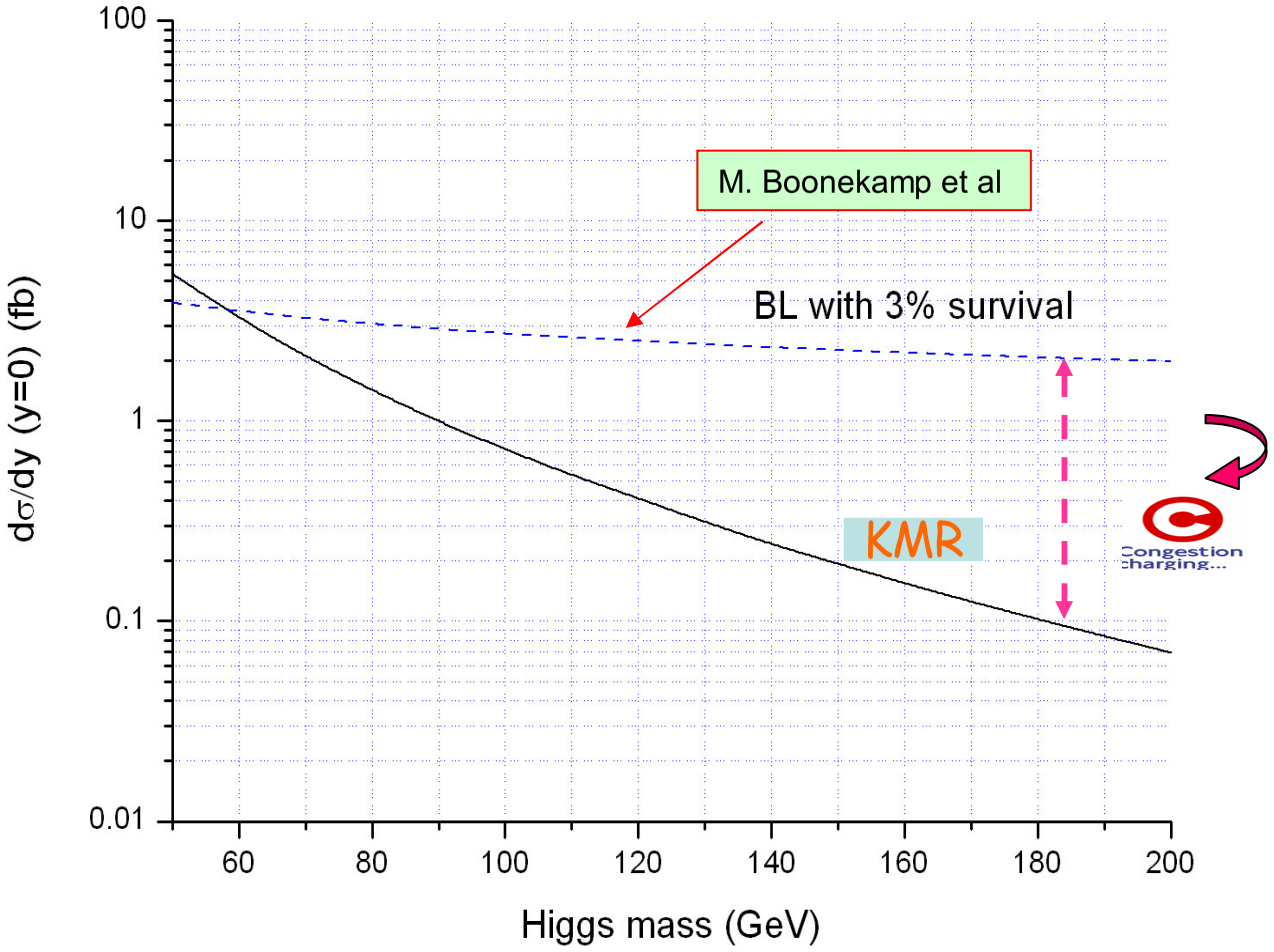
• the cross sections overshoot KMR-02 top/stop threshold results by up two orders of magnitude

Why is it so ?

- NO Sudakov suppression (QCD 'congestion charging')
- integration over the wide mass region

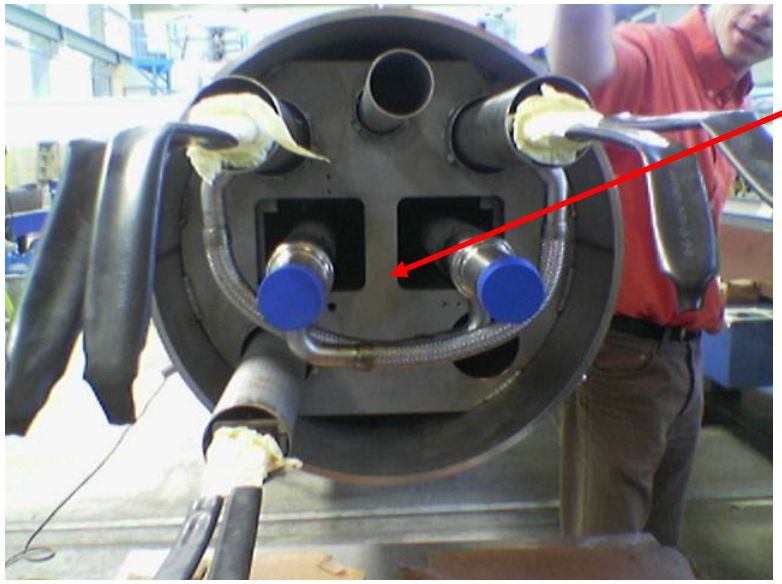
J. Forshaw (HERA-LHC)

(A. Bzdak-05)



We cannot simply scale down the results by dividing by the 'overshoot factor' KMR-02

Instrumenting the 420m region



Diffracted protons emerge between beam pipes

- Most likely scenario : Cryogenic bypass, warm beam pipes
- First opportunity to replace 420m cryostat is in planned long shutdown after first physics runs of LHC (autumn 2008?)

- UK FP420 is funded for R&D (including 3D silicon detector research)
- Belgium FP420 is funded for R&D (detector mechanics and electronics)
- Negotiations in progress for cryogenic engineer to design prototype 420m cryostat (in collaboration with AT-CRI group at CERN and UK Cockcroft Institute)
- FP420 meeting at CERN May 30th - 31st. Video available. Aim for LOI to LHCC at end of June. All welcome (Contact Brian Cox / Albert De Roeck / Mike Albrow (US)) .
- FP420 is not a 'collaboration'. It is an R&D project which will hopefully lead to new sub-detectors for ATLAS and / or CMS.