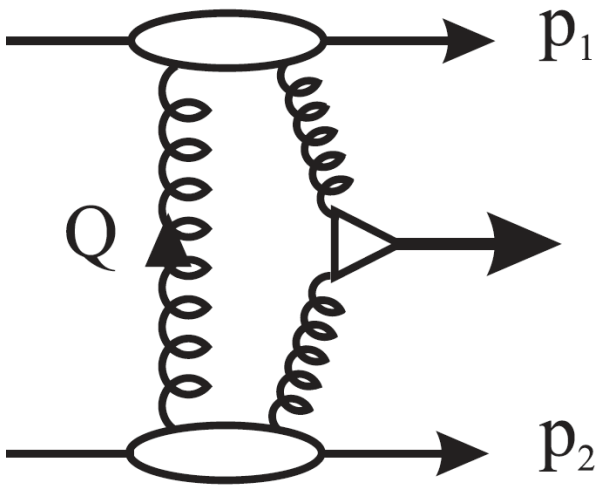
Forward Physics at 420m at LHC



- 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 …

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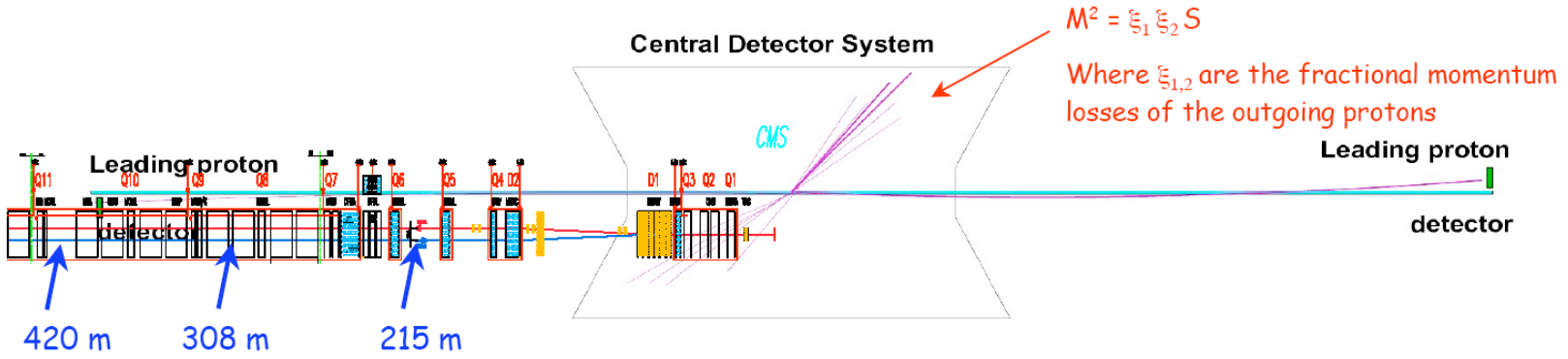
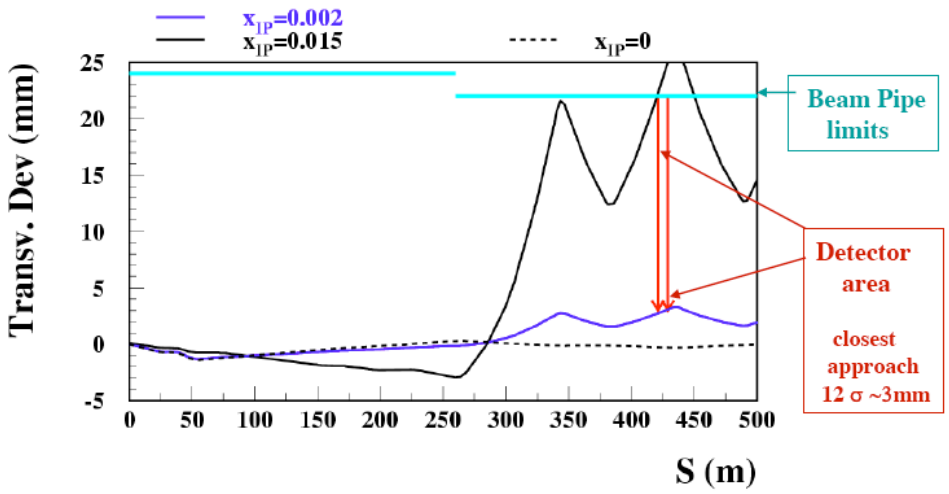
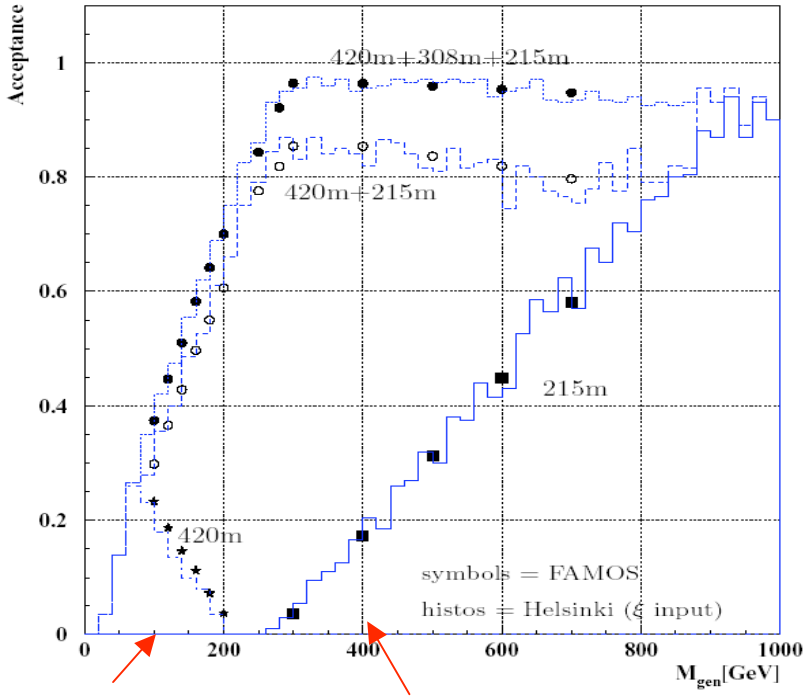
Central Production at LHC







Plots from Henri Kowalski and TOTEM (Helsinki group)

TOTEM

The University

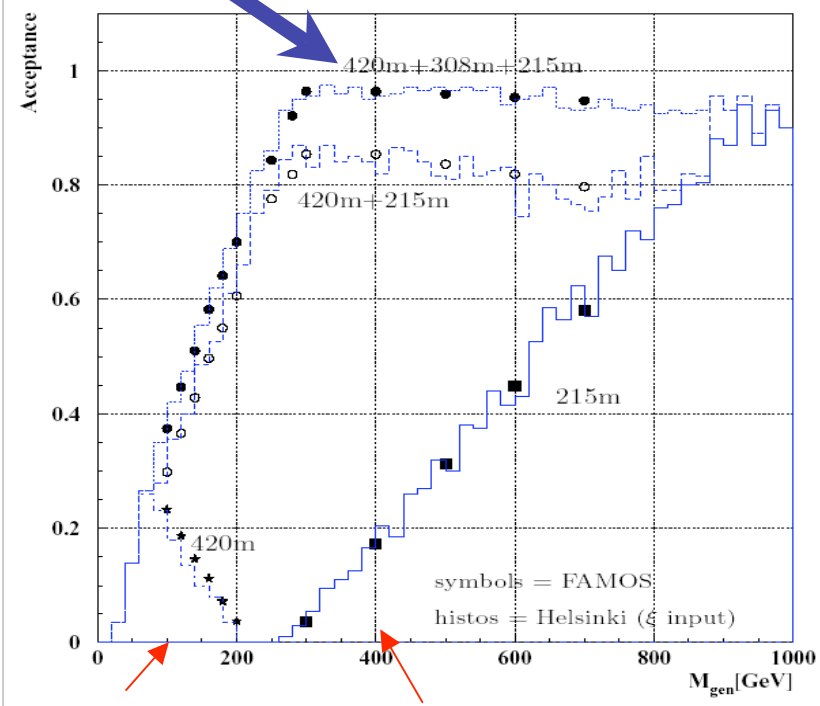
Transv. Dev (mm)

uctio at LHC

Systen

tional momentum

MADE THIS PLOT



x_{IP}~ 0.007

x_{IP}~ 0.03

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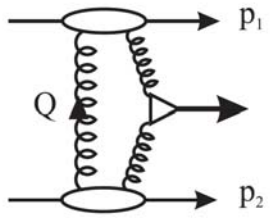
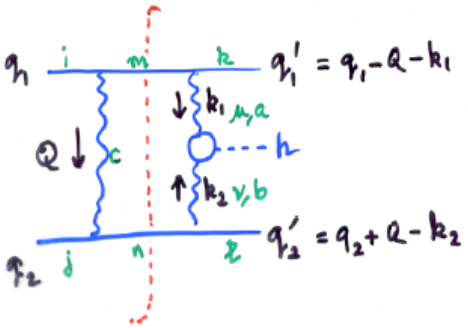
The KMR Calculation of the Exclusive Process



$qq \to q+H+q$



q -> Proton

$$\frac{d\sigma}{dy_H} \simeq \frac{1}{256\pi b^2} \frac{\alpha_s^2 G_F \sqrt{2}}{9} \left[\int \frac{d^2Q_1}{Q_1^4} f(x_1,Q_1^2)\, f(x_2,Q_1^2)\right]^2$$

$$f(x_i,Q_1^2) = \frac{\partial G(x_i,Q_1^2)}{\partial Q_1^2} \quad (x_i = \alpha_i)$$

Dominant uncertainty: KMR estimate factor of 2-3. Independent estimate by Lund group "definitely less than 10".

Divergent: controlled by Sudakov

exponentiating generates a factor in amplitude of

$$\exp(-S) = \exp\left(-\frac{C_A}{\pi}\int_{Q_T^2}^{\sim M_H^2} \alpha_s \frac{dp_T^2}{p_T^2} \int_{p_T}^{M_H/2} \frac{dE}{E}\right)$$ ← double logs

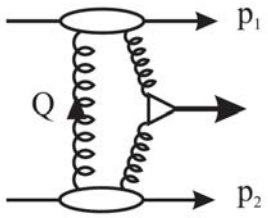
assuming $f \sim (Q^2)^{\gamma}$

$$Q \sim \frac{M_H}{2} \exp\left(-\frac{2\pi}{N_c \alpha_s}\left[\frac{n}{2}-1-2\gamma\right]\right)$$

$\alpha_s = 0.2$, $M_H = 100$ GeV, $n = 4$, $\gamma = 0.2$

→ 2 GeV

The KMR Calculation of the Exclusive Process



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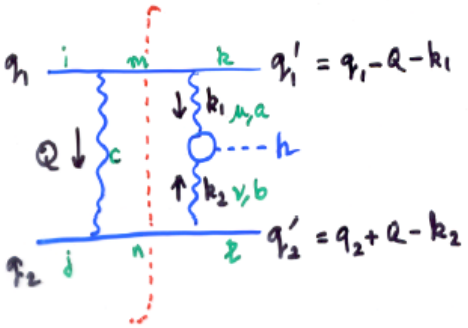

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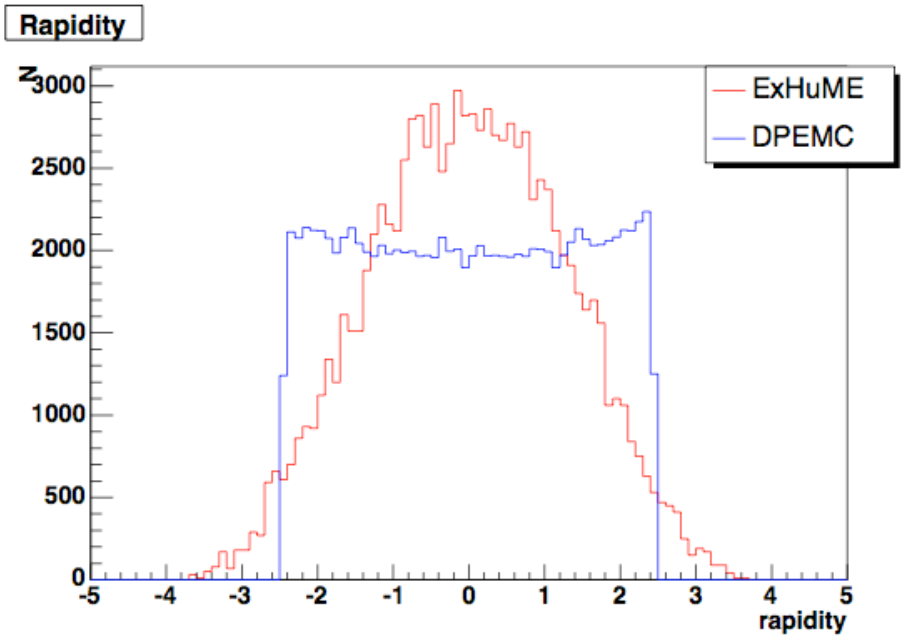
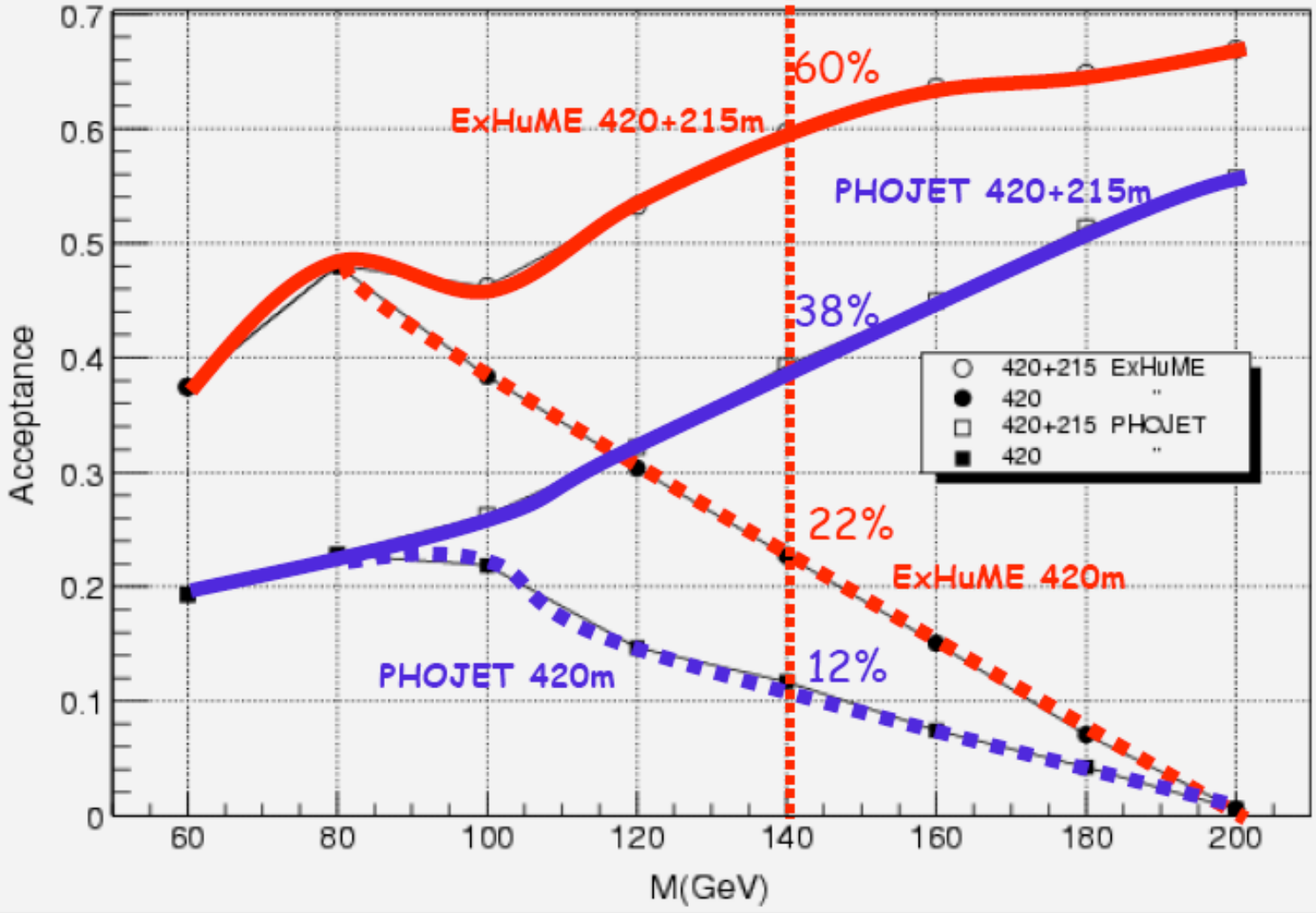


$$\exp(-S) = \exp\left(-\frac{C_A}{\pi}\int_{Q_T^2}^{(\frac{1}{2}M_H)^2} \frac{d\mu_T^2}{\mu_T^2}\,\alpha_s \int_{p_T}^{M_H/2} \frac{dE}{E}\right)$$ ← double logs

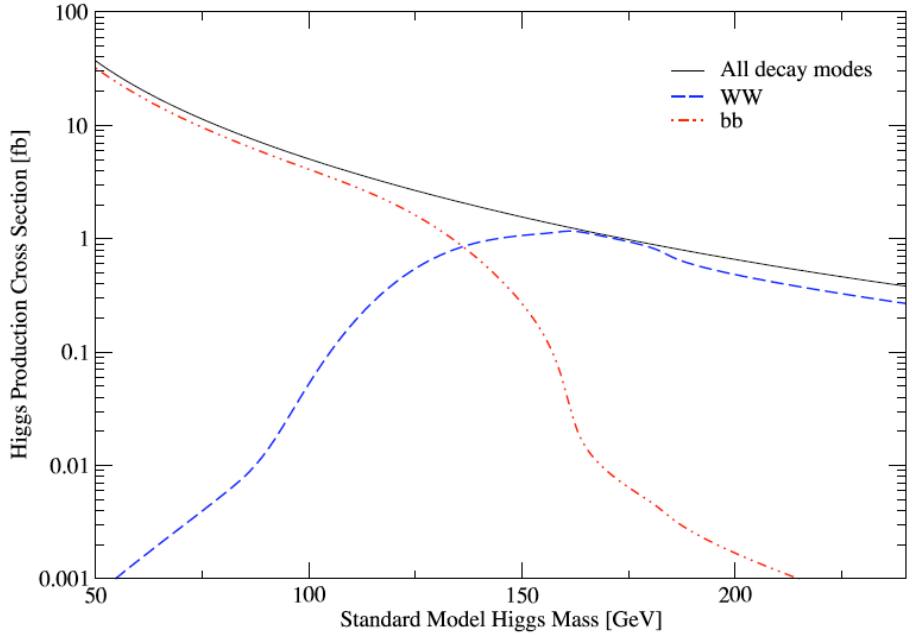
Latest Acceptance curves from Helsinki Group

"420+215" calculation: either both protons are detected at 420m, or both protons are detected at 215m, or one proton is detected at 420 [215]m with the other one detected at 215 [420]m.



Helsinki group: J.Lamsa (parametrisations of the MAD simulation results of T. Mäki by RO)

The Benchmark process : SM Higgs production



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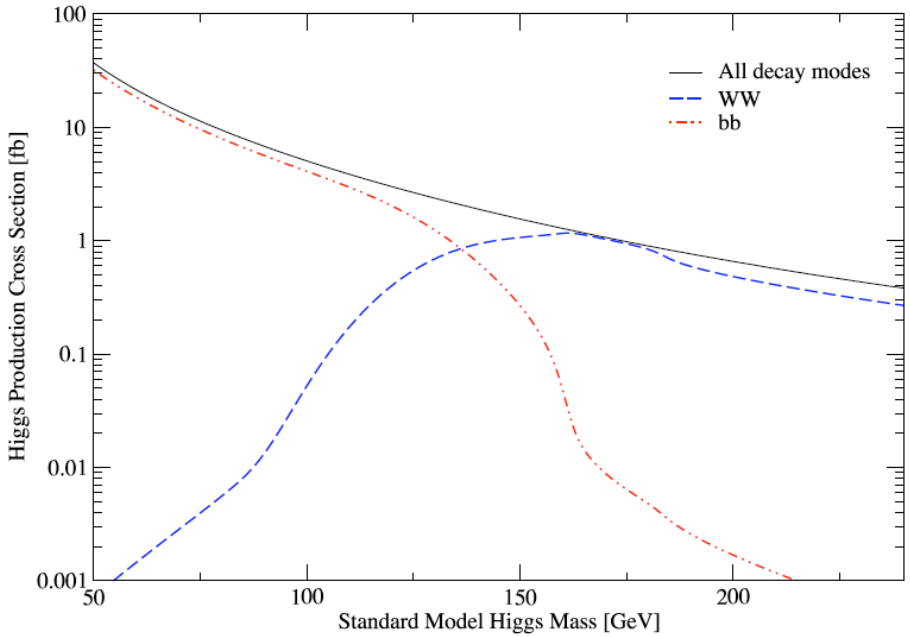
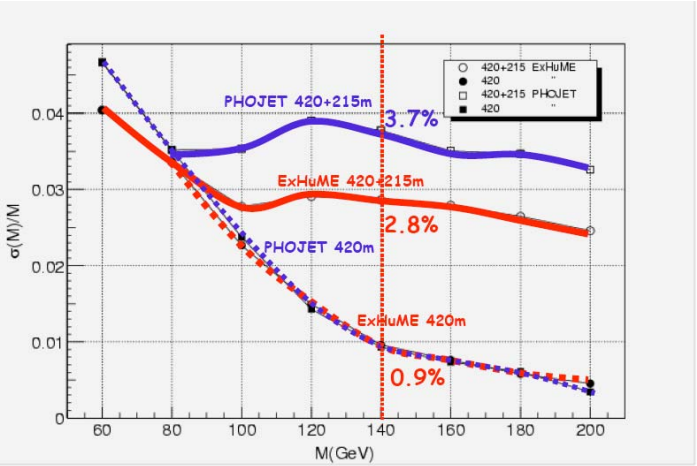


b jets : M_H = 120 GeV σ = 2 fb

M_H = 140 GeV σ = 0.7 fb

M_H = 120 GeV : 11 signal, S/B ~ 1 in 30 fb^{-1}



Helsinki group: J.Lamsa (parametrisations of the MAD simulation results of T. Mäki by RO)

0^{++} Selection rule

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

Also, since resolution of taggers > Higgs width:

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

- The b jet channel is possible, with a good understanding of detectors and clever level 1 trigger
- The WW* (ZZ*) channel is extremely promising : no trigger problems, better mass resolution at higher masses (even in leptonic / semi-leptonic channel)
- If we see Higgs + tags - the quantum numbers are 0^{++}

Resolution from R. Orava, FP420 FNAL meeting , 26 April

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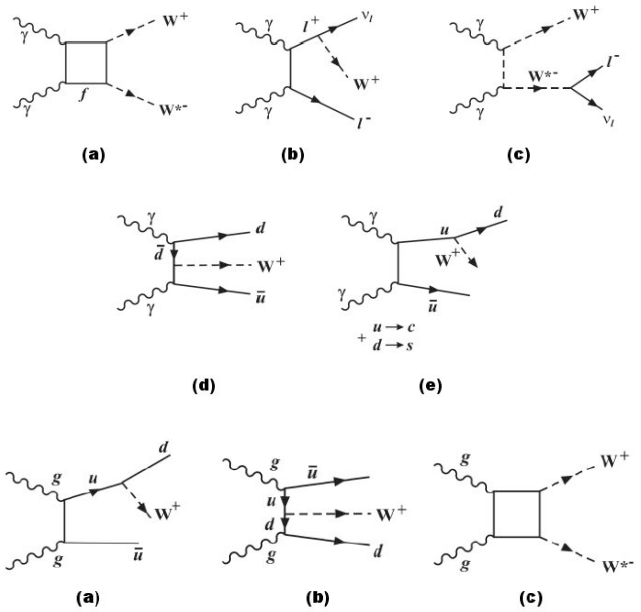
The Benchmark process : SM Higgs production

Selection cuts	Higgs Mass (GeV)	Efficiency	Signal σ (fb)	Events / 30 fb^{-1}
Generated	120	100%	0.40	12
	140	100%	0.93	28
	160	100%	1.16	35
	180	100%	0.84	25
	200	100%	0.48	15
Single lepton trigger: an electron with $p_T > 25$ GeV or a muon with $p_T > 20$ GeV within $\|\eta\| < 2.5$	120	14 %	0.06	2
	140	19 %	0.18	5
	160	23 %	0.27	8
	180	25 %	0.21	6
	200	26 %	0.12	4
2 or more jets within $\|\eta\| < 2.5$	120	11 %	0.05	1
	140	15 %	0.14	4
	160	19 %	0.22	7
	180	20 %	0.17	5
	200	22 %	0.10	3
Acceptance of proton taggers (420m + 220m)	120	7 %	0.03	1
	140	10 %	0.10	3
	160	14 %	0.16	5
	180	15 %	0.13	4
	200	17 %	0.08	2
p_T(protons) > 100 MeV	120	–	–	–
	140	–	–	–
	160	13 %	0.13	4
	180	14 %	0.12	3
	200	15 %	0.07	2
Mass of the hadronic W 70 GeV $< M_W <$ 90 GeV	120	0.5 %	0.002	0
	140	2 %	0.02	1
	160	7 %	0.08	2
	180	9 %	0.07	2
	200	10 %	0.05	1



B.C., A. De Roeck, V. A. Khoze, W. J. Stirling et. al. To be published

The MSSM can be very proton-tagging friendly

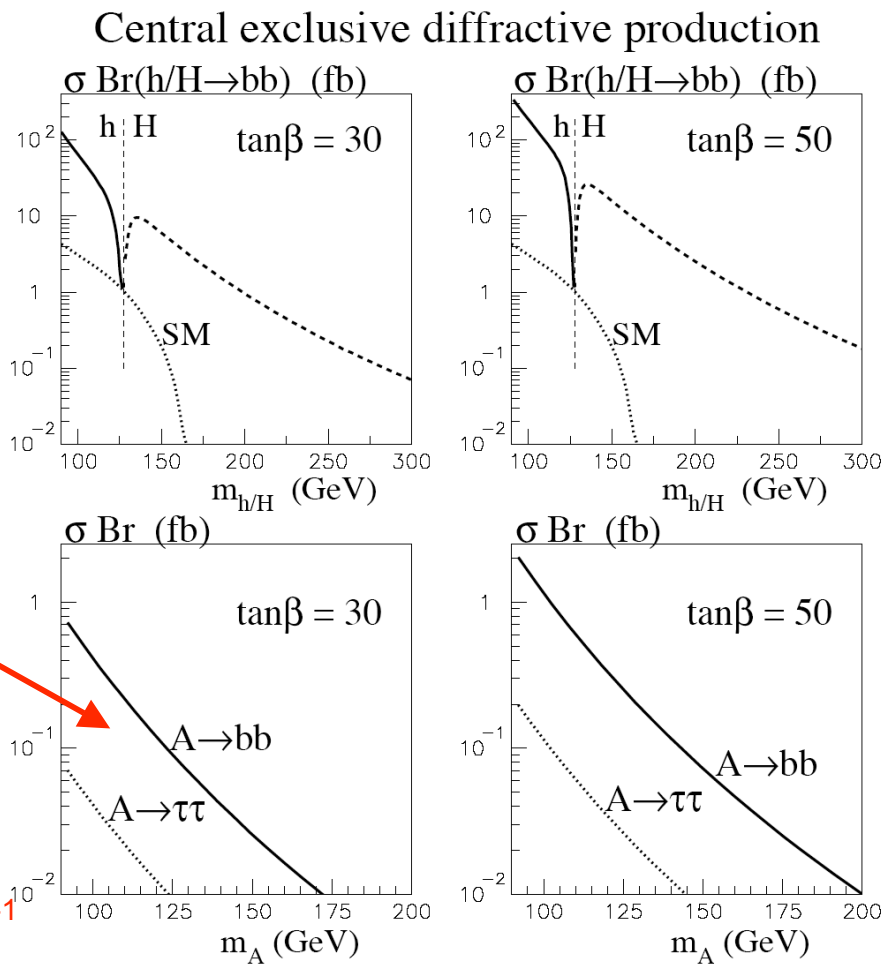
The intense coupling regime is where the masses of the 3 neutral Higgs bosons are close to each other and tan β is large

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

$gg \rightarrow \phi$ enhanced

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

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



M_A = 130 GeV, tan β = 50

M_h = 124 GeV : 71 signal / 3 background in 30 fb^{-1}

M_H = 135 GeV : 124 signal / 2 background in 30 fb^{-1}

M_A = 130 GeV : 3 signal / 2 background in 30 fb^{-1}

Tagged channel may well be the discovery channel, if L1 trigger can be provided. Powerful spin/parity filter may be key to disentangling such a Higgs sector

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Probing CP violation in the Higgs Sector

Azimuthal asymmetry in tagged protons provides direct evidence for CP violation in Higgs sector

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

$M(H_1)$ 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

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

'CPX' scenario
σ in fb

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

CP even

CP odd active at non-zero t

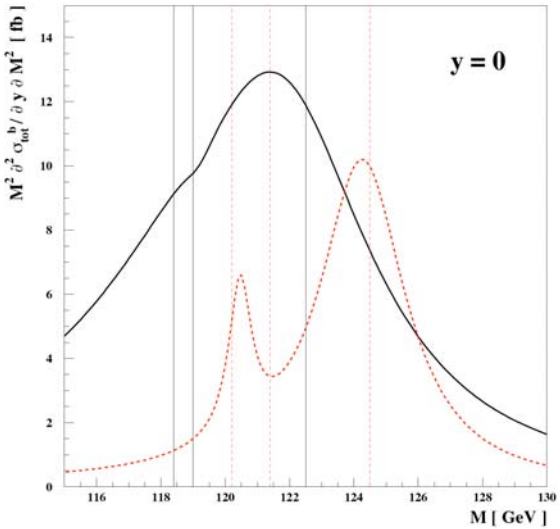
Ongoing work - are there regions of MSSM parameter space where there are large CP violating couplings AND enhanced gluon couplings?

B.C., Forshaw, Lee, Monk and Pilaftsis Phys. Rev. D. 68 (2003) 075004

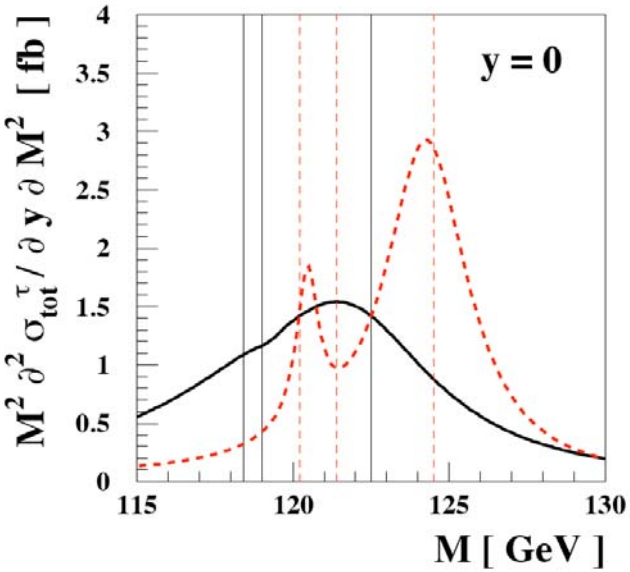
Khoze, Martin and Ryskin Eur. Phys. J. C 24 (2004) 327

CP violation in the Higgs Sector

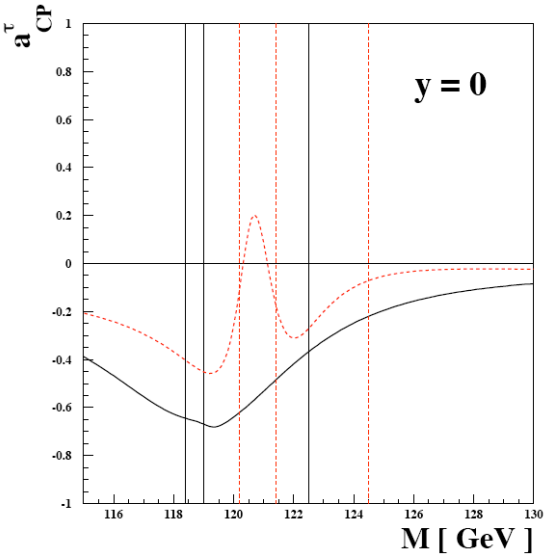
bb decay



ττ decay



ττ decay



This example shows that exclusive double diffraction may offer unique possibilities for exploring Higgs physics in ways that would be difficult or even impossible in inclusive Higgs production. In particular, we have shown that exclusive double diffraction constitutes an efficient CP and lineshape analyzer of the resonant Higgs-boson dynamics in multi-Higgs models. In the specific case of CP-violating MSSM Higgs physics discussed here, which is potentially of great importance for electroweak baryogenesis, diffractive production may be the most promising probe at the LHC.

J. Ellis et. al. hep-ph/0502251

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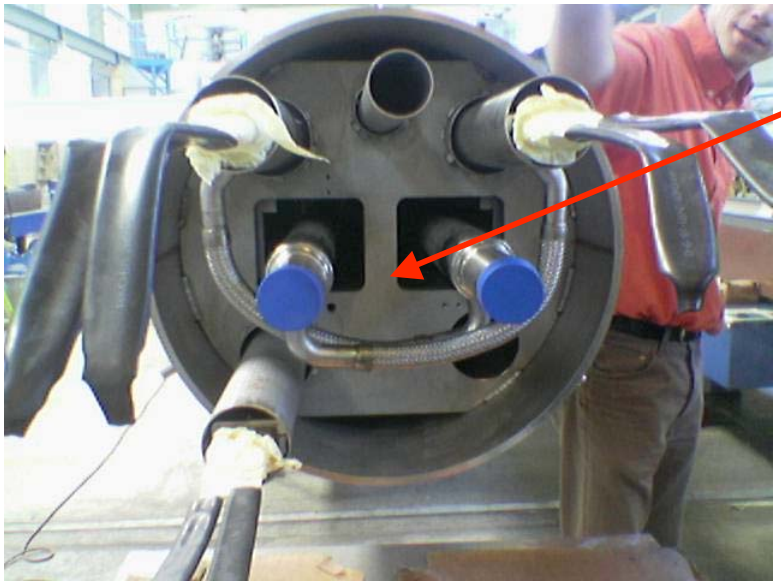
Instrumenting the 420m region

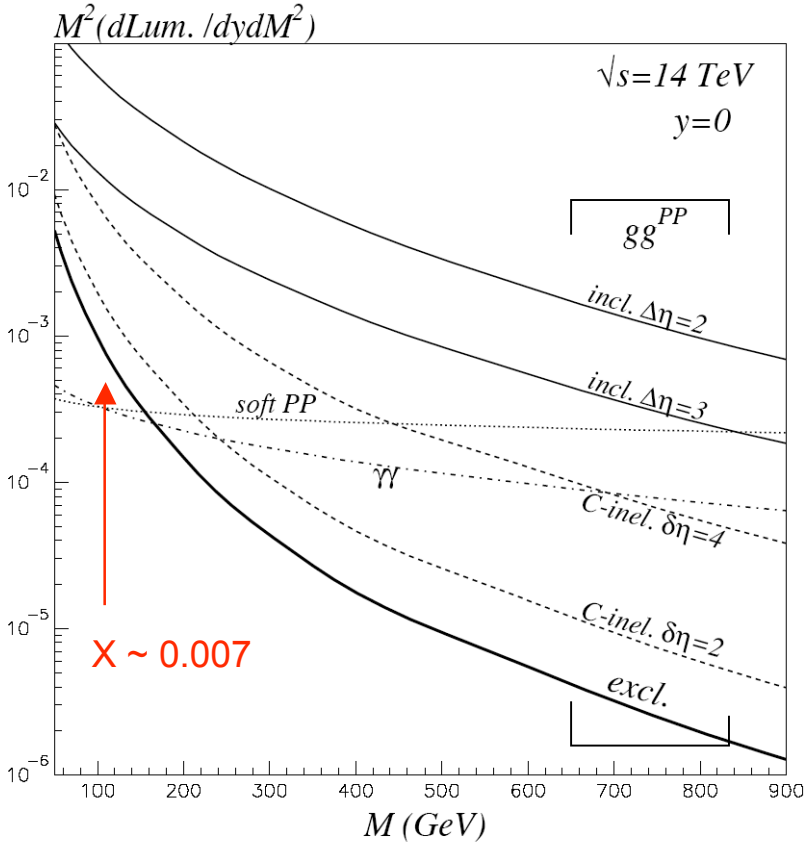


Diffracted protons emerge between beam pipes

- 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 Cockroft 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.

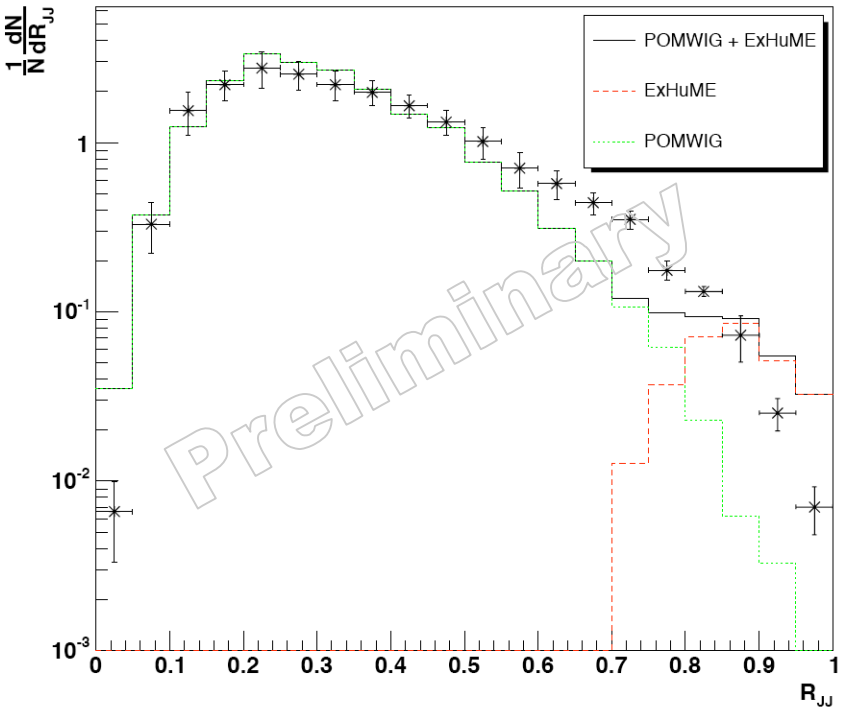
Exclusive dijets at Tevatron



ExHuME Monte Carlo - direct implementation of KMR

www.exhume-me.com

J. Monk and A. Pilkington, hep-ph/0502077



Plot from B.C. and A. Pilkington, to be published

Khoze, Martin and Ryskin, Eur.Phys.J.C23:311-327,2002

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The case for FP420

- 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

For a review and references, see hep-ph/0409144