Les Rencontres de Physique de la Vallée d'Aoste

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Diffractive processes at the LHC as a tool to discover New Physics

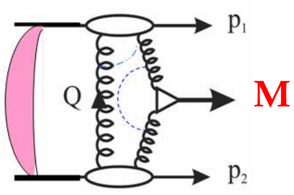
Durham University

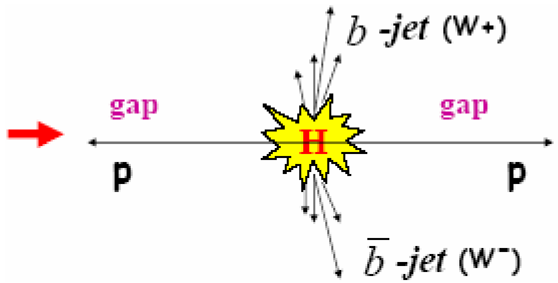
V.A. Khoze (IPPP, Durham)

"…The mechanic, who wishes to do his work well, must first sharpen his tools …"

—Chapter15, **'The Analects'** attributed to Confucius, translated by James Legge. (from X. Zu at DIS05)

main aim: to show that the Central Exclusive Diffractive Processes may provide an exceptionally clean environment to search for and to identify the nature of new physics at the LHC





PLAN

1. **Introduction** (gluonic Aladdin's lamp)

2. **Basic elements of KMR approach** (qualitative guide)

3. **Prospects for CED Higgs production.**

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4. ***'Exotics'***

5. ***The 'standard candle' processes(*** *experimental checks* ***).*** ***(K.Goulianos)***

6. **Conclusion**

7. **Ten commandments of Physics with Forward Protons at the LHC**

.

CMS & ATLAS were designed and optimised to look *beyond the SM*

- *High -pt signatures in the central region*

The LHC is a very challenging machine!

But… *'incomplete'*

- Main physics **'goes Forward'**

- Difficult background conditions.

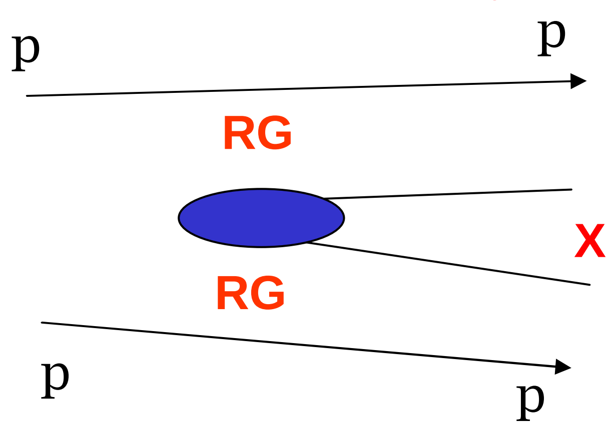
- The precision measurements are limited by systematics (luminosity goal of $\delta L \leq 5\%$)

Lack of :

- Threshold scanning , resolution of nearly degenerate states (e.g. MSSM Higgs sector)
- Quantum number analysing

- Handle on CP-violating effects in the Higgs sector
- Photon – photon reactions

ILC *chartered territory*



Is there a way out?

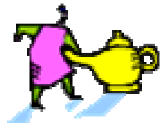
YES → Forward Proton Tagging

Rapidity Gaps ⇨ Hadron Free Zones

matching Δ Mx ~ δM (Missing Mass)

Forward Proton Taggers as a gluonic Aladdin's Lamp

(Old and New Physics menu)



- Higgs Hunting (the LHC 'core business') — K(KMR)S-97-06, Saclay, Petrov et al. Brodsky et al.
- Photon-Photon, Photon - Hadron Physics — KMR-02, K.Piotrzkowski et al.
- **'Threshold Scan'**: 'Light' SUSY ... — KMR-02 , Manchester
- Various aspects of Diffractive Physics (*soft & hard*). — KMR-01 , K. Goulianos, A. Gotsman et al.

High intensity **Gluon Factory** *(underrated gluons)* — KMR-00, KMR-01
QCD test reactions, dijet P-luminosity monitor

- Luminometry — R. Orava+KMR-01
- Searches for new heavy gluophilic states — KMR-02, KMRS-04

FPT

✷ Would provide a unique additional tool to complement the conventional strategies at the LHC and ILC.

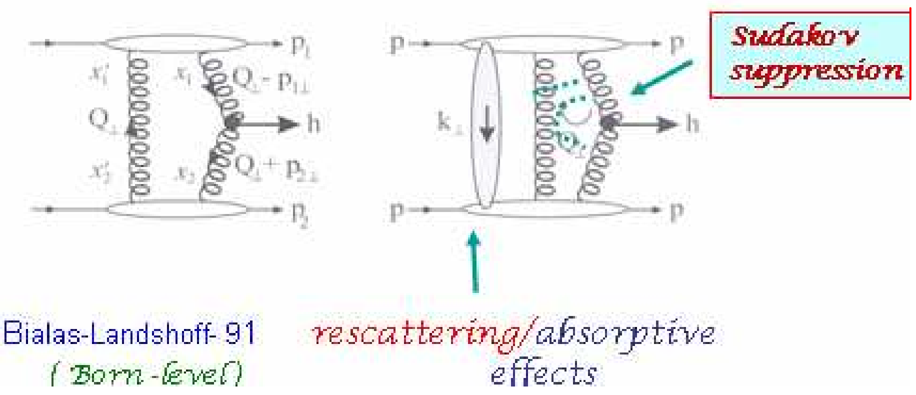
FPT ▶ will open up an additional rich physics menu ILC@LHC

✷ Higgs is only a part of the broad EW, BSM and diffractive program@LHC
wealth of QCD studies, glue-glue collider, photon-hadron, photon-photon interactions…

The basic ingredients of the KMR approach
(Khoze-Martin-Ryskin 1997-2007)

Interplay between the soft and hard dynamics

RG signature for Higgs hunting (Dokshitzer, Khoze, Troyan, 1987). Developed and promoted by Bjorken (1992-93)



Main requirements:

- inelastically scattered protons remain intact
- active gluons do not radiate in the course of evolution up to the scale M
- $\langle Qt \rangle \gg \Lambda_{QCD}$ in order to go by pQCD book

$$\sigma(CDPE) \sim 10^{-4} * \sigma\ (incl)$$

High price to pay for such a clean environment:

σ (CEDP) ~ 10^{-4} σ(inclus.)

Rapidity Gaps should survive **hostile** hadronic *radiation damages* and *'partonic pile-up'*

$$W = S^2\, T^2$$

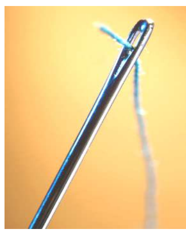
Colour charges of the 'digluon dipole' are screened only at $r_d \geq 1/(Q_t)_{ch}$

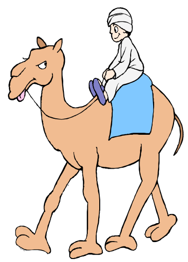
GAP Keepers (Survival Factors) , protecting RG against:

- the debris of QCD radiation with $1/Q_t \geq \lambda \geq 1/M$ **(T)**
- soft rescattering effects (necessitated by unitariy) **(S)**

How would you explain it to your (grand) children ?

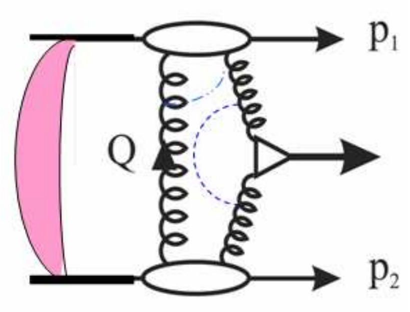
Forcing two (inflatable) camels to go through the eye of a needle





P **H** **P**

KMR technology (implemented in ExHume MC)



$$\sigma_{pp}(M^2,\ldots) = L_{eff}(M^2,y) * \sigma_{hard}(M^2,\ldots)$$

$$\frac{\partial^2 L_{eff}}{\partial y \partial M^2} M^2 = S^2 * L(M^2)$$

$L_{eff}(M^2,y)$ → the same for Signal and Bgds

$$L_{eff} \sim \frac{\hat{S}^2}{b^2} \left| N \int \frac{dQ_t^2}{Q_t^4} f_g(x_1, x_1', Q_t^2, \mu^2) f_g(x_2, x_2', Q_t^2, \mu^2) \right|^2$$

contain Sudakov factor T_g which exponentially suppresses infrared Q_t region → pQCD

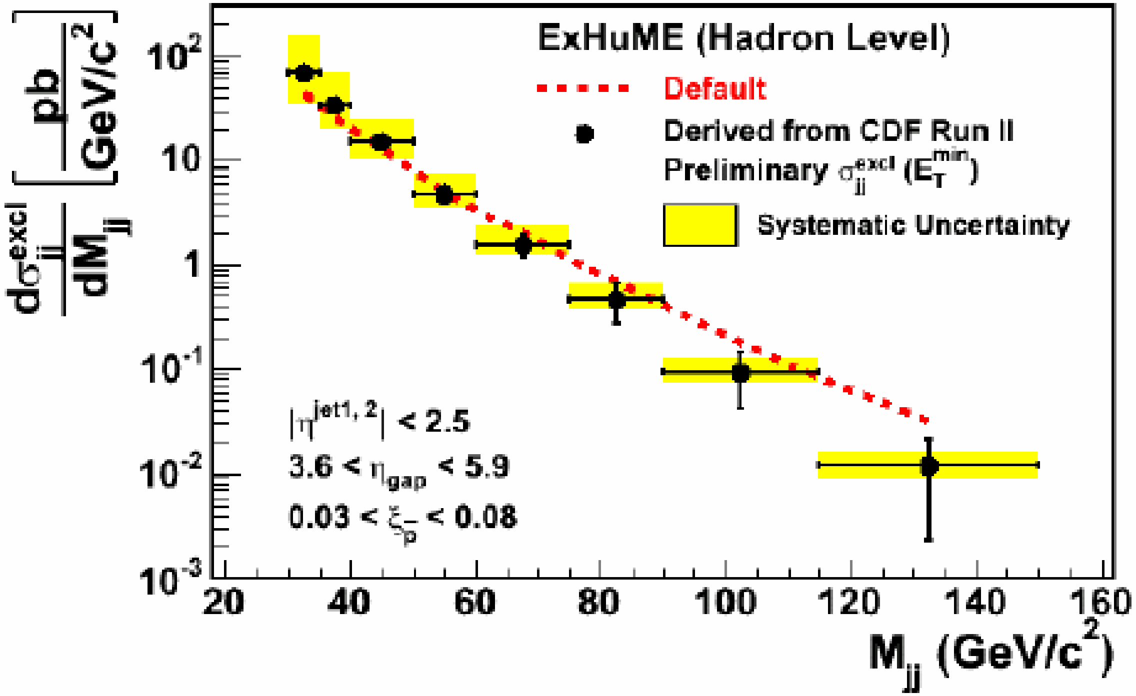
new CDF experimental confirmation, 2006

S^2 is the prob. that the rapidity gaps survive population by secondary hadrons → soft physics; S^2 =0.026 (LHC),

S^2/b^2 -*weak dependence on* b *(models)*

JJ_{excl} : cross section predictions

ExHuME Hadron-Level Differential Exclusive Dijet Cross Section vs Dijet Mass
(dotted/red): Default ExHuME prediction
(points): Derived from CDF Run II Preliminary excl. dijet cross sections



Statistical and systematic errors are propagated from measured cross section uncertainties using ExHuME M_{jj} distribution shapes.

(K. Goulianos)

good agreement with the default ExHuME prediction up to masses in the region of the standard model Higgs mass predicted from global fits to electroweak data lends credence to the calculation of Ref. [9]. for exclusive Higgs boson production at the LHC.

[9] V. Khoze, A. Kaidalov, A. Martin, M. Ryskin, and W. Stirling, *Diffractive processes as a tool for searching for new physics*, e-Print Archive:hep-ph/0507040, and references therein.

Current consensus on the LHC Higgs search prospects

•SM Higgs : detection is in principle guaranteed for any mass. ☺

•In the MSSM h-boson most probably cannot escape detection, and in large areas of parameter space other Higgses can be found. ☺

•But there are still *troublesome* areas of the parameter space:
intense coupling regime of MSSM, MSSM with CP-violation….. ☹

•More surprises may arise in other SUSY
non-minimal extensions: NMSSM……

'Just' a discovery will not be sufficient! 

• After discovery stage (*Higgs Identification*):

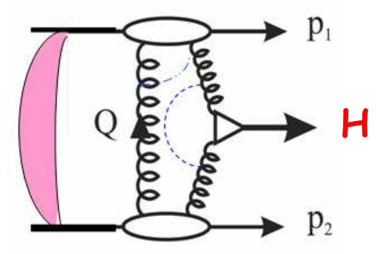
✴ The ambitious program of precise measurements of the Higgs mass, width, couplings, and, especially of the quantum numbers and CP properties would require an interplay with a *ILC*

How do we know what we have found?

Experimental questions

- Is it a Higgs boson?
- What are its mass, spin and $\mathcal{CP}$ properties?
- What are its couplings to fermions and gauge bosons? Are they really proportional to the masses of the particles?
- What are its self-couplings?
- Are its properties compatible with the SM, the MSSM, the NMSSM, ...?
- Are there indications that there are more than one Higgs bosons?
- Are there indications for other new states that influence Higgs physics?

The main advantages of CED Higgs production



- Prospects for high accuracy mass measurements (irrespectively of the decay mode).
- Quantum number filter/analyser.
  (0++ dominance ;C,P-even)
- H ->bb opens up (Hbb- coupl.)

(gg)CED bb in LO ; NLO,NNLO, b- mass effects - controllable.

- For some areas of the MSSM param. space CEDP may become *a* **discovery channel !**
- H →WW*/WW - **an added value** (less challenging experimentally + small bgds., better PU cond.)
- New run of the MSSM studies is underway.
- New leverage –proton momentum correlations (probes of QCD dynamics , CP- violation effects…)

✷ LHC : 'after discovery stage', Higgs **ID**..... *How do we know what we've found?*

mass, spin, couplings to fermions and Gauge Bosons, invisible modes…
➔ for all these purposes the CEDP will be particularly handy !

☺ Experimental Advantages

– Measure the Higgs mass via the missing mass technique
  Mass measurements do not involve Higgs decay products
  Cleanness of the events in the central detectors.

Experimental Challenges

– Tagging the leading protons
– Selection of exclusive events & backgrounds, PU -events
– Triggering at L1 in the LHC experiments.
– bb-mode requires special attention.

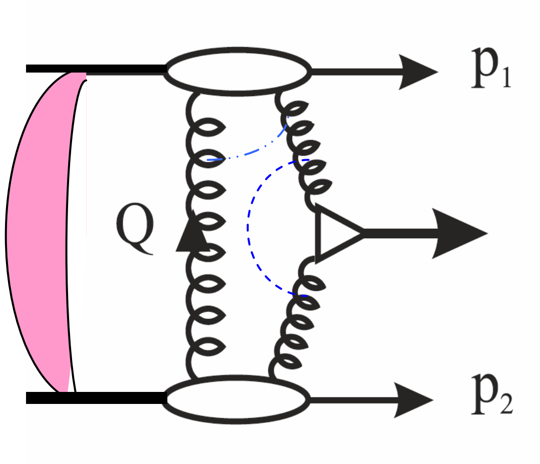
Uncertainties in the theory

(Unusually& uncomfortably) large higher-order effects,
model dependence of predictions *(soft hadronic physics is involved after all)*

- There is still a lot to learn from the Tevatron diffractive data (KKMRS- friendly so far).

The MSSM and more *exotic* scenarios

$$pp \rightarrow p + \phi + p$$



If the coupling of the Higgs-like object to gluons is large, double proton tagging becomes very attractive

- *The intense coupling regime of the MSSM*

(E.Boos et al, 02-03)

- CP-violating MSSM Higgs physics (B.Cox et al . 03, KMR-03, J. Ellis et al. -05)

Potentially of great importance for electroweak baryogenesis

- an *'Invisible' Higgs* (BKMR-04)

- *NMSSM* (with J. Gunion and A.De Roeck)

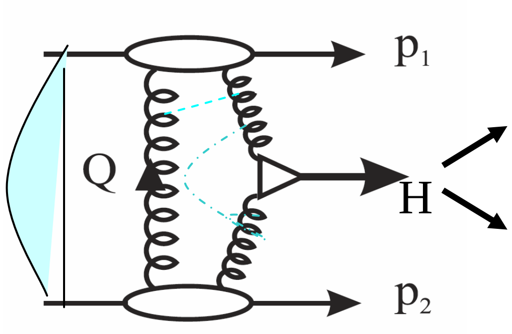
Exclusive SM Higgs production

b jets : M_H = 120 GeV s = 2 fb (uncertainty factor ~2.5)

M_H = 140 GeV s = 0.7 fb

WishList

(with detector cuts)



WW* : M_H = 120 GeV s = 0.4 fb

M_H = 140 GeV s = 1 fb

M_H = 140 GeV : 5-6 signal / O(3) background in 30 fb^{-1} (with detector cuts)

- The b jet channel is possible, with a good understanding of detectors and clever level 1 trigger (μ-trigger from the central detector at L1 or/and RP(220) +jet condition)
- The WW channel is extremely promising : no trigger problems, better mass resolution at higher masses (even in leptonic / semi-leptonic channel), weaker dependence on jet finding algorithms, better PU situation
- The ττ mode looks advantageous

✷ If we see SM-like Higgs + p- tags ⇨ the quantum numbers are 0^{++}

Theoretical Input

Higgs potential of the MSSM

MSSM Higgs potential contains two Higgs doublets:

$$V = m_1^2 H_1 \bar{H}_1 + m_2^2 H_2 \bar{H}_2 - m_{12}^2 (\epsilon_{ab} H_1^a H_2^b + \text{h.c.})$$
$$+ \underbrace{\frac{g'^2 + g^2}{8}}(H_1 \bar{H}_1 - H_2 \bar{H}_2)^2 + \underbrace{\frac{g^2}{2}} |H_1 \bar{H}_2|^2$$

gauge couplings, in contrast to SM

Five physical states: $h^0, H^0, A^0, H^\pm$

Input parameters: $\tan\beta = \frac{v_2}{v_1}$, M_A

$\Rightarrow m_h$, m_H, mixing angle α, $m_{H^\pm}$: no free parameters

a 'simplest' extension of the minimal Higgs sector

Higgs couplings

Higgs couplings, tree level:

$$g_{\mathrm{hVV}} \;=\; \sin(\beta-\alpha)\; g^{\mathrm{SM}}_{\mathrm{HVV}}, \quad g_{\mathrm{HVV}} = \cos(\beta-\alpha)\; g^{\mathrm{SM}}_{\mathrm{HVV}}, \quad V = W^{\pm}, Z$$

$$g_{\mathrm{hAZ}} \;=\; \cos(\beta-\alpha)\,\frac{g'}{2\cos\theta_{\mathrm{W}}}, \quad g_{\mathrm{HAZ}} = \sin(\beta-\alpha)\,\frac{-g'}{2\cos\theta_{\mathrm{W}}}$$

$\Rightarrow$ $g_{\mathrm{hVV}} \leq g^{\mathrm{SM}}_{\mathrm{HVV}}$, $\quad g_{\mathrm{hVV}}, g_{\mathrm{HVV}}, g_{\mathrm{hAZ}}, g_{\mathrm{HAZ}}$ cannot all be small

In decoupling limit, $M_{\mathrm{A}} \gg M_{\mathrm{Z}}$ (already realized for $M_{\mathrm{A}} \gtrsim 150$ GeV):

$\cos(\beta-\alpha) \to 0$ $\quad$ (h ▸ SM-like, H/A- degenerate.)

$\Rightarrow$ H and A decouple from gauge bosons (only g_{HAV} is sizable)

$\Rightarrow$ Cannot use WBF channels for production of heavy SUSY Higgses; no $H \to ZZ \to 4\mu$ decay

GOOD NEWS!

$-$ $\mathrm{BR}(H, A \to b\bar{b}, \tau^+\tau^-) \gg \mathrm{BR}(H^{\mathrm{SM}} \to b\bar{b}, \tau^+\tau^-)$

$\Rightarrow$ Good prospects for CED channel: $pp \to p + H + p$, $H \to b\bar{b}$

The MSSM can be very proton tagging friendly

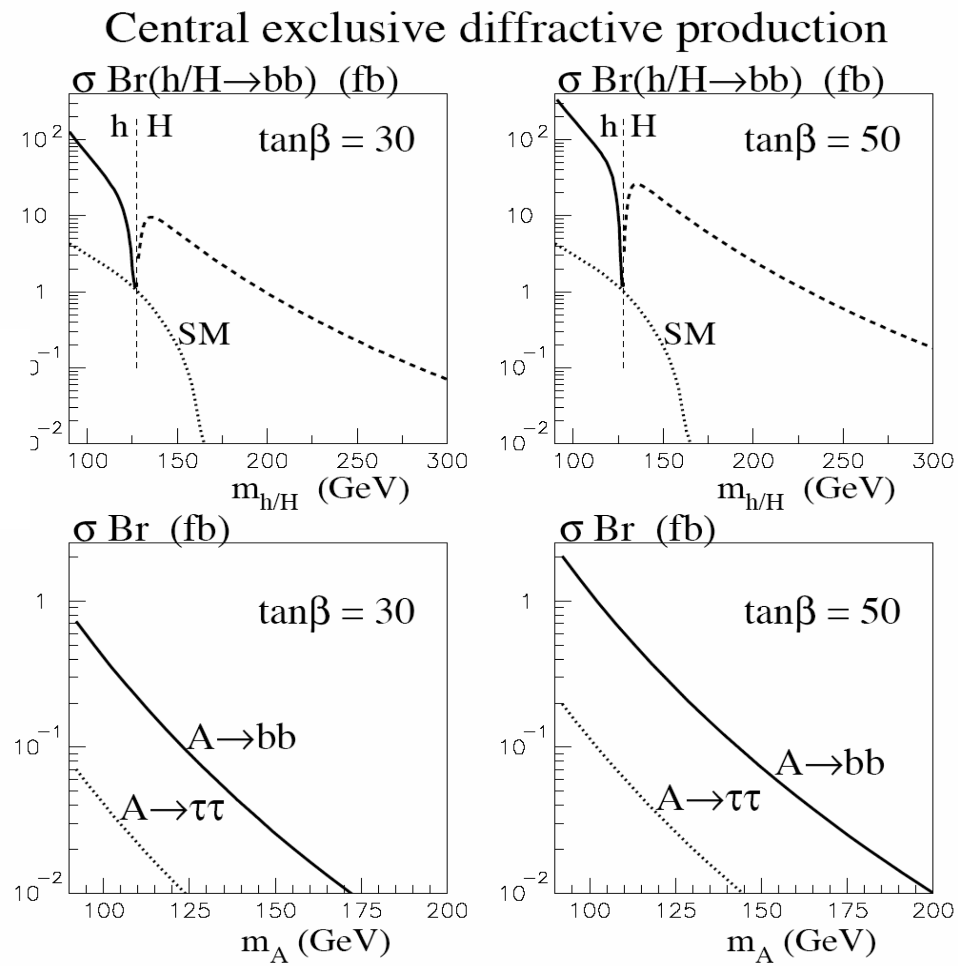
The *intense coupling regime* is where the masses of the 3 neutral Higgs bosons are close to each other and tan β is large

$\gamma\gamma, WW^\star, ZZ^\star$ suppressed

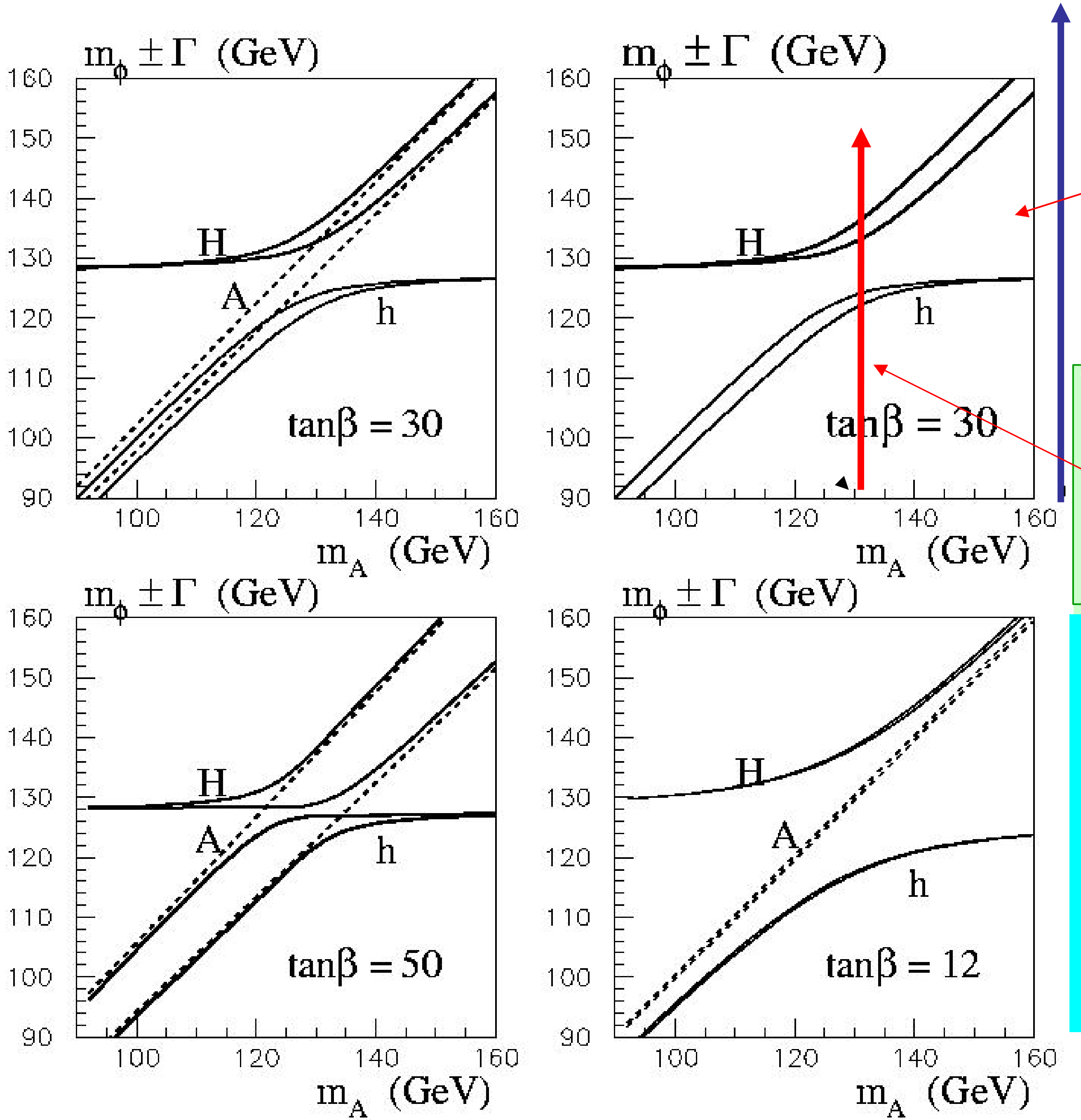
$gg \to \phi$ enhanced

0^{++} selection rule suppresses A production:

CEDP 'filters out' pseudoscalar production, leaving pure H sample for study



Well known difficult region for conventional channels, tagged proton channel may well be the *discovery channel*, and is certainly a powerful *spin/parity filter*



decoupling regime

$m_A \sim m_H \geq 150$GeV,

$\tan\beta > 10$;

h = SM

intense coupling:

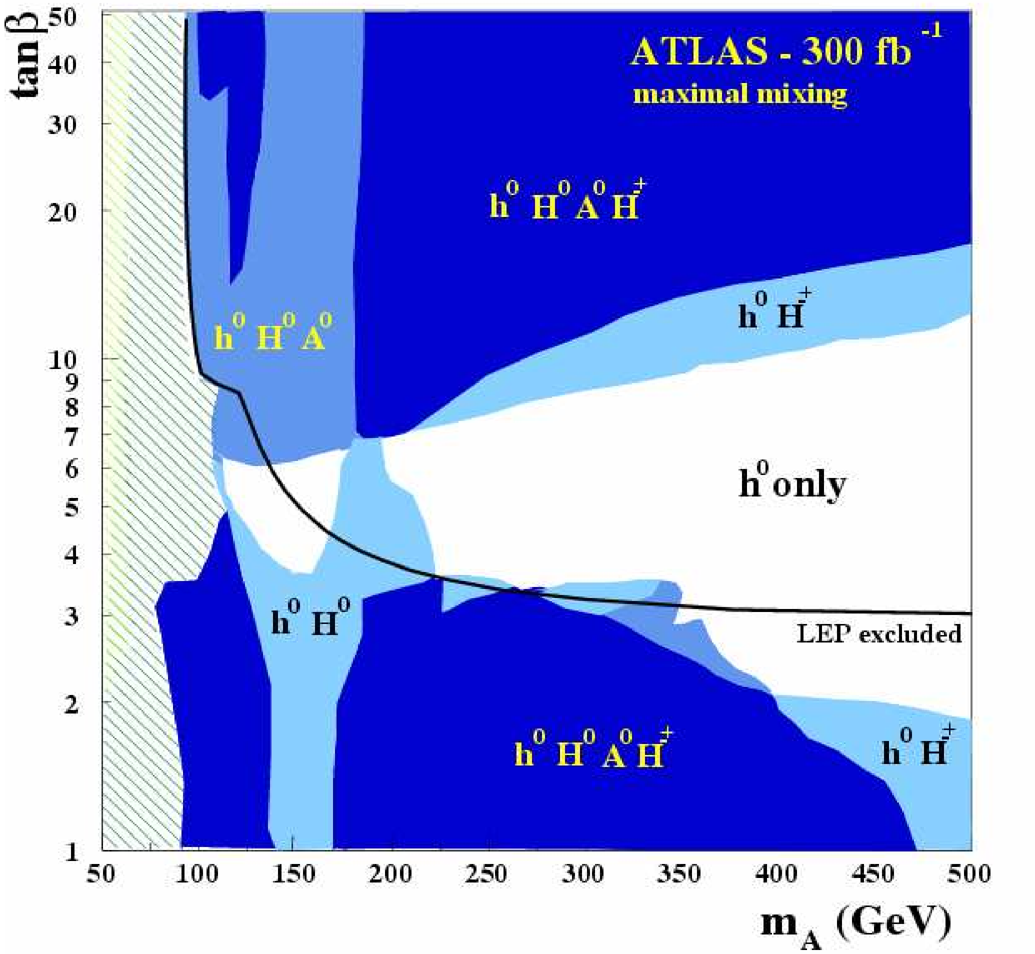
$m_h \sim m_A \sim m_H$

$\gamma\gamma$,WW.. coupl suppressed

with CEDP:

- **h,H** may be clearly distinguishable outside130+-5 GeV range,
- **h,H** widths are quite different

Helping to cover the LHC gap?



With CEDP the mass range up to 160-170 GeV can be covered at medium tanβ and up to 250 GeV for very high tan β, with 300 fb^{-1}

Needs, however, still full simulation

pile-up ?

Ongoing studies

(S.Heinemeyer, V.A. Khoze , W.J.Stirling, M. Ryskin, ,M. Tasevsky and G. Weiglein)

- H→bb in the high mass range ($M_A \approx 180$-250 GeV)

-unique signature for the MSSM,
cross-sections overshoot the SM case by orders of magnitude.
-possibility to measure the Hbb Yukawa coupling,
-nicely complements the conventional Higgs→ττ searches
- CP properties, separation of H from A,
-unique mass resolution,
-may open a possibility to probe the 'wedge region' !?
-further improvements needed (going to high lumi ?....)
(more detailed theoretical studies required)

- h, H→bb, in the low mass range ($M_A < 180$ GeV)

-coverage mainly in the large tan β and low M_A region,
-further improvements (trigger efficiency….) needed in order to increase coverage

• h,H→ ττ in the low mass range (M_A<180 GeV)
-essentially bkgd –free production,
-need further improvements, better understanding..,
-possibility to combine with the bb-signal
(trigger cocktail …)

-can we trigger on ττ without the RP condition ?

• h→ WW
-significant (~4) enhancement as compared to the SM case in some favourable regions of the MSSM parameter space.

• small and controllable backgrounds

• Hunting the CP-odd boson, A

a way out : to allow incoming protons to dissociate (E-flow ET>10-20 GeV) KKMR-04

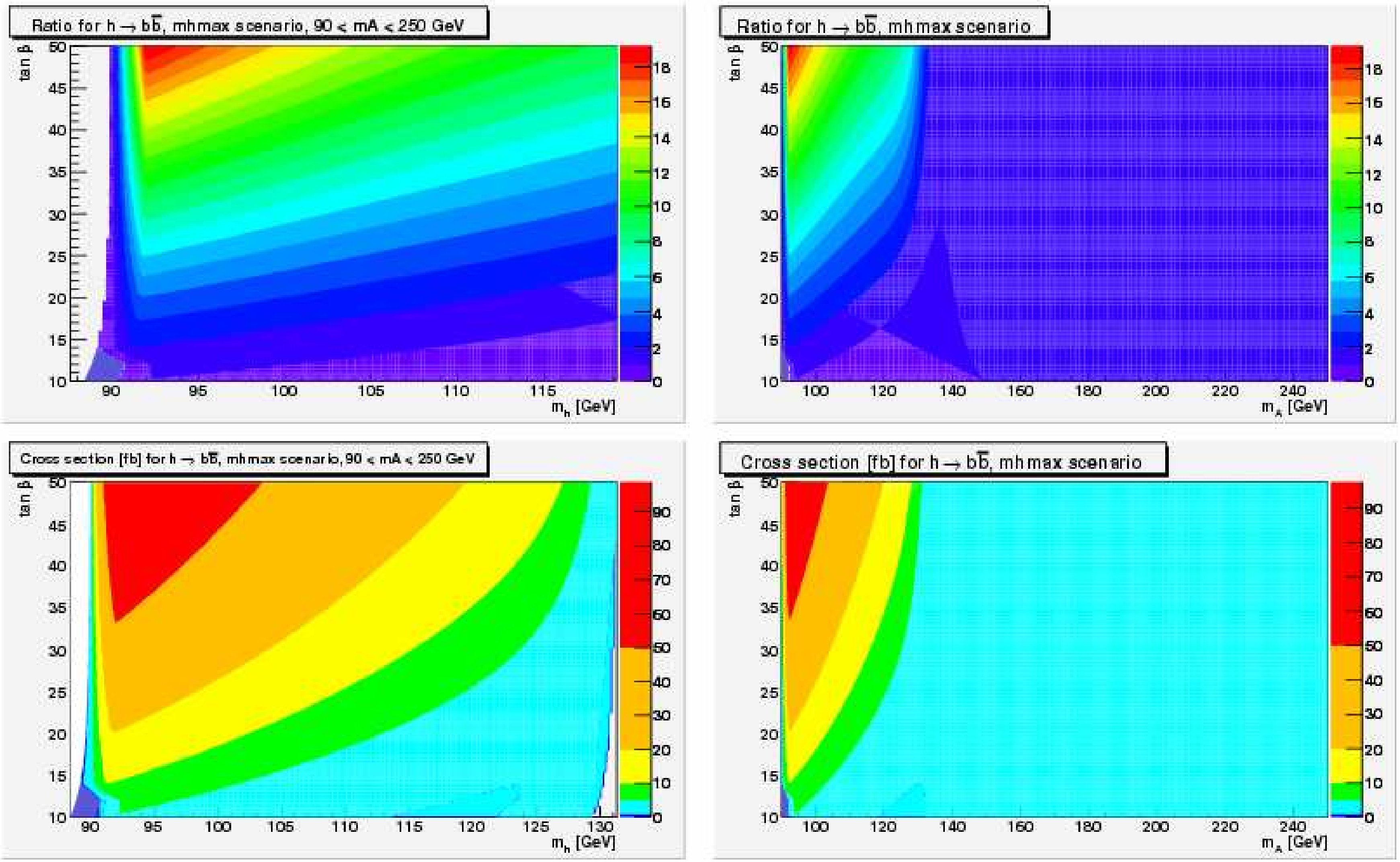
pp→ p + X +A +Y +p

At the moment the situation looks borderline

PRELIMINARY

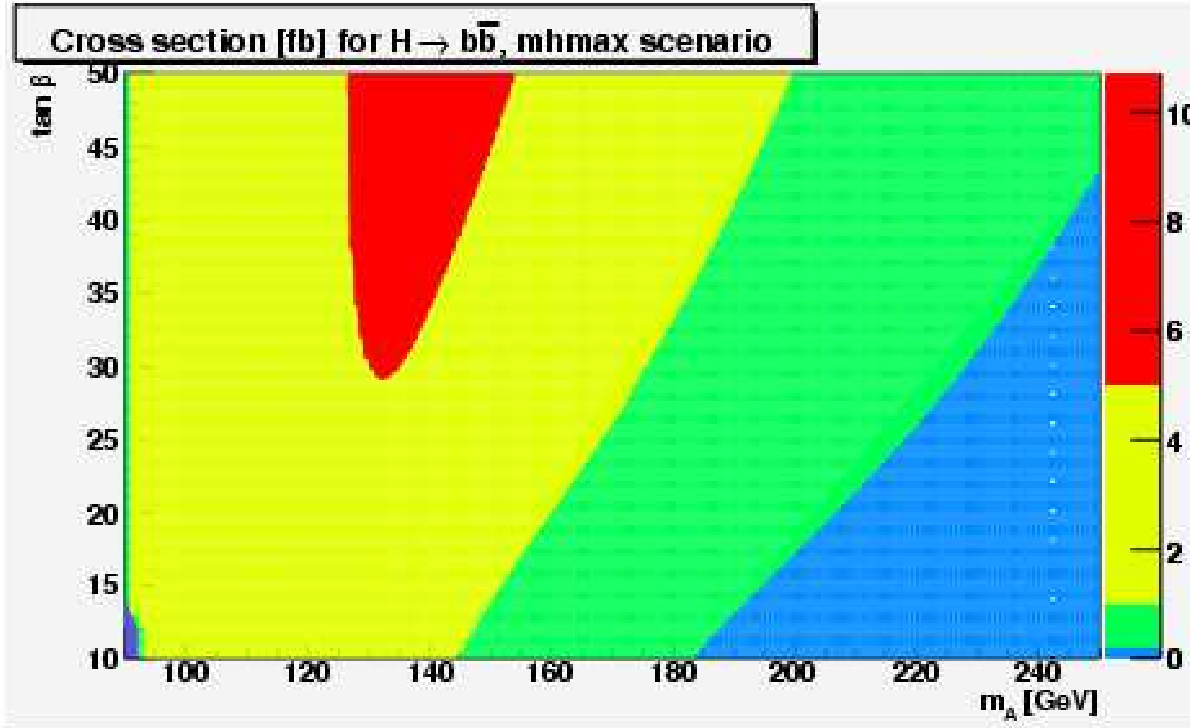
h→bb

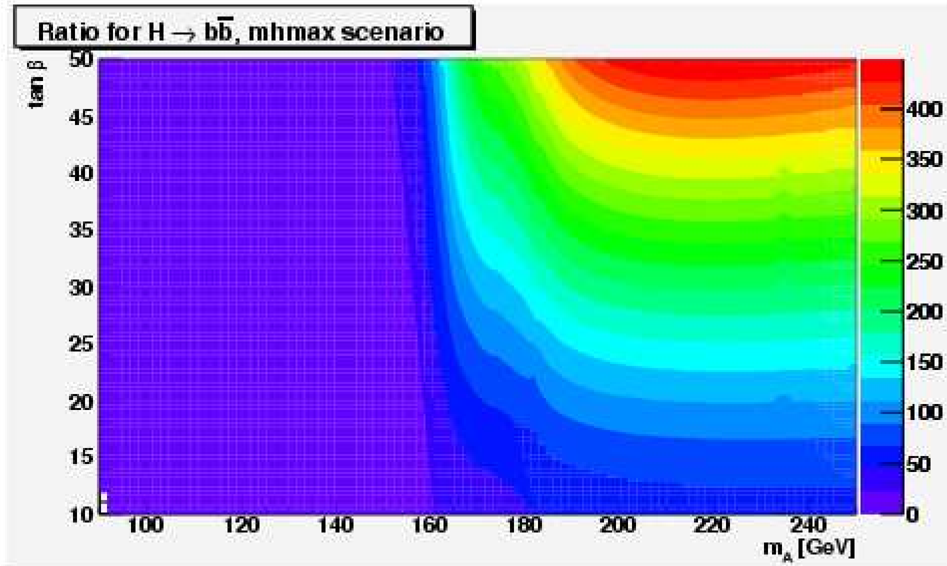
mhmax scenario, μ=200 GeV, MSUSY =1000 GeV



H→bb

PRELIMINARY





Exotics

① *Gluinoniums*

② *An 'Invisible' Higgs*

☞ Gluinonium (gluinoball) : $G = \tilde{g}\tilde{g}$

…the LHC as a 'gluino factory' , *N. Arkani-Hamed (Pheno-05)*

scenarios where gluino $\tilde{g}$ is the the LSP (or next- to-LSP)

⇨ *hit of the day -split -SUSY*

the lowest-lying bound state 0++ ($^3P_0$)

the energies of P-wave states $E_n = -9/4\, m_{\tilde{g}}\, \alpha_s^2/n^2 \quad (n \geq 2)$

G — a 'Bohr atom' of the $\tilde{g}\tilde{g}$- system

BFK-92

$\Gamma_G = (M_G/100\ \mathrm{GeV})\ 0.33\ \mathrm{MeV}$,

New studies: Manchester Group (ExHuMe)

$(S/B)_{gg} = 0.25\ 10^{-2} (1/\Delta M)\ (M_G/100\ \mathrm{GeV})$

visualization is challenging even with angular cuts

KMR-02

pp ➔ pp + 'nothing'

further progress depends on the survival ….

➔ 'Invisible ' Higgs KMR-04

several extensions of the SM: a fourth generation
some SUSY scenarios,
large extra dimensions

(one of the 'LHC headaches')

the potential advantages of the CEDP – a sharp peak in the MM spectrum, mass determination, quantum numbers

strong requirements :

• triggering directly on L1 on the proton taggers

•forward calorimeters (...ZDC) (QED radiation , soft DDD)

⇨ *various potential problems of the FPT approach reveal themselves*

⇨ *however there is a chance to observe such an invisible object, which, otherwise, may have to await a ILC*

➔ **searches for extra dimensions – diphoton production** (KMR-02)

EXPERIMENTAL CHECKS

✳ Up to now the diffractive production data are consistent with K(KMR)S results
Still more work to be done to constrain the uncertainties

(K. Goulianos)

- CED high-Et dijets
  (CDF: Run I, Run II)   data up to $(E_t)_{min}$>50 GeV

- 'Factorization breaking' between the effective diffractive structure functions measured at the Tevatron and HERA.

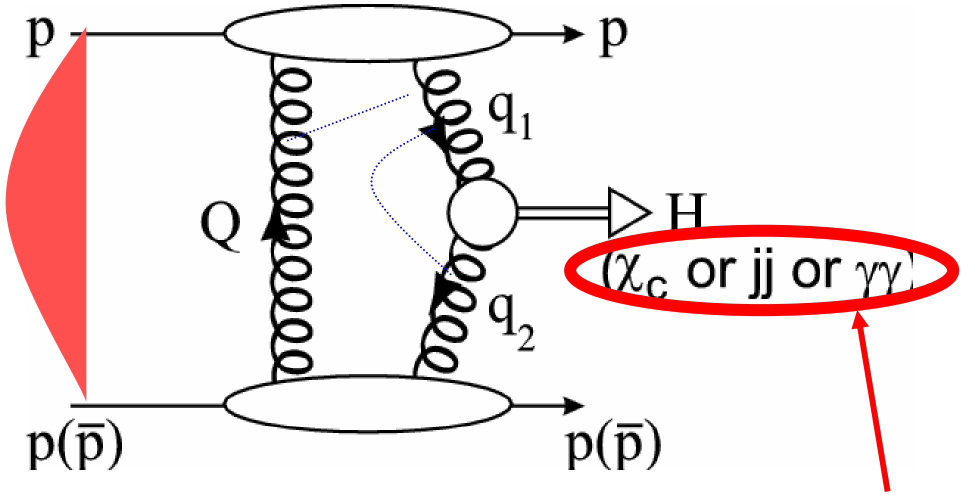
(KKMR-01 ,a quantitative description of the results, both in normalization and the shape of the distribution)

- The ratio of high Et dijets in production with one and two rapidity gaps

- Preliminary CDF results on exclusive charmonium CEDP.

- Energy dependence of the RG survival (D0, CDF).

- CDP of γγ (….ππ,ηη)
  (in line with the KMRS calculations)



"standard candles"

"Standard Candles"
at Tevatron to test exclusive prod. mechanism

pre-dictions, KMRS

$pp \rightarrow p + \chi + p$ high rate, but low scale (uncertainties in the estimates)

$pp \rightarrow p + jj + p$ rate rather high, but exclusive events should be separated

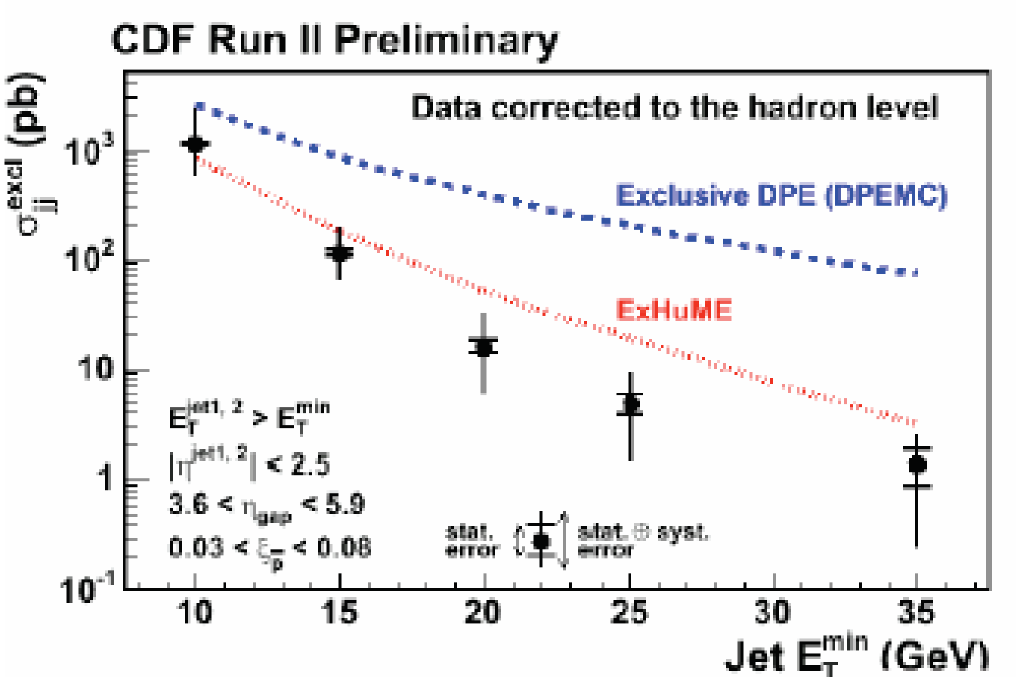
$pp \rightarrow p + \gamma\gamma + p$ low rate, but cleaner signal

(K. Goulianos)

Experimental results are quite encouraging

QCD Mediated Dijet Production

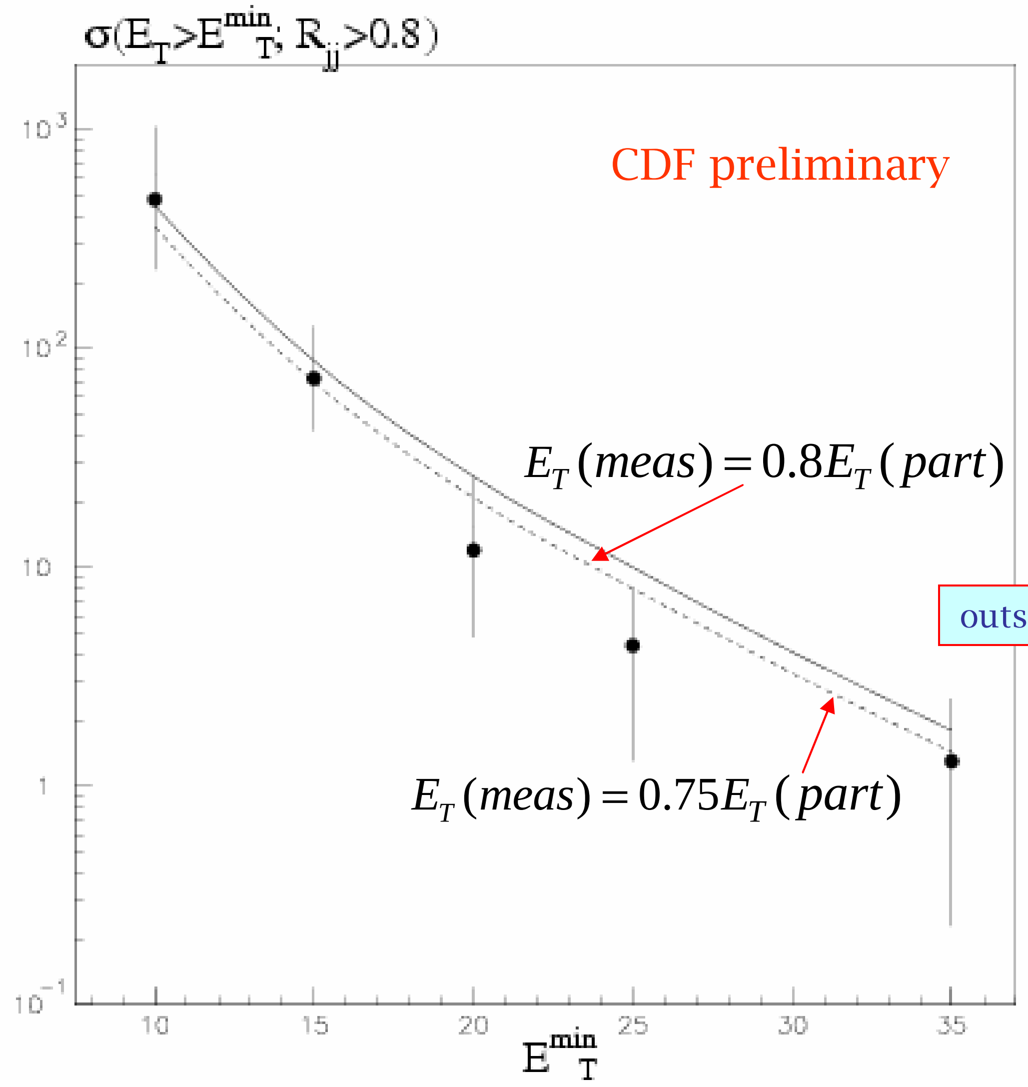
Congratulations to CDF !
….a lot of new exciting plots to come…



(K. Goulianos)

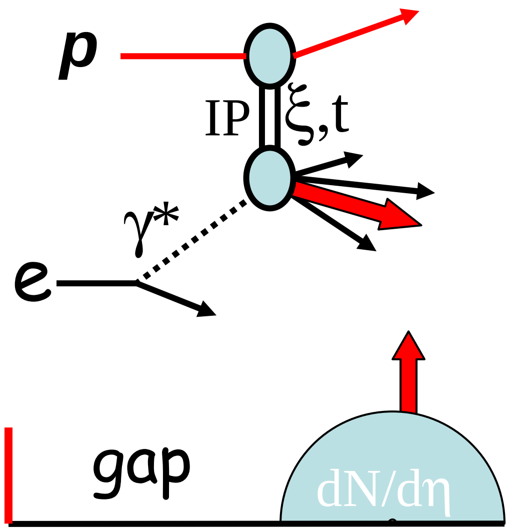
ExHuMe (KMR-based)

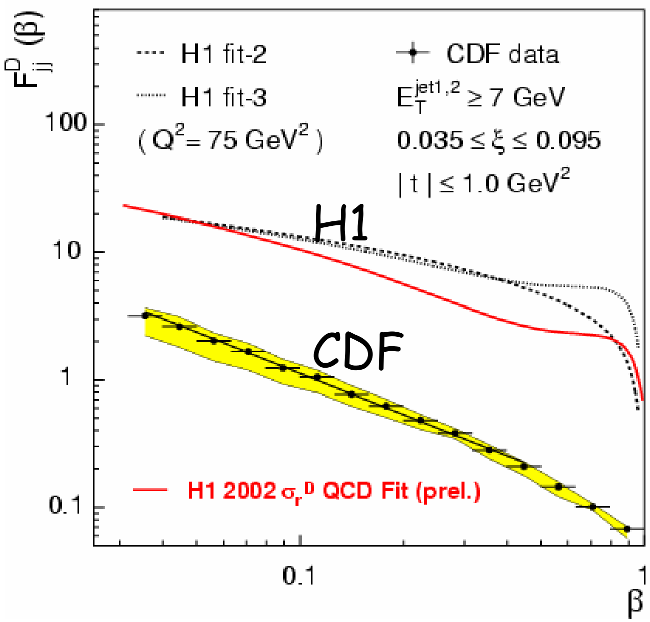
KMR analytical results

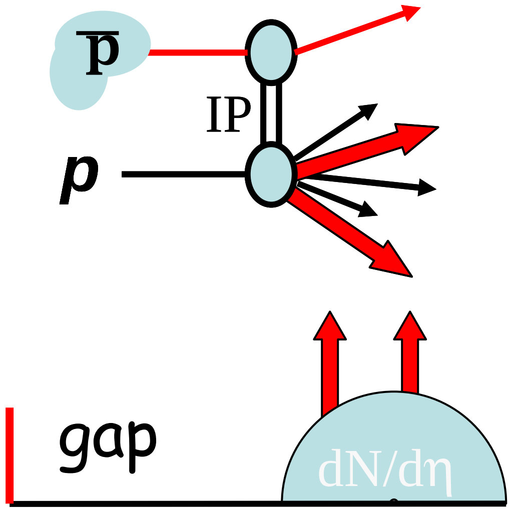


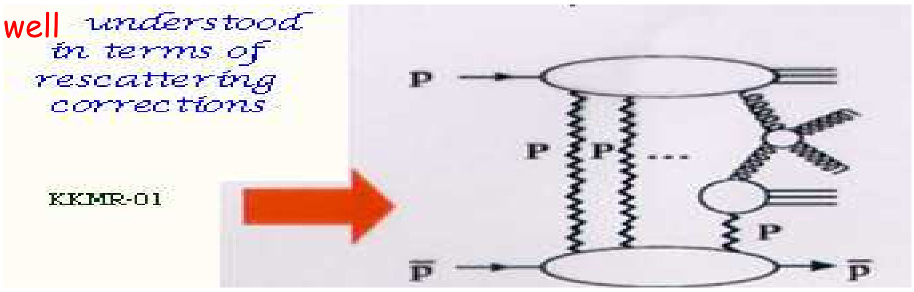
outside-cone energy (Koji Terashi)

Tevatron vs HERA:
Factorization Breakdown









CONCLUSION

- Forward Proton Tagging would significantly extend the physics reach of the ATLAS and CMS detectors by giving access to a wide range of exciting new physics channels.

- FPT has the potential to make measurements which are unique at LHC and challenging even at a ILC.

- For certain BSM scenarios the FPT may be the Higgs discovery channel

- FPT offers a sensitive probe of the CP structure of the Higgs sector.

- *Nothing would happen before the experimentalists & engineers come FORWARD and do the REAL WORK .*

1. Thou shalt not worship any other god but the *First Principles*, and even if **thou likest it not,** go by **thy** *Book.*

2. Thou slalt not make unto **thee** any **graven image, thou shalt not** bow down **thyself** to them **.**

3.Thou shalt treat the existing diffractive experimental data in ways that show great consideration and respect.

4. Thou shalt draw **thy** daily guidance from the *standard candle processes* for testing **thy** theoretical models.

5. Thou shalt remember the speed of light to keep it **holy.** (*trigger latency*)

6.Thou shalt not dishonour backgrounds and **shalt** study them with great care.

7.Thou shalt not forget about the pile-up (an invention of **Satan**).

8. Though shalt not exceed the trigger thresholds and the L1 saturation limit. Otherwise **thy** god shall surely punish **thee** for **thy** arrogance.

9. Thou shalt not annoy machine people.

10. Thou shalt not delay, the LHC start-up is approaching

FP420 R&D Collaboration

- Spokes : Brian Cox (Manchester, ATLAS) and Albert DeRoeck (CERN,CMS)
- Technical Co-ordinator : Cinzia DaVia (Manchester)

Collaboration : FNAL, The University of Manchester, University of Eastern Piedmont, Novara and INFN-Turin, The Cockcroft Institute, University of Antwerpen, University of Texas at Arlington, The University of Glasgow, University of Calabria and INFN-Cosenza, CERN, Lawrence Livermore National Laboratory, University of Turin and INFN-Turin, University of Lund, Rutherford Appleton Laboratory, Molecular Biology Consortium, Institute for Particle Physics Phenomenology, Durham University, DESY, Helsinki Institute of Physics and University of Helsinki, UC Louvain, University of Hawaii, LAL Orsay, University of Alberta, Stony Brook University, Boston University, University of Nebraska, Institute of Physics, Academy of Sciences of the Czech Republic, Brookhaven National Laboratory, University College London, Cambridge University

(physics co-ordination: B. Cox & V. A. Khoze)

FP420 R&D Funding (ATLAS & CMS) :

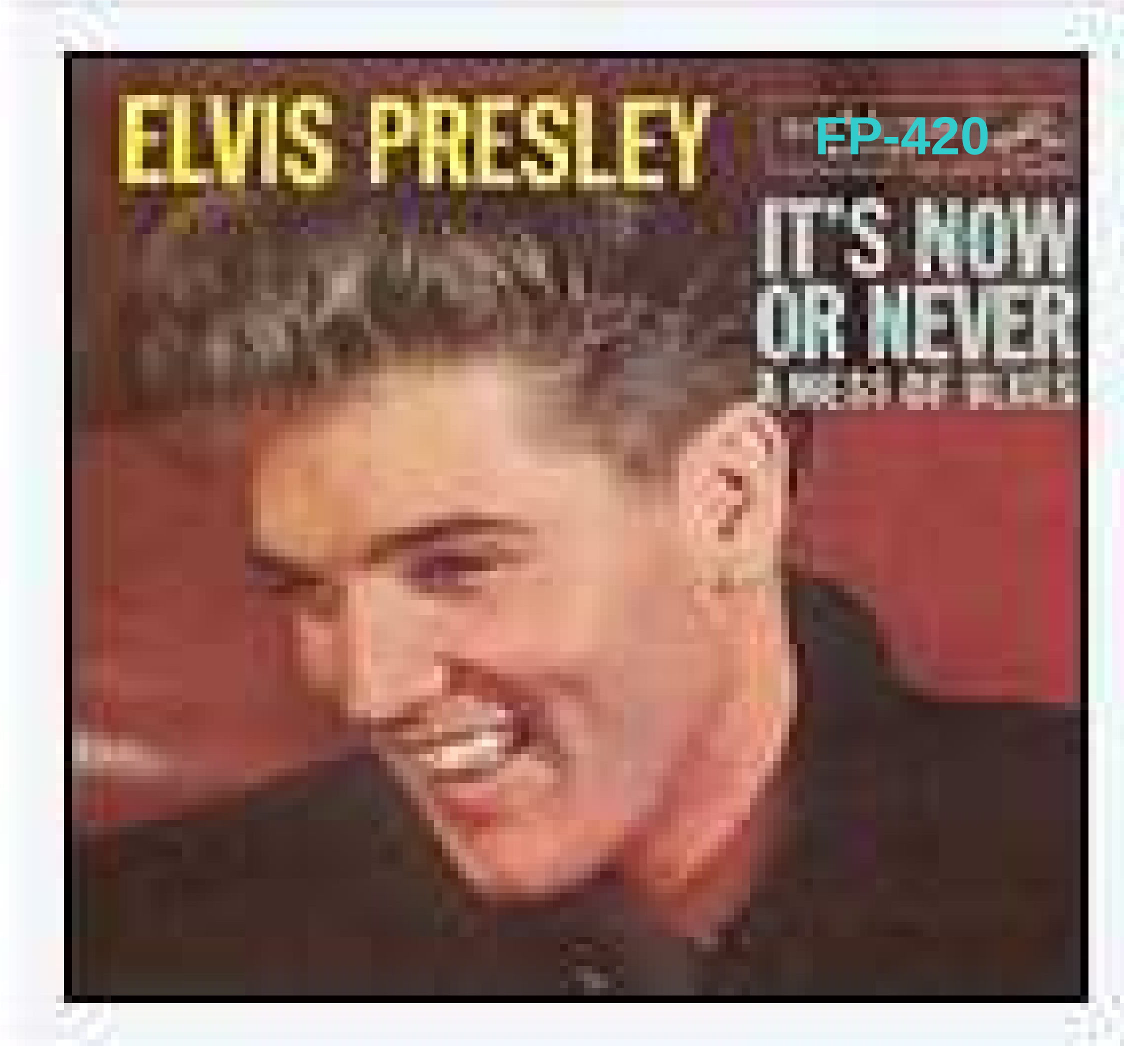
"The panel believed that this offers a unique opportunity to extend the potential of the LHC and has the potential to give a high scientific return." - UK PPRP (PPARC)

R&D now fully funded : £500k from UK (Silicon, detector stations, beam pipe + LHC optics and cryostat design), $100k from US (QUARTIC, Andrew Brandt/UTA), €100 Belgium (+Italy / Finland) (mechanics)

Funding bids will be assessed in Summer 2007 in the UK, and ATLAS and CMS will be asked to approve the project as an upgrade to the forward physics programs of each experiment at the same time.

Forward Physics Timetable

- FP420 is currently an R&D collaboration between ATLAS, CMS and non-affiliated groups.
- In addition, there is a strong, complementary program to upgrade the 220m region with horizontal pots at ATLAS, which adds significant value to 420m program
- Aim is to submit proposal to ATLAS for a sub-detector upgrade in Spring / Summer this year for 420m and 220m upgrades
- If accepted by ATLAS (and / or CMS), this would lead to TDR from experiment to LHCC in summer 2007
- The FP420 design phase is fully funded, and will be completed in summer 2007
- If funding is secured by Autumn 2007, cryostats (built by TS-MME) and baseline detectors could be ready for installation in Autumn 2008
- 220m detectors ready for installation in Autumn 2009
- 220m and 420m tagging detectors have the potential to add significantly to the discovery reach of ATLAS and CMS for modest cost, particularly in certain regions of MSSM parameter space
- There is a rich QCD and electroweak physics program in parallel with discovery physics



The LHC is coming!

Backup

B. Cox, DIS-06

The FP420 R&D Project

LOI to LHCC signed by 29 institutes from 11 countries - more in the process of joining

The aim of FP420 is to install high precision silicon tracking and fast timing detectors close to the beams at 420m from ATLAS and / or CMS

FP420 is basically a spectrometer using LHC magnets to bend protons with small momentum loss out of the beam (moveable silicon tracker ~ 8m long)

"The LHCC acknowledges the scientific merit of the FP420 physics program and the nterest in its exploring its feasibility." - LHCC

"The panel believed that this offers a unique opportunity to extend the potential of the LHC and has the potential to give a high scientific return." - UK PPRP (PPARC)

R&D fully funded till middle of 2007

FP420 Summary

B. Cox, DIS-06

• We have built a strong international collaboration with the manpower and expertise to deliver forward proton tagging at high luminosity to the LHC

•FP420 adds real discovery potential to ATLAS / CMS.

• 12 month R&D study fully funded from UK (and elsewhere) (~1000K CHF)

• Funding bids and significant manpower from Belgium, Italy, Germany, Finland, US, Canada

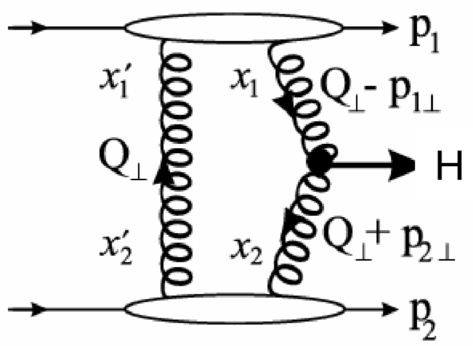
• Agreed list of key R&D areas (with CERN) to address machine safety issues and physics goals.

• Technical design by Feb 2007 (Manchester 2006) and (if successful) TDRs to LHCC from ATLAS / CMS spring 2007.

• First opportunity for installation 2009-2010 (first long break), dependent on LHC schedule.

• Physics returns potentially huge

Reliability of pred^n of $\sigma(pp \rightarrow p + H + p)$ crucial



$$\sigma \sim \frac{\hat{S}^2}{b^2} \left| N \int \frac{dQ_t^2}{Q_t^4} f_g(x_1, x_1', Q_t^2, \mu^2) f_g(x_2, x_2', Q_t^2, \mu^2) \right|^2$$

contain Sudakov factor T_g which exponentially suppresses infrared Q_t region → pQCD

$$f_g(x, x', Q_t^2, \mu^2) \;=\; R_g \frac{\partial}{\partial \ln Q_t^2} \left[\sqrt{T_g(Q_t, \mu)}\, x g(x, Q_t^2) \right]$$

$\langle Q_t \rangle_{SP} \sim M/2 \exp(-1/\bar{\alpha}_s)$, $\bar{\alpha}_s = N_c/\pi\, \alpha_s\, C_\gamma$

U. Maor

SM Higgs, $\langle Q_t \rangle_{SP} \approx 2$ GeV $\gg \Lambda_{QCD}$

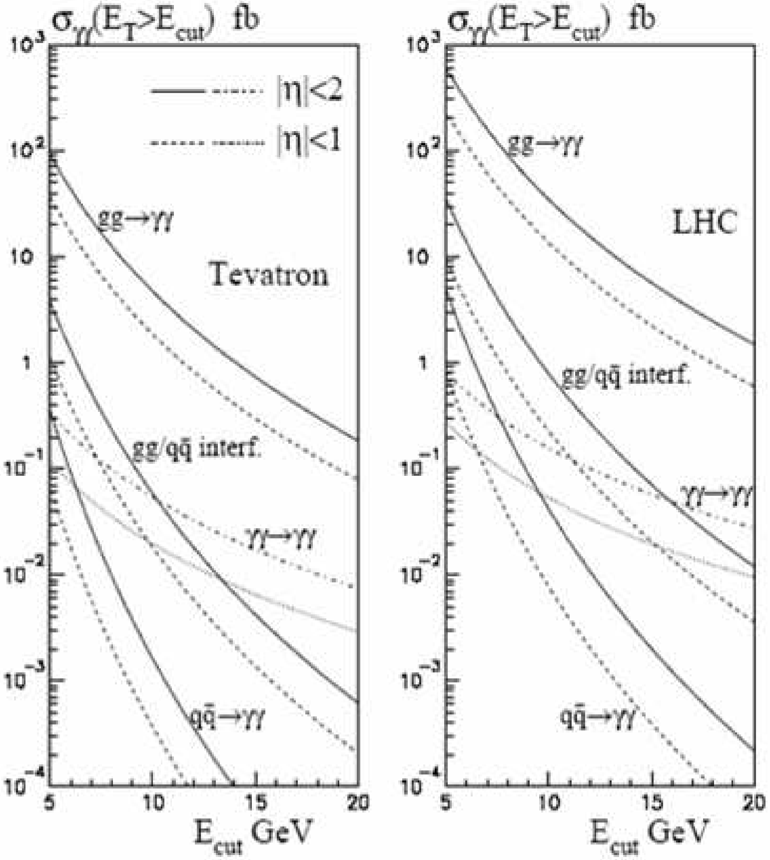
S^2 is the prob. that the rapidity gaps survive population by secondary hadrons
→ soft physics → S^2=0.026 (LHC) S^2=0.05 (Tevatron)

$\sigma(pp \rightarrow p + H + p) \sim 3$ fb at LHC for SM 120 GeV Higgs
~0.2 fb at Tevatron

Information from Tevatron!

Study of central exclusive processes

V. Khoze et al., hep-ph/0409037



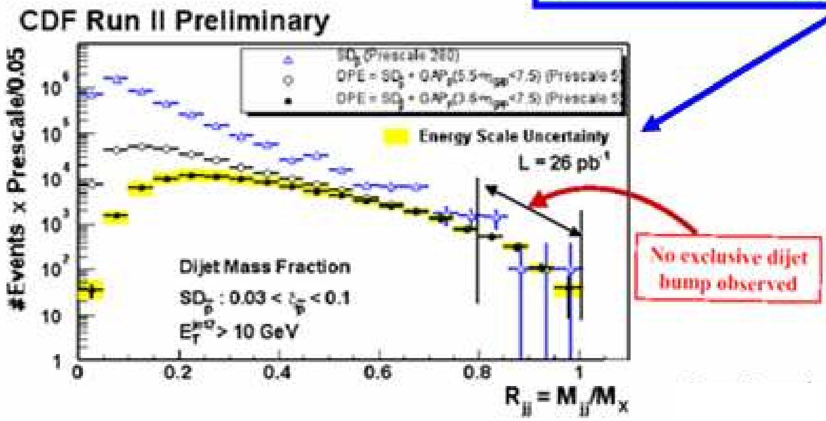
pp $\to$p + $\gamma\gamma$ +p

V. Khoze et al., hep-ph/0403218

	Tevatron $\sqrt{s}=2$ TeV χ_c	Tevatron $\sqrt{s}=2$ TeV χ_b	LHC $\sqrt{s}=14$ TeV χ_c	LHC $\sqrt{s}=14$ TeV χ_b
$d\sigma_{\rm excl}/dy\|_{y=0}$	130	0.2	340	0.6
$\sigma_{\rm excl}$	650	0.5	3000	4
$d\sigma_{\rm incl}/dy\|_{y=0}$	13	0.06	30	0.2
$\sigma_{\rm incl}$	70	0.3	200	2

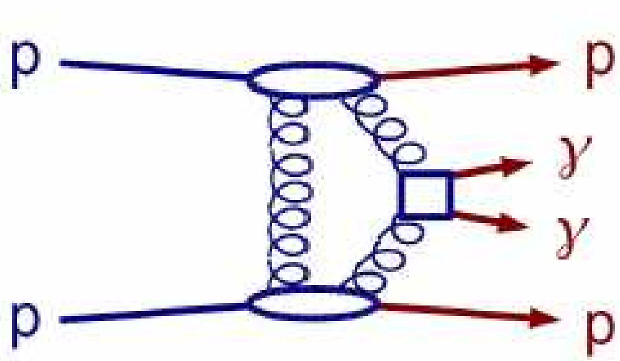
pp $\to$p + χ_c +p

pp $\to$p + dijets+p



pre-dictions

Exclusive $\gamma\gamma$ search



⇨ 3 candidate events found

background: $0.0\,^{+0.2}_{-0.0}$ events

$$\sigma_{MEASURED} = 0.14\ ^{+0.14}_{-0.04}\ (stat) \pm 0.03\ (sys)\ pb$$

good agreement with KMR:

$$\sigma_{KMR} = 0.04 \pm (\times 2-3)\ pb$$