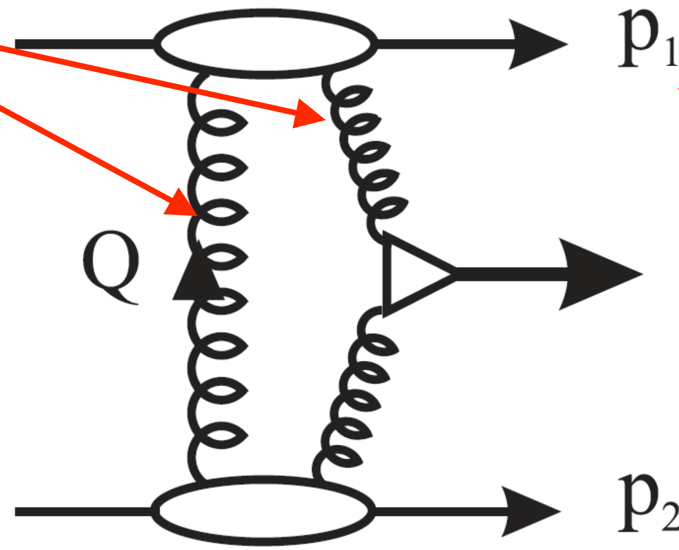
Forward Proton Tagging as a means to discover new physics

Only 0^{++} (or 2^{++}) systems produced

$b\bar{b}$ background strongly suppressed



Excellent mass resolution

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What are the key issues?

- We have to get detectors close to the beam at 420m

This means modifying the 420m cryostat.

The UK will bid for a 2 year post to work with LHC Cryogenic group on this modification

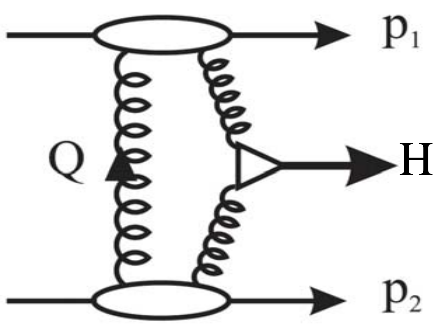
- We have to trigger on the events

This is a challenge for the b-decay mode for a light standard model Higgs. WW^* decay mode is under investigation

- We have to align / calibrate the detectors (almost certainly with a high cross section physics process)

Exclusive di-photon production is a candidate, as is diffractive production of e.g. upsilon

The Standard Model Higgs



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

M_H = 140 GeV σ = 0.7 fb

M_H = 120 GeV : 11 signal / 3? background in 30 fb^{-1}

0^{++} Selection rule

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

- The S/B depends on the missing mass resolution (and M_H)

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

- 420m pots are too far away for L1 trigger except in special running at CMS (ATLAS?)

Solution may be high p_T (~30) GeV lepton tagging (30% of events) + energy flow / centrality requirements on jets

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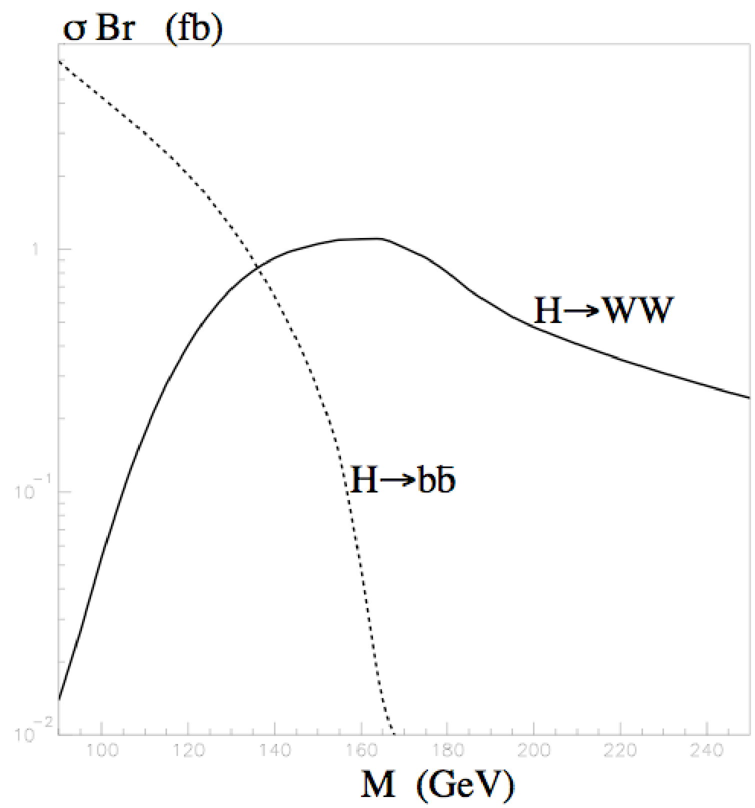
The Standard Model Higgs -> WW / WW*

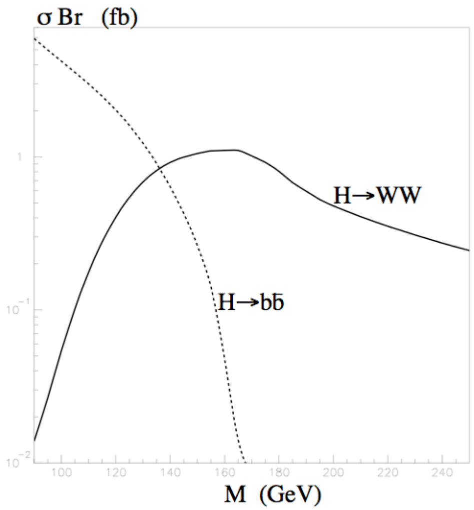


BR(W->e ν) = BR(W->mu ν) ~ 10.5%

B.C. , V. Khoze, A. DeRoeck et. al. To be published

e.g. at 135 GeV, expect efficiency of ~ 20% for all e/μ channels -> 4 events in 20 fb^{-1}

The Standard Model Higgs -> WW / WW*

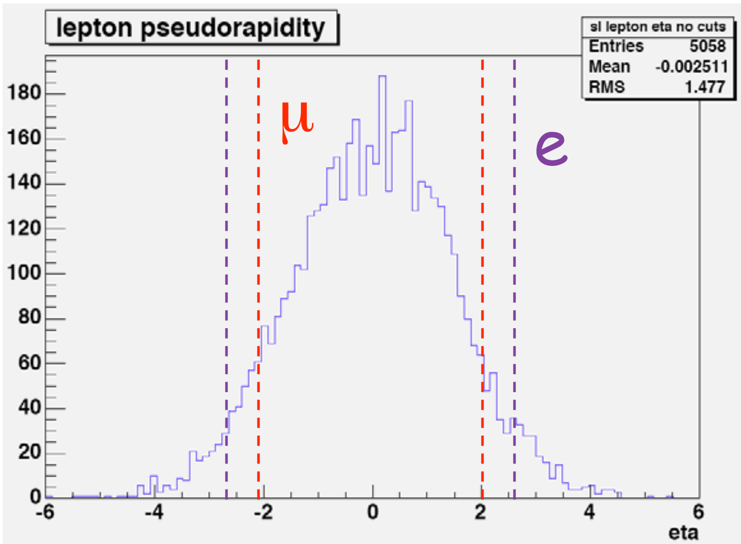


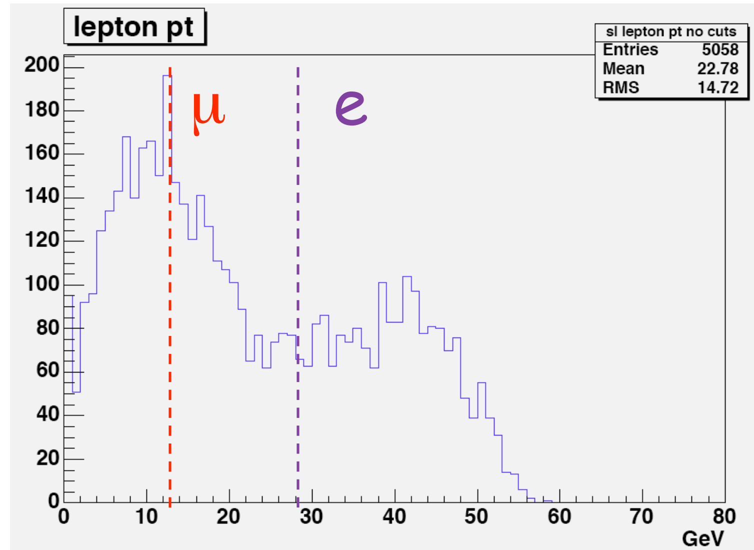
	120 GeV / 135 GeV
• 0) Acc(RP1)>0 and Acc(RP2)>0	57.9% / 66.5%

All following are total acceptances (incl BR, RP acceptance etc.):

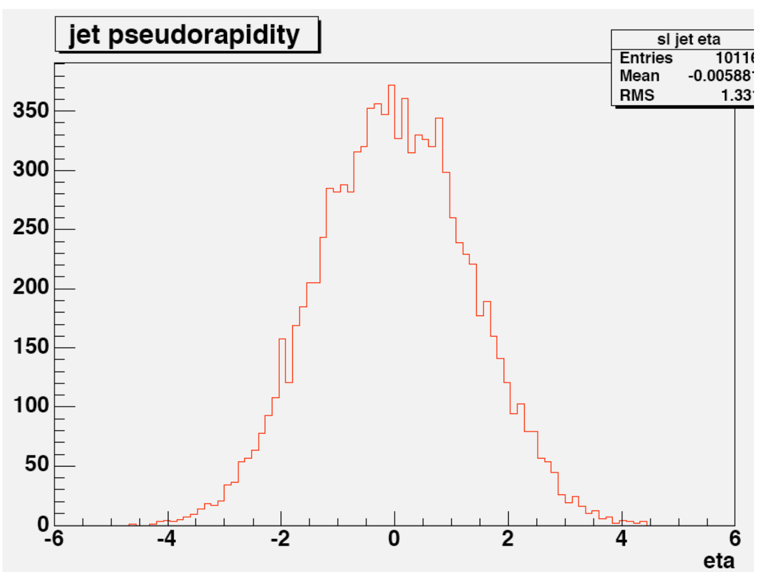
• 1) single e found: pt1>29GeV, |eta1|<2.5:	3.8% / 4.9%
• 2) two e found: pt1>17GeV,pt2>17GeV, |eta1|<2.5,|eta2|<2.5:	0.2%/ 0.4%
• 3) single mu found: pt1>14GeV, |eta1|<2.1:	7.9% / 10.7%
• 4) two mu found: pt1>3GeV,pt2>3GeV, |eta1|<2.1, |eta2|<2.1:	0.6%/ 1.5%
• 5) 1 lepton + 2 quark jets > 25 GeV	2.5%/ 2.8%

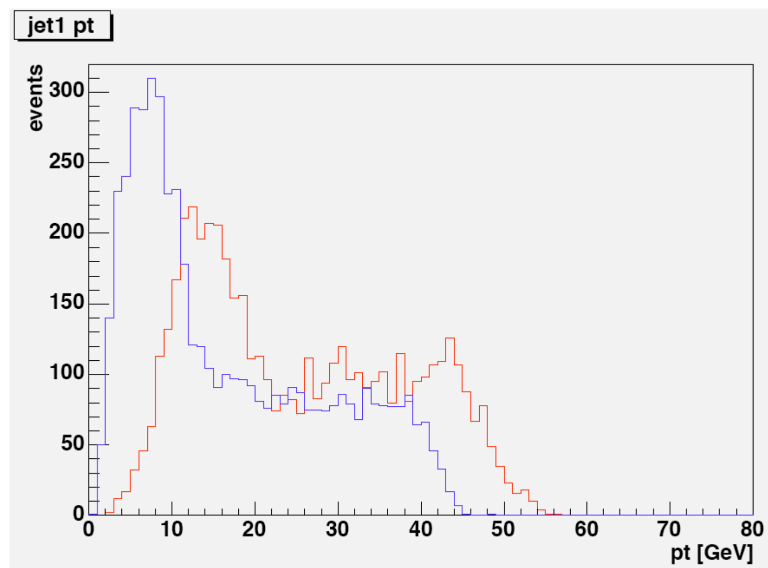
Preliminary plots from ExHume / PYTHIA, M_H = 120 GeV





Jets found using KTJET, exclusive mode forcing 2 jets





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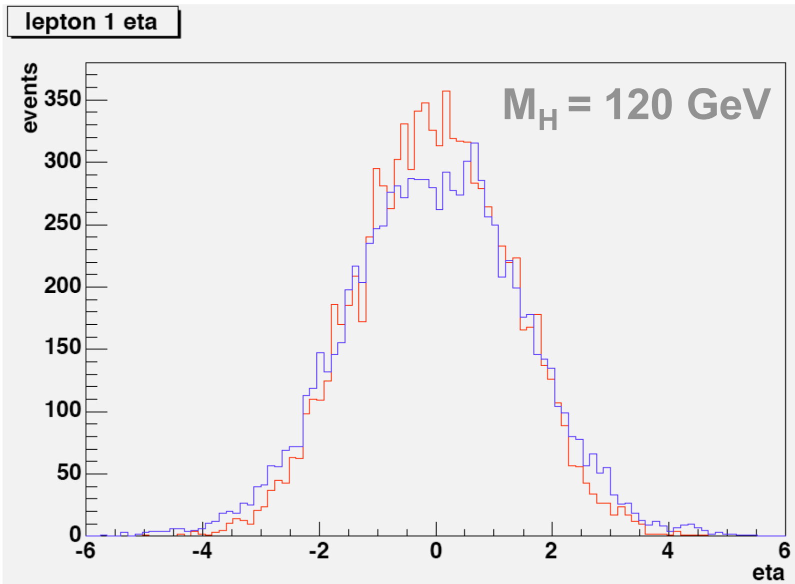
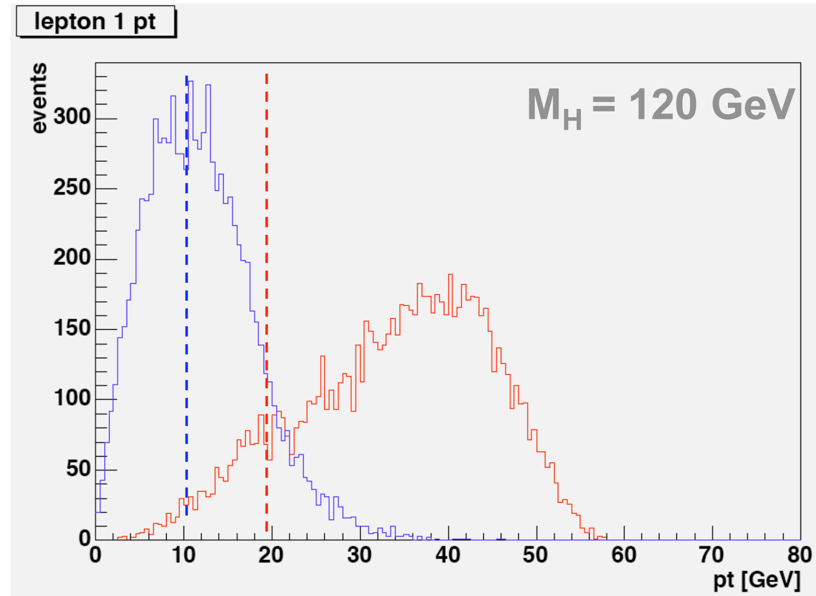
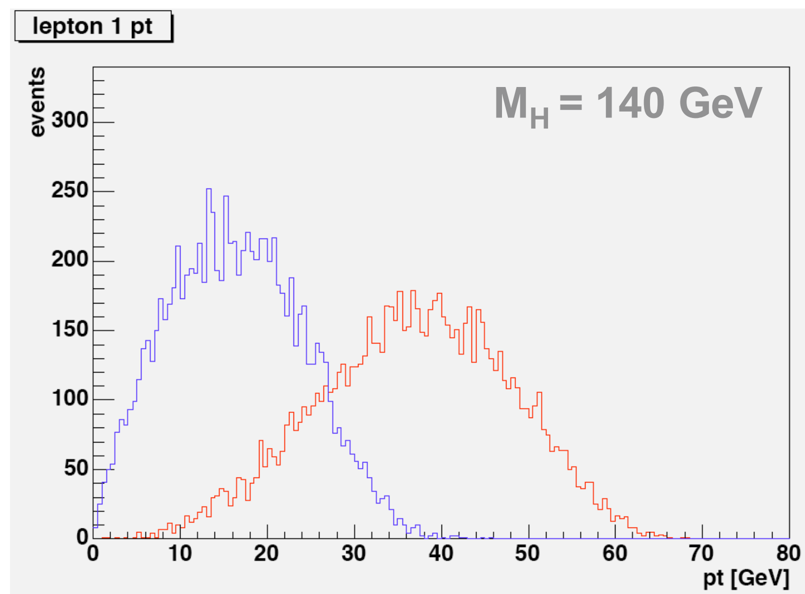
Preliminary plots from ExHume / PYTHIA, dileptons



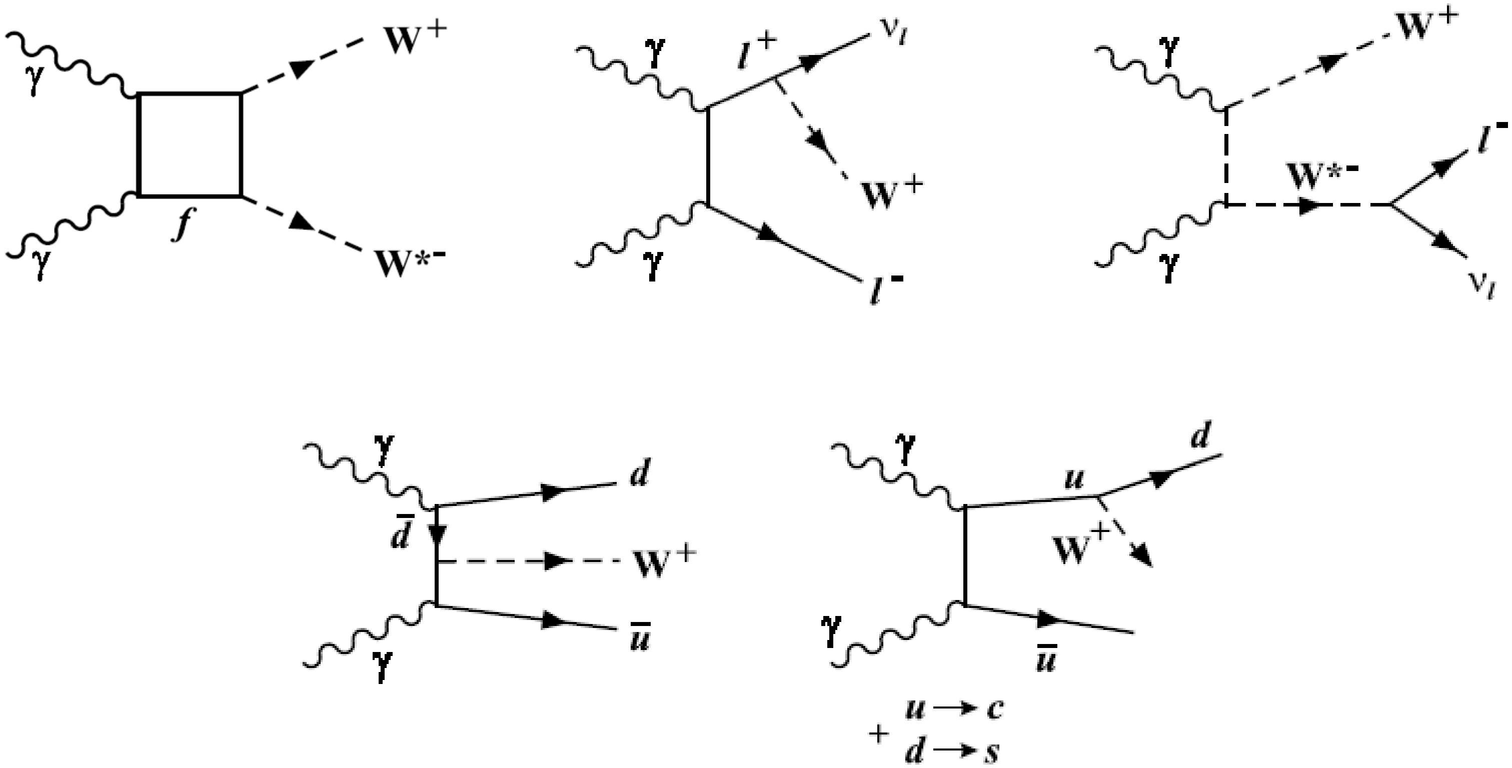




ATLAS TDR $p_{T(1)} > 20$ GeV, $p_{T(2)} > 10$ GeV, $|\eta| < 2.5$

Preliminary study with $p_{T(p)} >$ 100 MeV : efficiency = 44%

γγ backgrounds



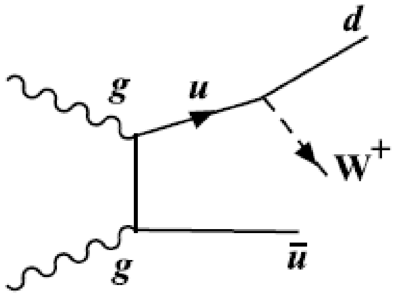
Calculated using CalcHEP

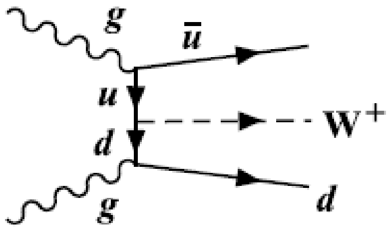
with centrality cuts ($|\eta|$ < 2.5 leptons and jets) and $\Delta M = 0.05\ M_H$

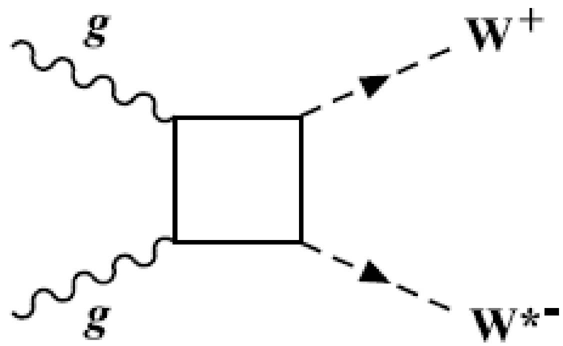
M_H = 120 GeV (140 GeV) $\sigma(WW^*)$ = 0.06 fb (0.12 fb)

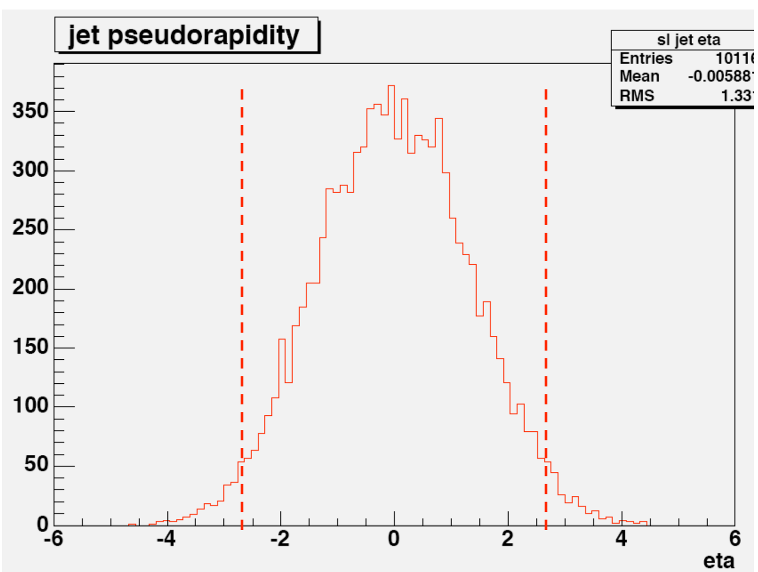
Note : these can be reduced if necessary by p_T > 100 MeV cut on protons. Mass resolution is conservative here)

gg backgrounds









$\sigma(M_H = 140\ \text{GeV}) = 0.8$ fb

Estimate reduction by factor of ~ 10 from jet / proton p_T cuts above WW threshold - more work needed below threshold.

WW / WW* Summary

- Trigger is no problem
- S/B ~ 1 (much better above WW threshold)
- expect to see double tagged SM Higgs up to ~180 GeV with increasing precision on mass
- MSSM low tan β results to come

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The MSSM can be very proton-tagging friendly

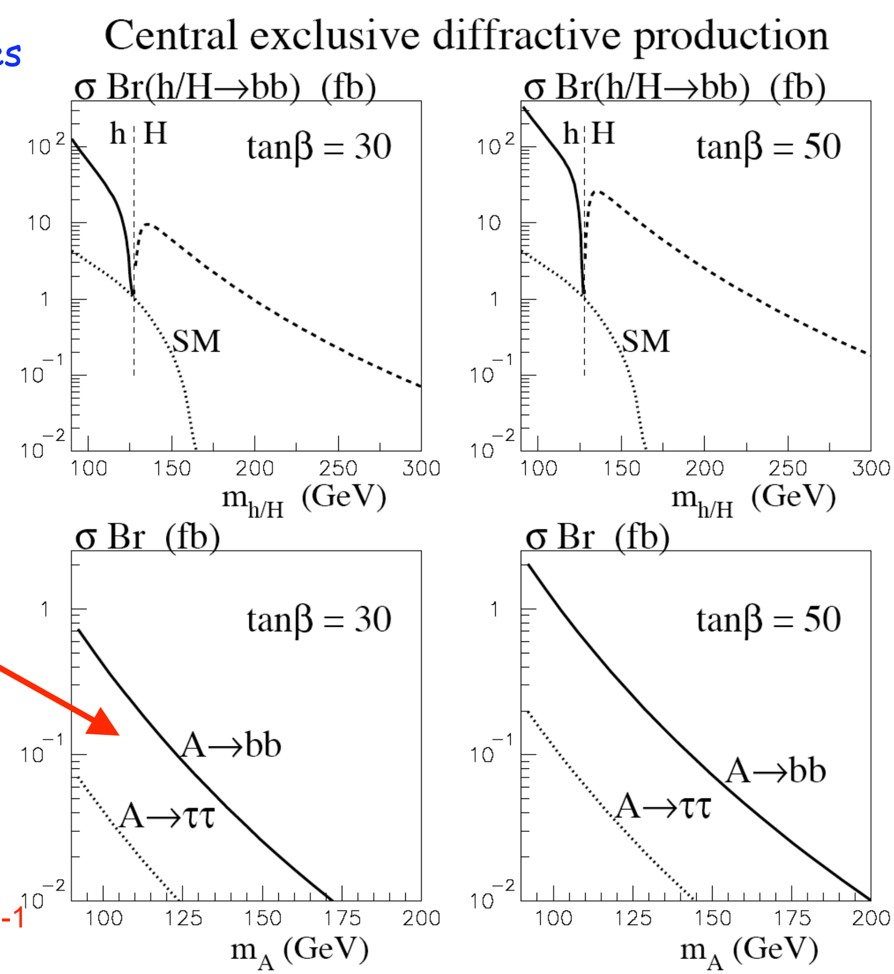
The intense coupling regime is where the masses of the 3 neutral Higgs bosons are close to each other and tan β is large

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

$gg \to \phi$ enhanced

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

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



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}

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

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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

'CPX' scenario σ in fb

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

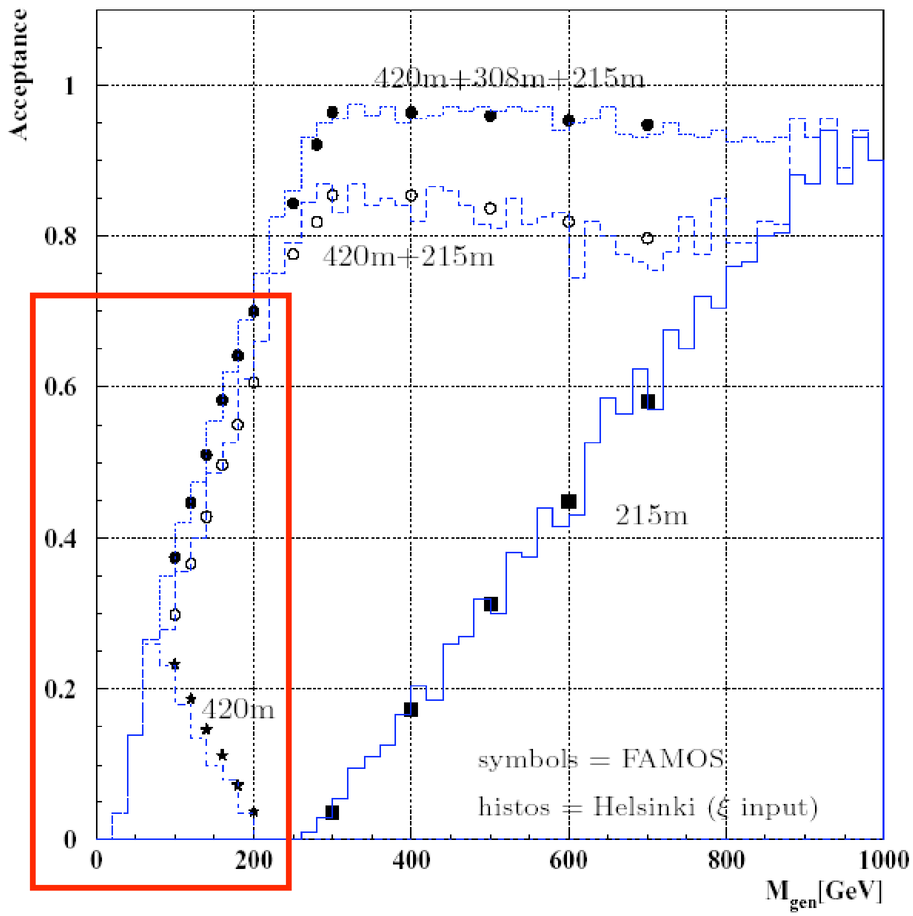
$$\mathcal{M} = g_S \cdot (e_1^{\perp} \cdot e_2^{\perp}) - g_P \cdot \varepsilon^{\mu\nu\alpha\beta} e_{1\mu} e_{2\nu} p_{1\alpha} p_{2\beta} / (p_1 \cdot p_2)$$

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?

How does the 420m program fit with the current 220m programs?



- Contributes largely for asymmetric events - i.e. one P at 220m, one P at 420m
- Increases acceptance by ~ 2 at 120 GeV
- Will provide a trigger for difficult central systems

Helsinki group

The physics case for proton tagging

• If you have a sample of Higgs candidates, triggered by any means, accompanied by proton tags, it is a 0^{++} state.

• The mass resolution will be better than central detectors (e.g. H -> WW -> νl jj … no need to measure missing E_T)

• With a mass resolution of 1 GeV 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 -> direct probe of CP structure of Higgs sector at LHC

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

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

Many of the calculations Khoze, Martin, Ryskin (Kaidalov), IPPP

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Summary

• We will hopefully have a cryostat design engineer in place by Summer

The R&D will be common to ATLAS and CMS

Non-UK collaborators?

• We need 220m pots

How do we integrate with already existing (in 2008 /9) ATLAS and CMS 220m systems?

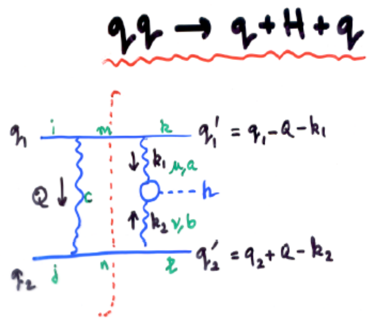
• Theory has provided the motivation

There is now a consensus, and the Monte Carlo tools are available to start detailed studies.

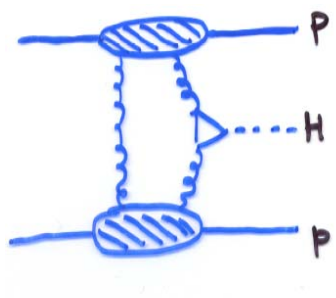
WW / WW^* modes are looking extremely attractive - also probably for low $\tan\beta$ MSSM

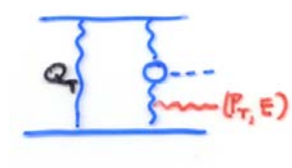
An independent view on the Theoretical Uncertainties

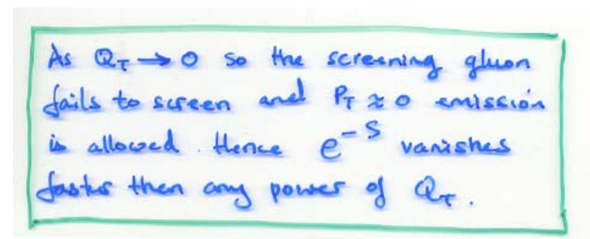
Jeff Forshaw, DESY June 2004

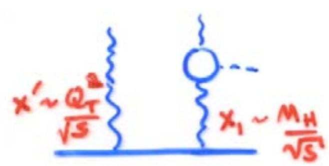


Easy - but divergent as Q -> 0









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