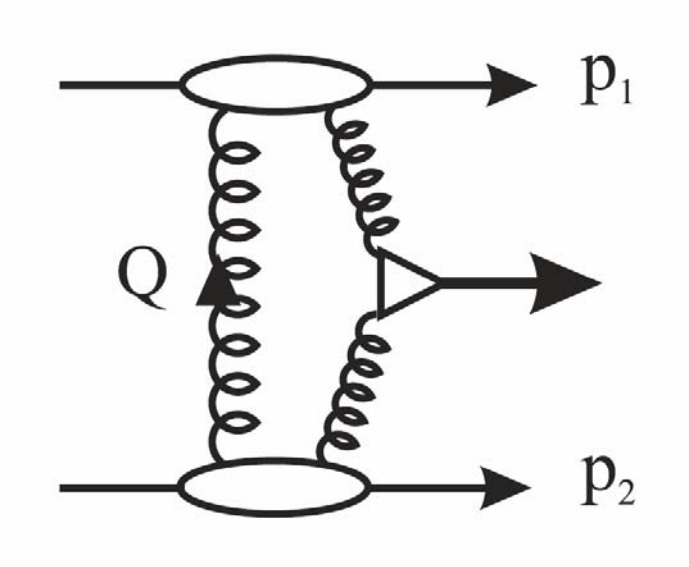
QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

# Double proton tagging at 420m as a means to discover new physics




- Tagging the protons means excellent mass resolution (~ several GeV)
- Selection rules mean that central system is (most likely) $0^{++}$ (or possibly $2^{++}$)
- If you see a new particle in any decay channel with proton tags, you know its quantum numbers
- CP violation in the couplings shows up directly as an azimuthal asymmetry in the tagged protons

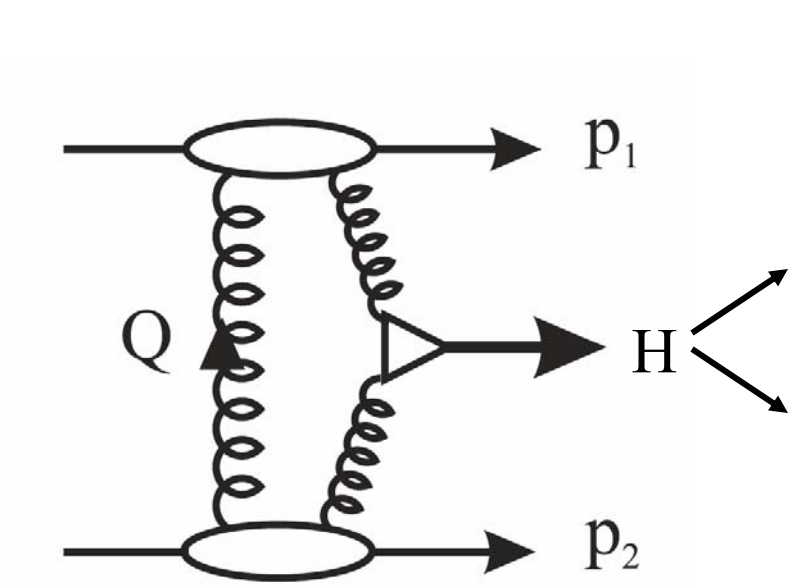
**hep-ph/0409144**

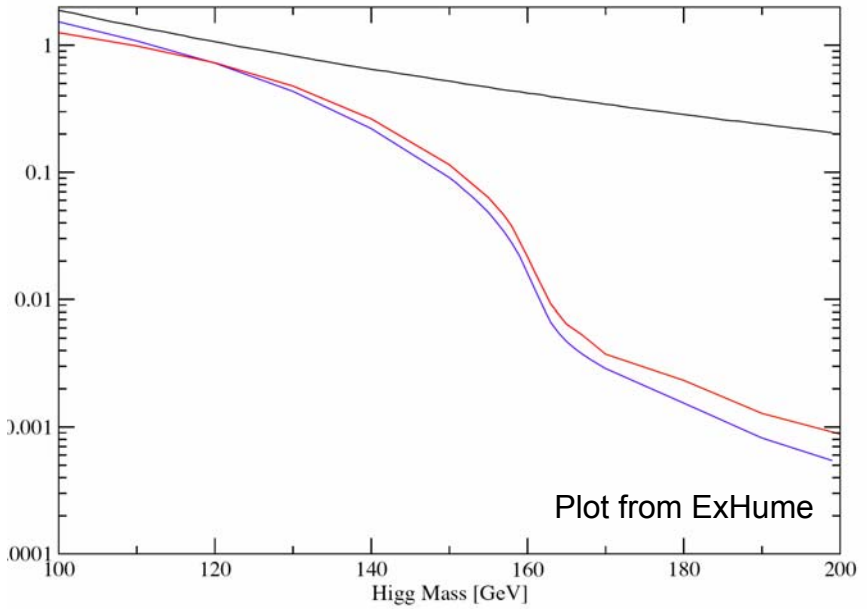


QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

# The phenomenology is moving fast, and getting more 'experiment friendly'

'Central exclusive production likes a heavy Higgs, and the best possible mass resolution'




• Assuming ~ 1 GeV mass resolution, the bb decay mode for standard model 120 GeV Higgs has S/B of order 1, with 11 signal events, in 30 $fb^{-1}$

$0^{++}$ Selection rule

QCD Background ~ $\frac{m_b^2}{E_T^2}\frac{\alpha_S^2}{M_{b\bar{b}}^2 E_T^2}$

Since resolution of taggers > SM Higgs width:

$$S/B \propto \Gamma(H \to gg)/\Delta M \propto G_F M_H^3/\Delta M$$

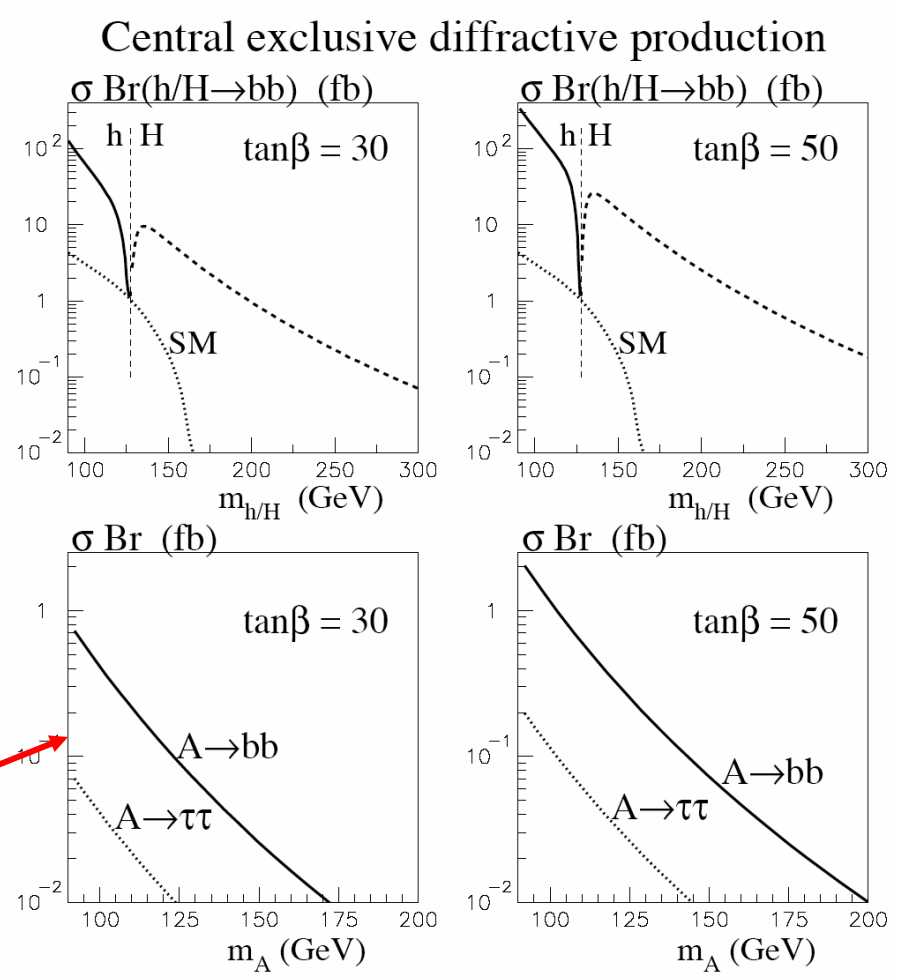
# The MSSM can be very proton-tagging friendly

e.g. $m_A$ = 130 GeV, tan β = 50
(difficult for conventional detection,
but exclusive diffractive favourable)

L = 30 fb$^{-1}$, ΔM = 1 GeV

| | S | B | |
|---|---|---|---|
| $m_h$ = 124.4 GeV | 71 | 9 | events |
| $m_H$ = 135.5 GeV | 124 | 6 | |
| $m_A$ = 130 GeV | 1 | 6 | |

Alan Martin Manchester Dec 2003



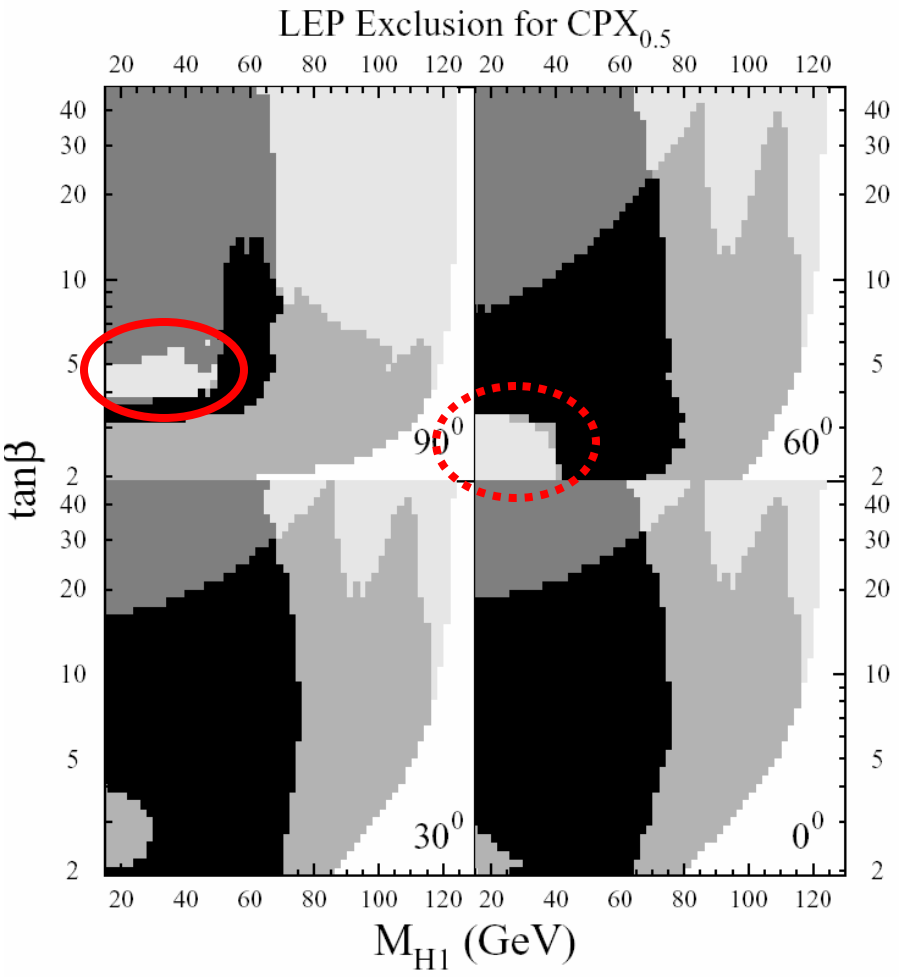

$0^{++}$ selection rule suppresses A production:

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

Kaidalov, Khoze, Martin, Ryskin hep-ph/0311023

# The MSSM with explicit CP violation - the 'CPX' scenario

Imagine a light scalar which couples predominantly to glue, and decays to b jets … would we see it at LEP, Tevatron or LHC?




In the CPX scenario, the three neutral MSSM Higgs bosons, (CP even) $h^0$ and $H^0$, and (CP odd) $a$ mix to produce 3 physical mass eigenstates $H_1$, $H_2$ and $H_3$ with mixed CP

Medium grey $e^+e^- \rightarrow ZH_i$

Dark grey $Z^* \rightarrow H_iH_j \rightarrow 4b$

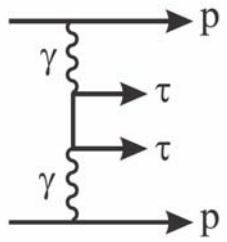
"there are small regions of parameter space in which none of the neutral Higgs bosons can be detected at the Tevatron and the LHC"

M. Carena, J. Ellis, S. Mrenna, A. Pilaftsis and C. E. M. Wagner, Nucl. Phys B659 (2003) 145

# The CPX Higgs - probably too light, but phenomenologically interesting

b bbar very difficult because of large background:

But ττ mode has only QED background




$$A = \frac{\sigma(\varphi < \pi) - \sigma(\varphi > \pi)}{\sigma(\varphi < \pi) + \sigma(\varphi > \pi)}$$

| $M(H_1)$ GeV | cuts | 30 | 40 | 50 |
|---|---|---|---|---|
| $\sigma(H_1)\mathrm{Br}(\tau\tau)$ | $a, b$ | 1.9 | 0.6 | 0.3 |
| $\sigma^{\mathrm{QED}}(\tau\tau)$ | $a, b$ | 0.2 | 0.1 | 0.04 |
| $A_{\tau\tau}$ | $b$ | 0.2 | 0.1 | 0.05 |

σ in fb

(b) $p_i^{\perp} > 300$ MeV for the forward outgoing protons

Direct evidence for CP violation in Higgs sector

$$\mathcal{M} = g_S \cdot (e_1^{\perp} \cdot e_2^{\perp}) - g_P \cdot \varepsilon^{\mu\nu\alpha\beta} e_{1\mu} e_{2\nu} p_{1\alpha} p_{2\beta} / (p_1 \cdot p_2)$$

CP even

CP odd active at non-zero t

Ongoing work - are there regions of MSSM parameter space where there are large CP violating couplings AND enhanced gluon coulpings?


B.C., Forshaw, Lee, Monk and Pilaftsis hep-ph/0303206

Khoze, Martin and Ryskin hep-ph/0401078

# Summary of the phenomenology

- If you have a sample of Higgs candidates, triggered by any means, accompanied by proton tags, it is a $0^{++}$ (or $2^{++}$) state. (see Valery Khozes' talk)
- AND the mass resolution will certainly be better than central detectors (e.g. H -> WW -> $\nu$l jj)

- If you can achieve good enough mass resolution (~1 GeV) then the standard model Higgs b decay mode opens up, with S/B ~ 1

- In certain regions of MSSM parameter space, S/B > 20, and double tagging is the discovery channel

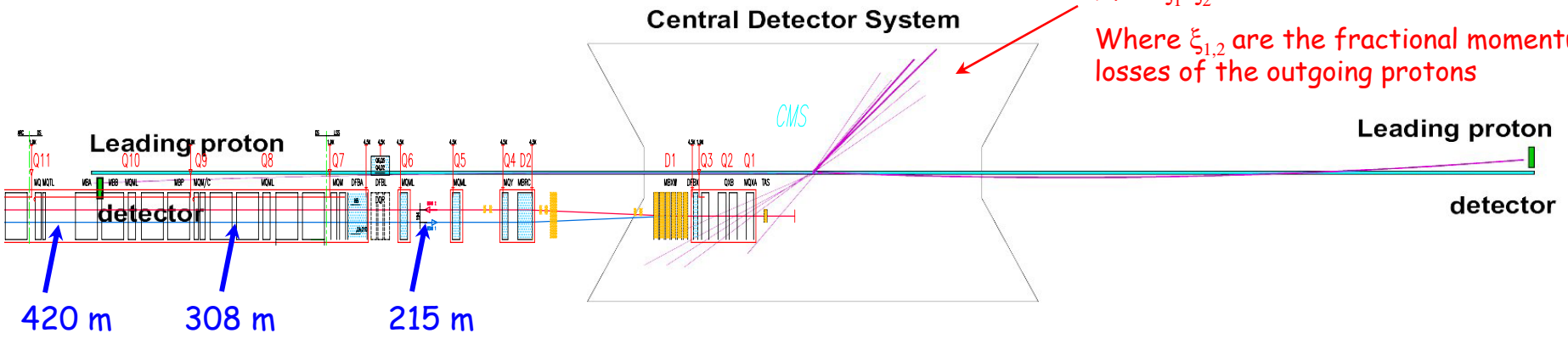
- In other regions of MSSM parameter space, explicit CP violation in the Higgs sector shows up as an azimuthal asymmetry in the tagged protons

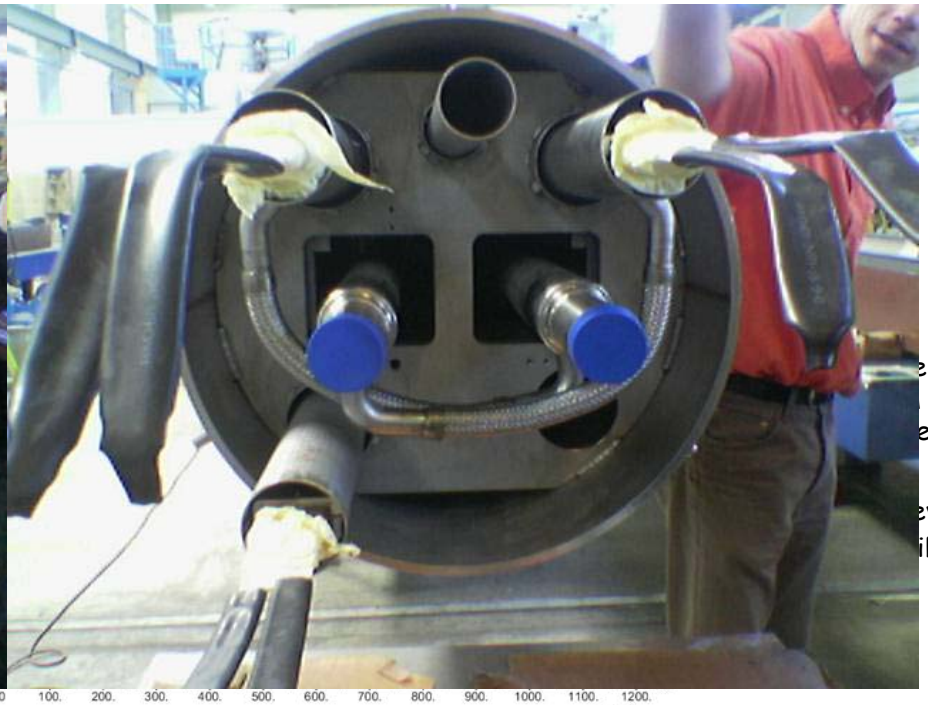
- Any $0^{++}$ state, which couples strongly to glue, is a real possibility (radions? gluinoballs? etc. etc.)

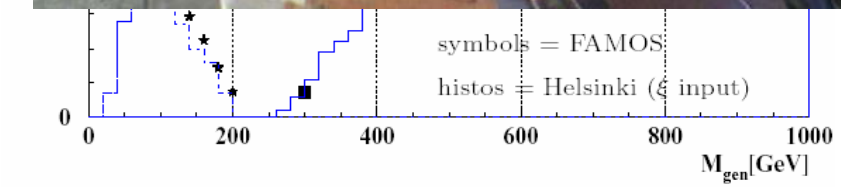
# The Experimental Challenges

$M^2 = \xi_1 \xi_2 S$

Where $\xi_{1,2}$ are the fractional momentum losses of the outgoing protons







K. Österberg

# What will it take to install taggers at 420m?

- Cryostat redesign?

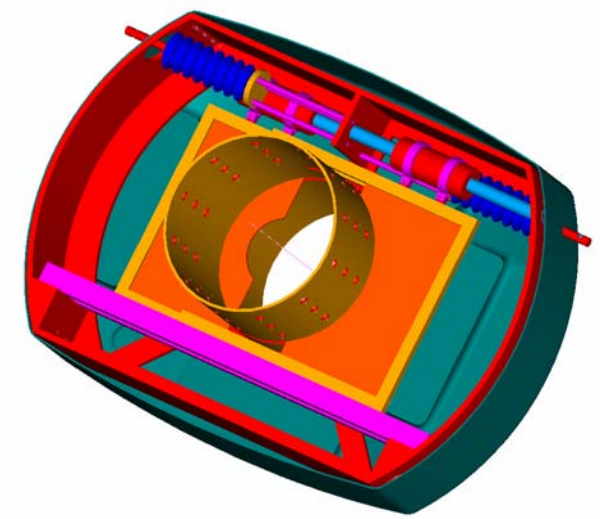
Design, fabrication, assembly and cold validation estimate 24 -30 months.

There is a planned shutdown long enough for installation in autumn 2008.

We (Manchester, Bristol, Brunel, IPPP, RAL, Glasgow, Cockroft institute) have bid for a cryostat engineer to work on R&D with CERN - hope to start Oct 2005

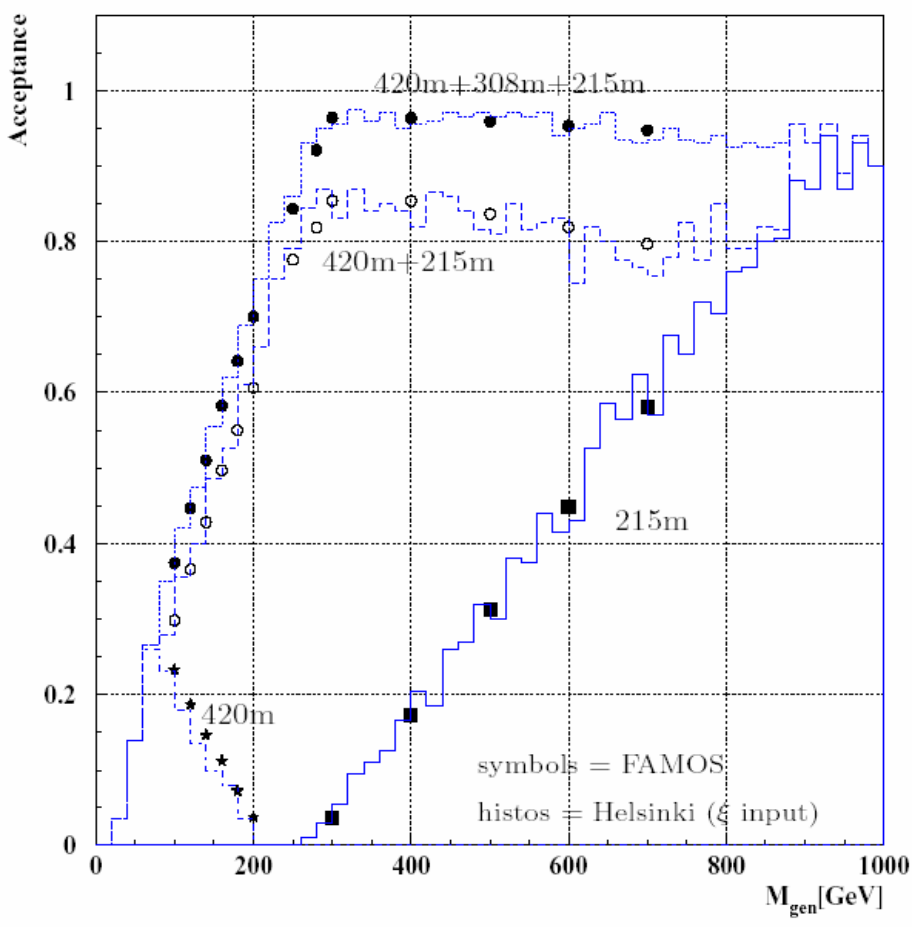
- Detector design?

Microstation-like design (but warm) from Helsinki



- Test beam will be available at Fermilab

# How does the 420m program fit with the current 220m proposals?



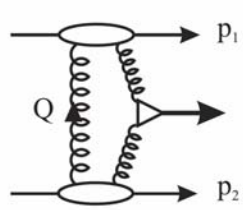

- Contributes largely for asymmetric events - i.e. one P at 220m, one P at 420m
- Increases acceptance by ~ 2 at 120 GeV
- May provide a 'last resort' trigger for difficult central systems
- Expertise gained at 220m will be extremely valuable for the 420m project

# Searching for exclusive production before 2009

- The cross section ~ factorises …

Hard subprocess cross section

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




Effective luminosity for production of mass M at rapidity y

… so can be checked by measuring higher rate processes at Tevatron and LHC

| Particle | $\sigma_{excl}$ | Decay channel | BR | Rate at $2.4\times10^{29}$ cm$^{-2}$ s$^{-1}$ $\beta^*$ = 1540 m (no acceptance / analysis cuts) | Rate at $10^{31}$ cm$^{-2}$ s$^{-1}$ $\beta^*$ = 200-400m |
|---|---|---|---|---|---|
| $\chi_{c0}$ (3.4 GeV) | 3 μb [KMRS] | $\gamma$ J/$\psi \to \gamma\, \mu^+\mu^-$<br>$\pi^+\pi^-$ K$^+$ K$^-$ | 6 x $10^{-4}$<br>0.018 | 1.5 / h<br>46 / h | 62 / h<br>1900 / h |
| $\chi_{b0}$ (9.9 GeV) | 4 nb [KMRS] | $\gamma\, \Upsilon \to \gamma\, \mu^+\mu^-$ | $10^{-3}$? | 0.08 / d | 3.5 / d |
| H (120 GeV) | 0.1 ÷ 10 fb assume 3 fb | $b\bar{b}$ | 0.68 | 0.02 / y | 1 / y |

KMR Prediction → $\sigma(\bar{p}p \to \bar{p} + \chi_c^{\,0}(\to J/\Psi + \gamma) + p)$

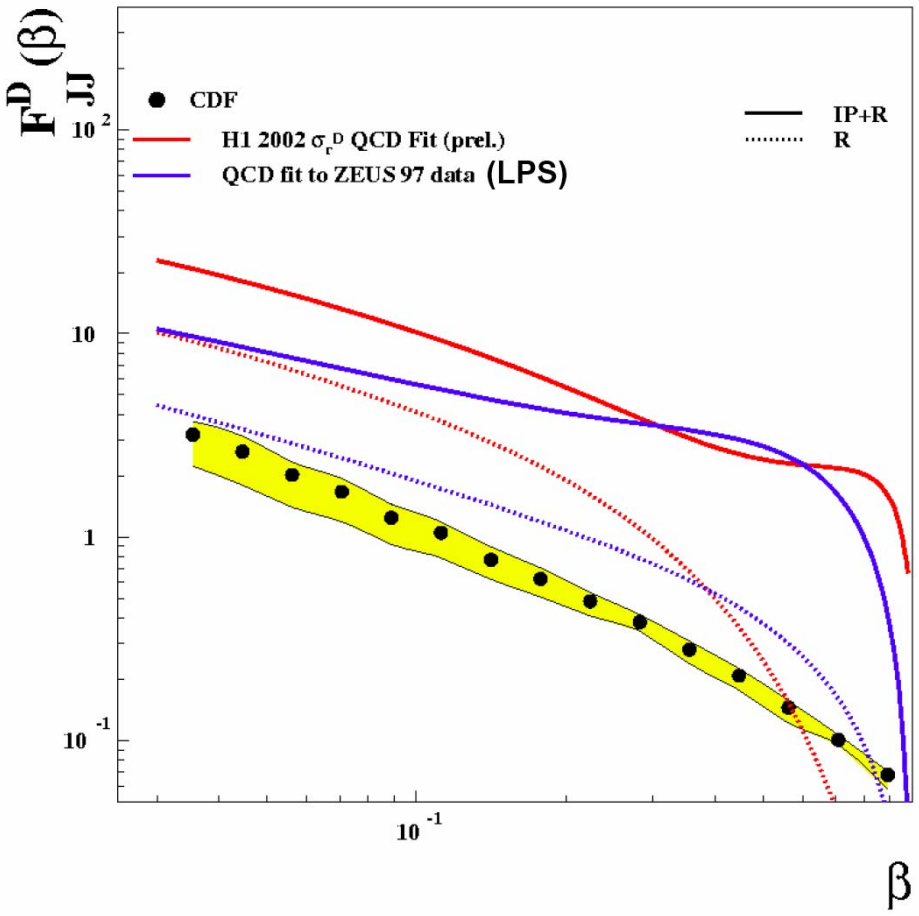
Eur. Phys. J. C19, 477 (2001)

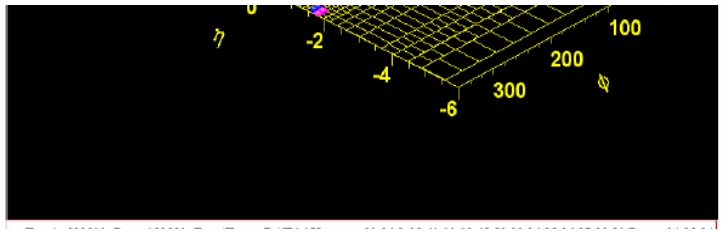
≈ 70 pb at $|y^{J/\Psi}|<0.6$ (factor 2-5 uncertainty)

K. Terashi (Rockefeller Univ.)

# The ‘inelastic’ process is an important background

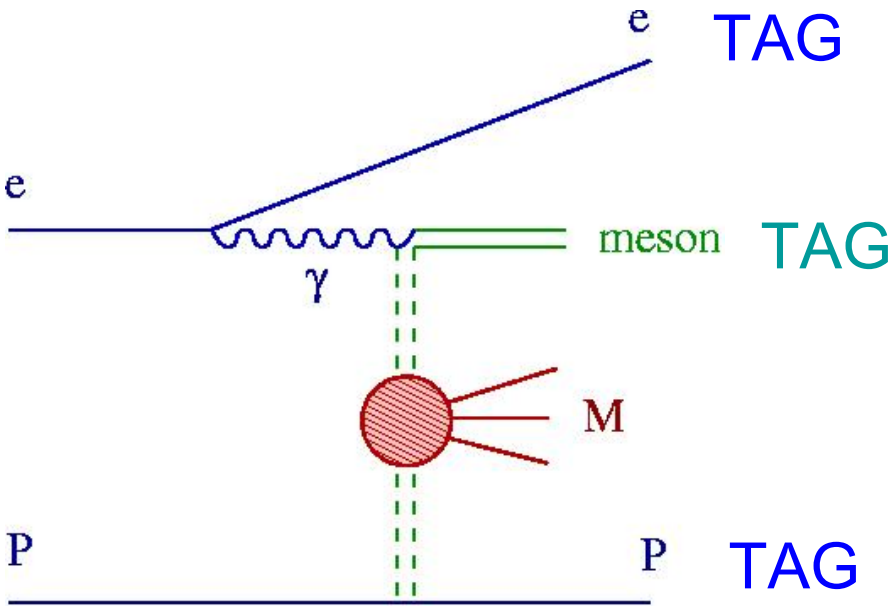
… at least for bb modes




…e tagged -
…b in this

Need the most accurate pomeron / reggeon pdf’s possible, plus gap survival



# Summary and work in progress

- If you see a resonance with proton tags, you know its quantum numbers
- Proton tagging allows excellent mass resolution
- If the Higgs (or any other new particles) couple strongly to gluons, proton tagging may be the discovery channel
- Proton tagging allows access to bb decay modes if good enough detector resolution can be acheived

- The Monte Carlo tools are coming on stream (see James Monks talk)
- The detectors can be warm at 420m - cryostat redesign is cheap
- It is still desirable (and possible?) to trigger directly at level 1 on 420m pots (at least at CMS) - work in progress
- Central bb trigger strategies including 220m asymmetric options) under study
- We (UK groups) are bidding to begin serious R&D by mid 2005