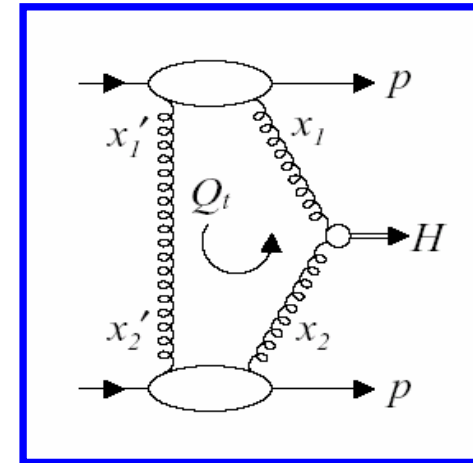


Central Exclusive Production and the FP420 project



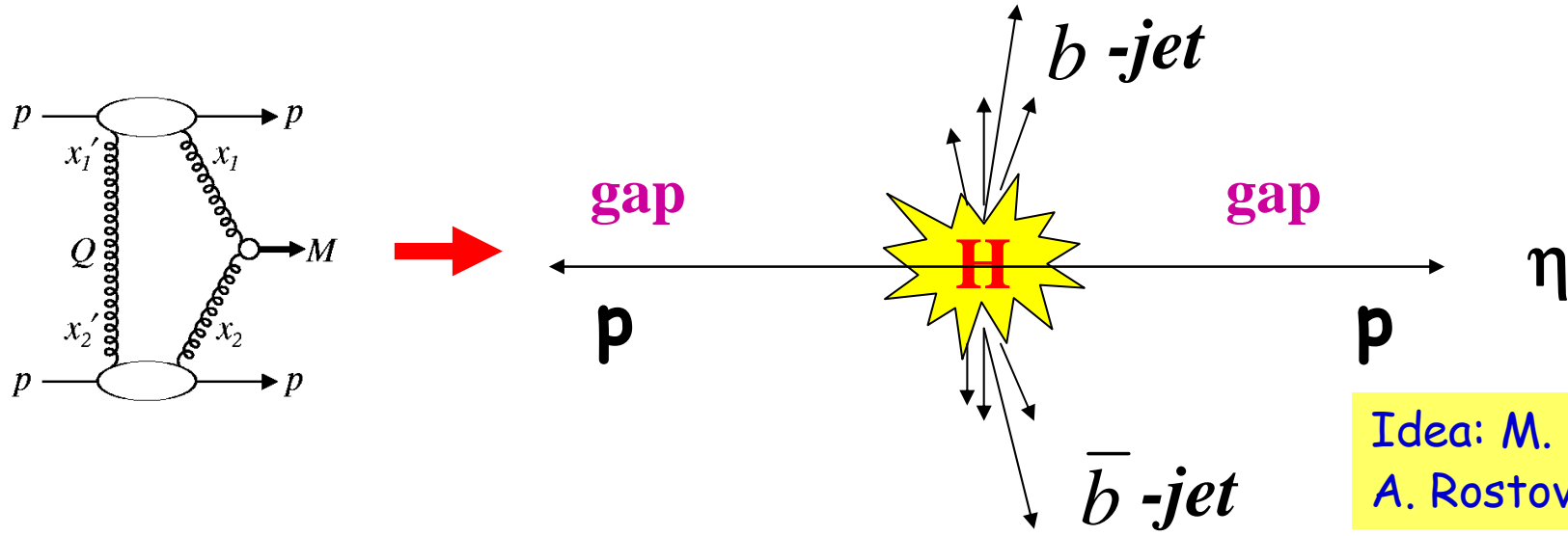
TeV LHC



Albert De Roeck
CERN and University of Antwerp

Central Exclusive Higgs Production

Central Exclusive Higgs production $pp \rightarrow p H p$: 3-10 fb
 Central Inclusive Higgs production $pp \rightarrow p+X+H+Y+p$: 50-200 fb

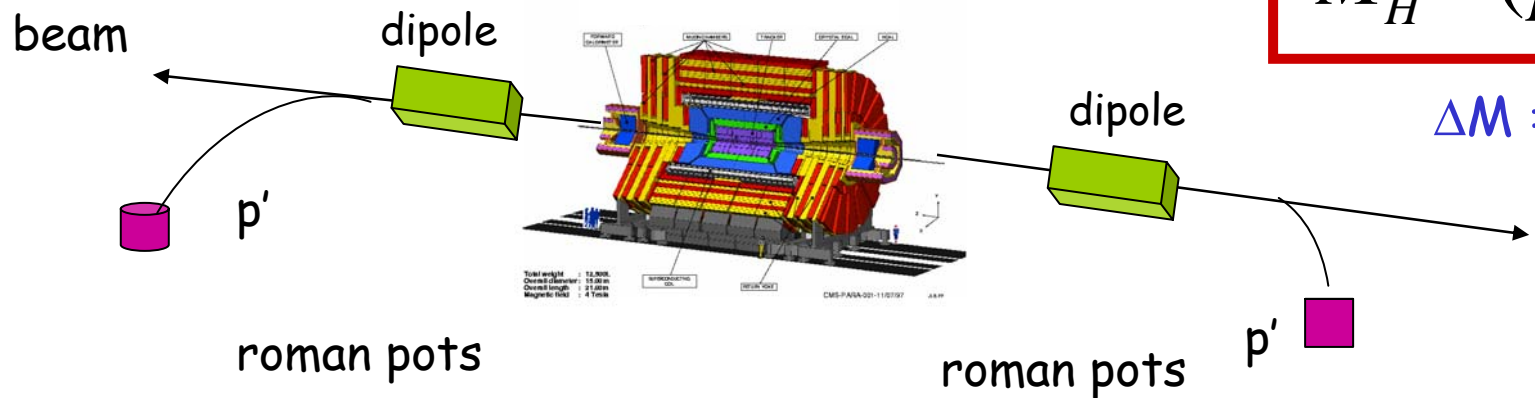


E.g. V. Khoze et al
 M. Boonekamp et al
 B. Cox et al.
 V. Petrov et al...
 Levin et al...

Idea: M. Albrow & A. Rostovtsev for Tevatron

$$M_H^2 = (p + \bar{p} - p' - \bar{p}')^2$$

$$\Delta M = O(1.0 - 2.0) \text{ GeV}$$

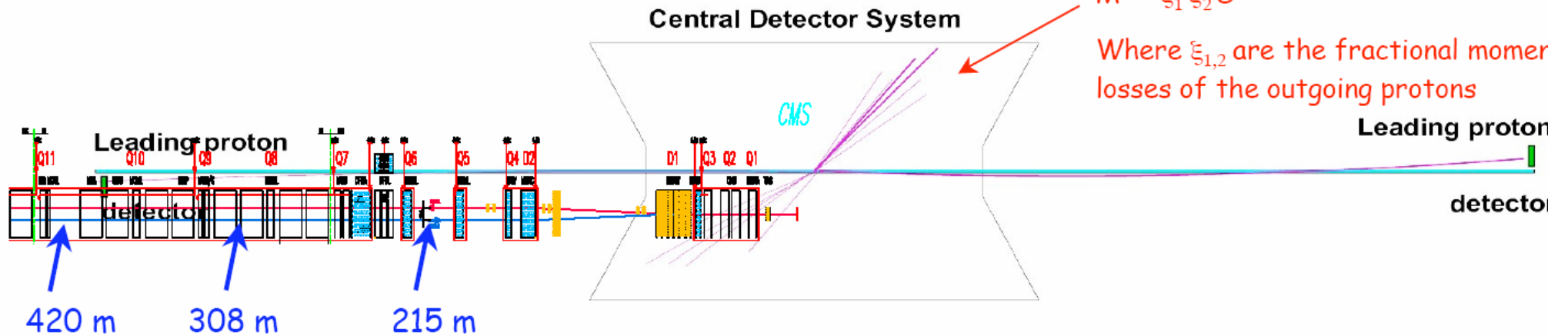


Note: P. Lanshoff still believes the cross section could be larger

Roman pot acceptances

$$M^2 = \xi_1 \xi_2 S$$

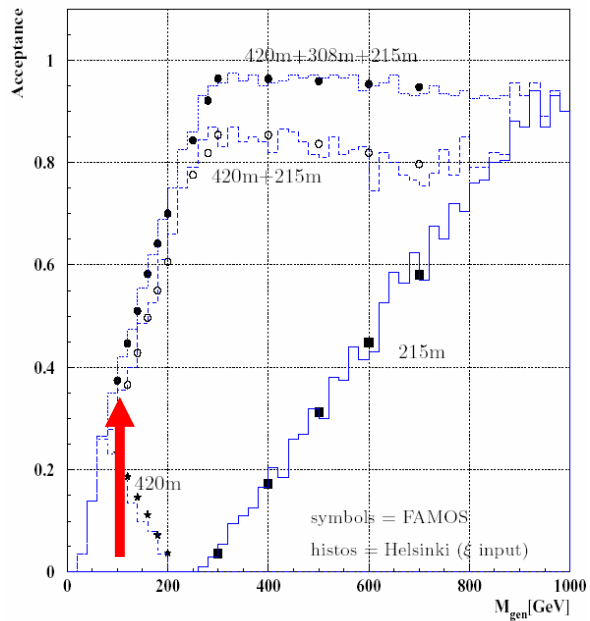
Where $\xi_{1,2}$ are the fractional momer losses of the outgoing protons



FP420

TOTEM (ATLAS)

Low β^* : (0.5m): Lumi $10^{33}-10^{34} \text{cm}^{-2}\text{s}^{-1}$
 220m: $0.02 < \xi < 0.2$
 300/400m: $0.002 < \xi < 0.02$
 RPs in the cold region/FP420 are needed to access the low ξ values

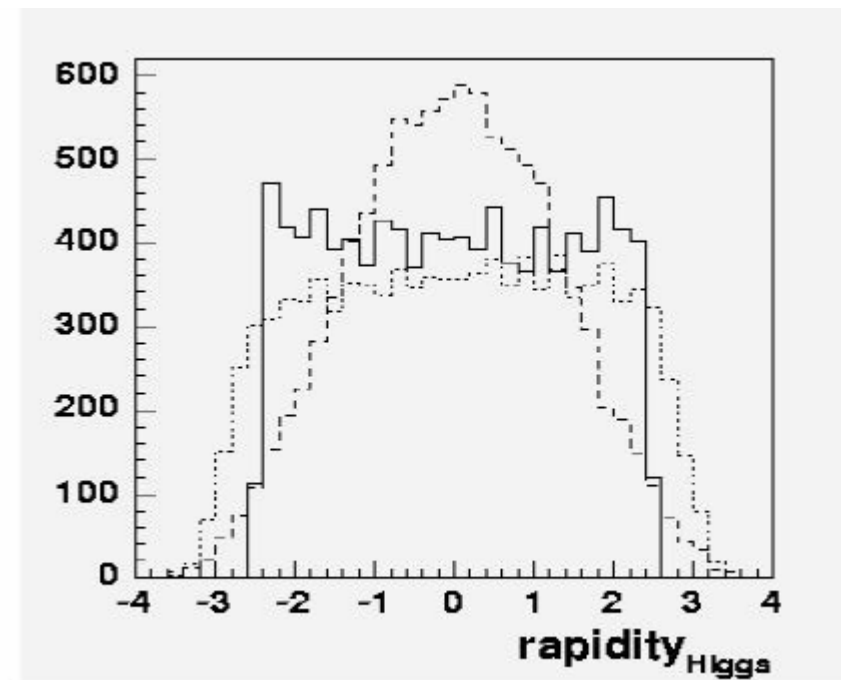
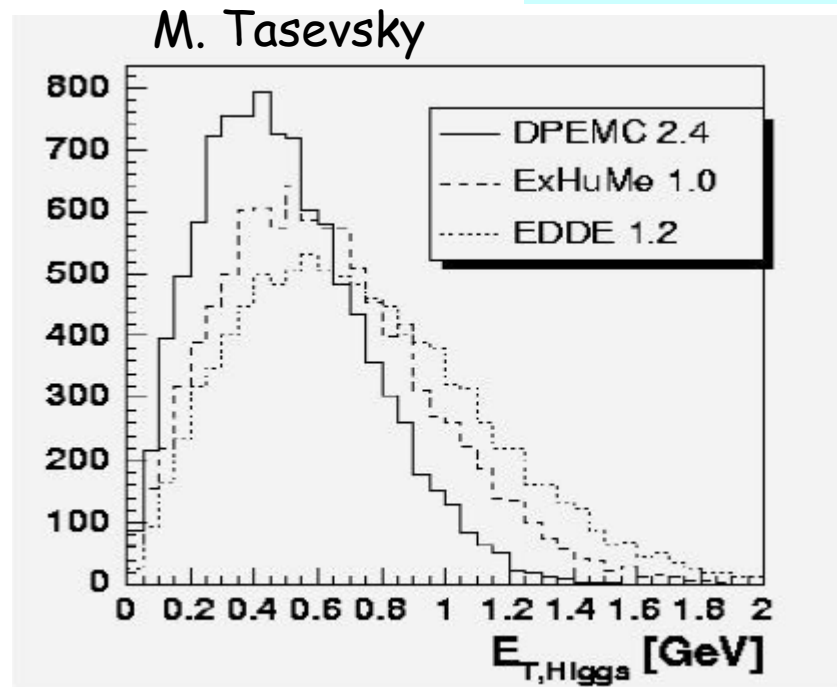


• Problem: 420m to late for CMS/ATLAS L1 trigger. Trigger on central activity

Central Exclusive Higgs Production

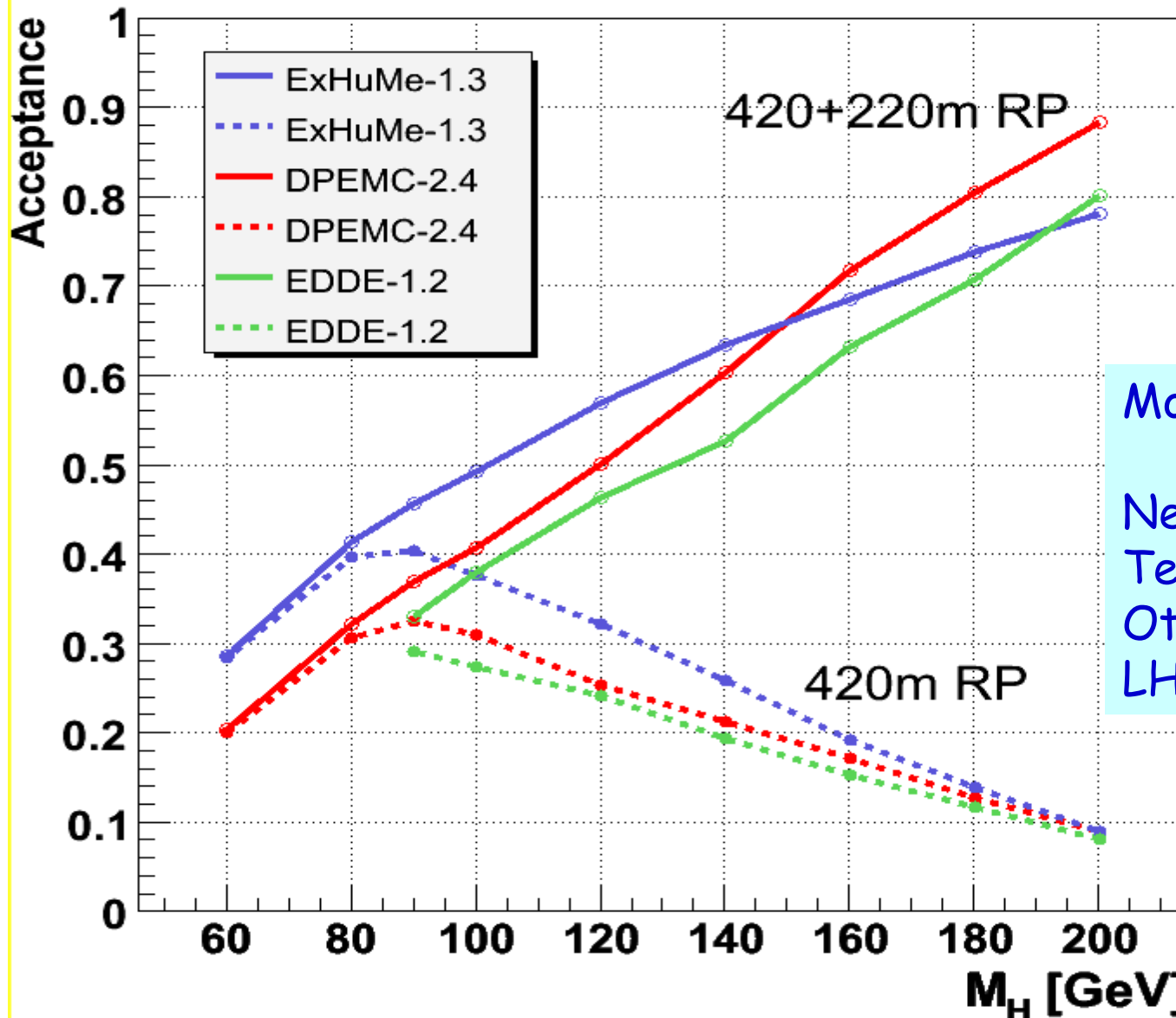
Different models (generators) available to simulate central exclusive Higgs production. Exhume based on Khoze-Martin-Ryskin calculations

A lot of comparisons/discussion in HERALHC workshop



- Differences understood (Sudakov factors, parton distributions...)
- Khoze-Martin-Ryskin calculations checked by independent group \Rightarrow ok

M_H Acceptance

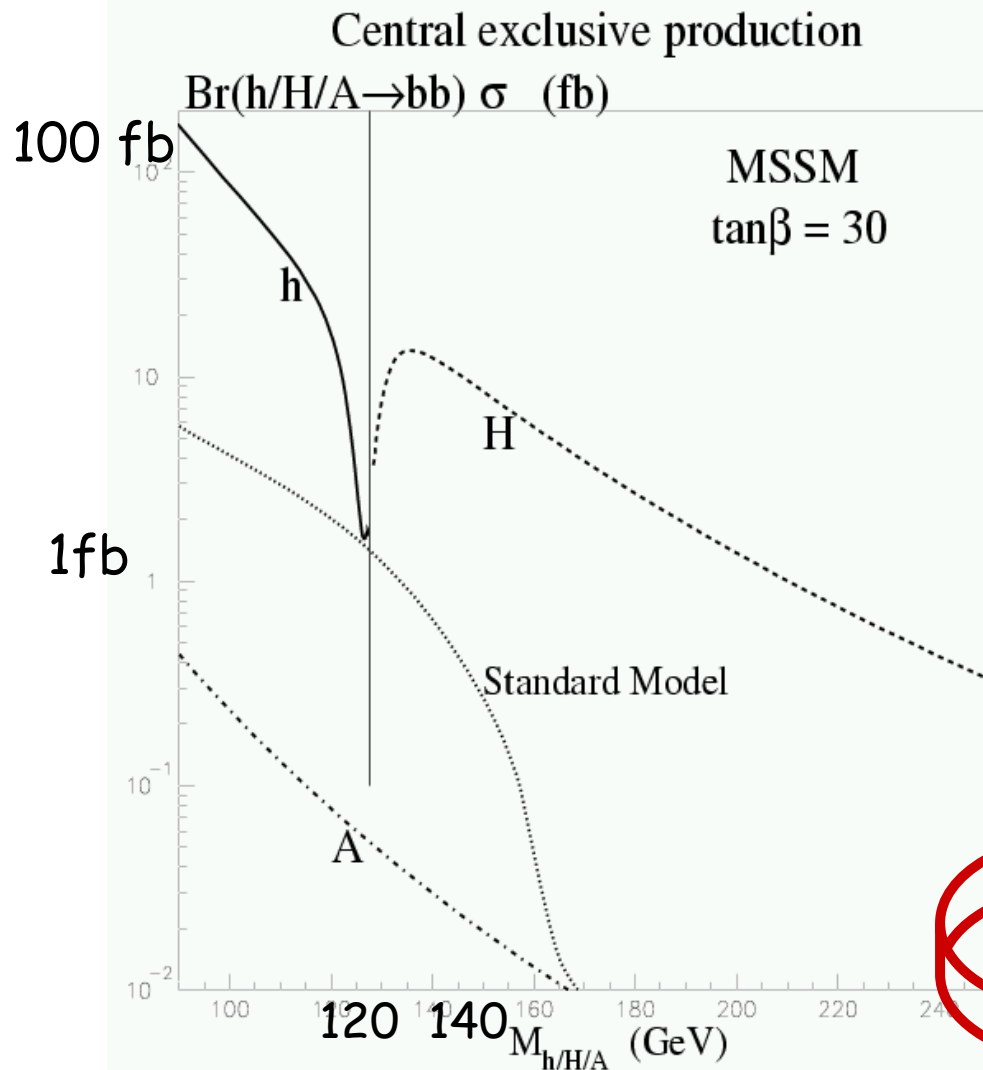


Helsinki Group
TOTEM study
FP420 study

Model Dependence!

Need HERA and/or
Tevatron to referee
Otherwise wait for
LHC data

Higgs Studies



SM Higgs: (30fb⁻¹)
 11 signal events (after cuts)
 O(10) background events

Cross section factor
 ~ 10-20 larger in MSSM
 (high $\tan\beta$)

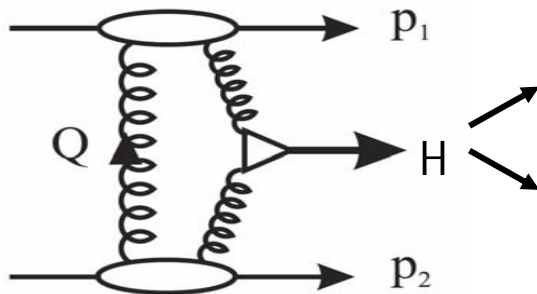
Kaidalov et al.,
 hep-ph/0307064

⇒ Study correlations
 between the outgoing
 protons to analyse the
 spin-parity structure of
 the produced boson

A way to get information
 on the spin of the Higgs
 ⇒ ADDED VALUE TO LHC

Central Exclusive Higgs production

Standard Model Higgs



b jets : $M_H = 120 \text{ GeV}$ $s = 2 \text{ fb}$ (uncertainty factor ~ 2.5)

$M_H = 140 \text{ GeV}$ $s = 0.7 \text{ fb}$

$M_H = 120 \text{ GeV}$: 11 signal / $O(10)$ background in 30 fb^{-1}
with detector cuts

WW^* : $M_H = 120 \text{ GeV}$ $s = 0.4 \text{ fb}$

$M_H = 140 \text{ GeV}$ $s = 1 \text{ fb}$

$M_H = 140 \text{ GeV}$: 8 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 (need trigger from the central detector at Level-1)
- 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 SM Higgs + tags - the quantum numbers are 0^{++}

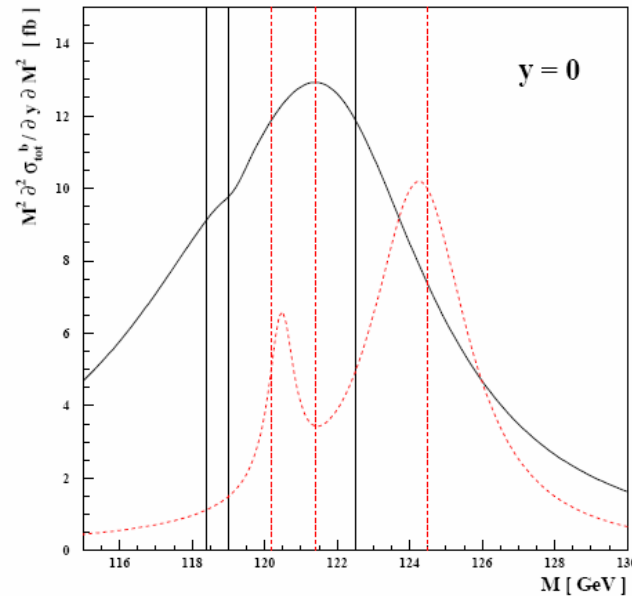
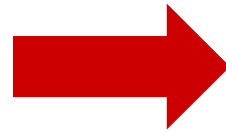
Phenomenology moving on fast

See e.g. J. Forshaw HERA/LHC workshop

“lineshape analysis”

J. Ellis et al.
hep-ph/0502251

Scenario with CP
violation in the
Higgs sector and
tri-mixing

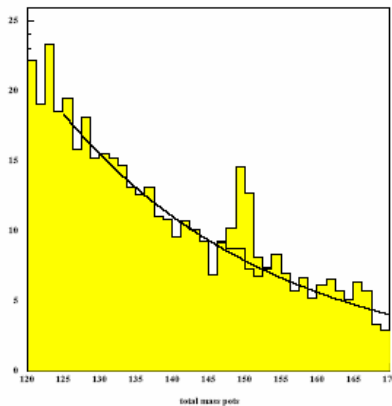
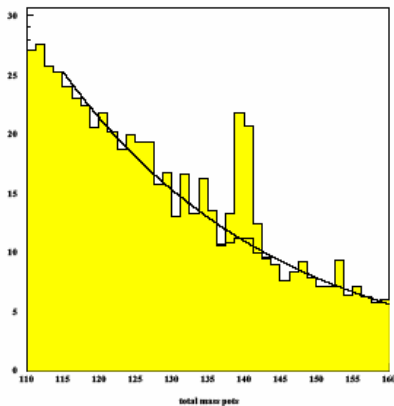
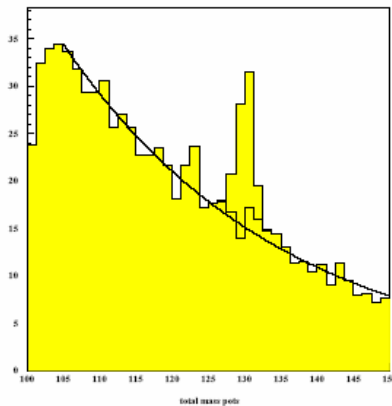
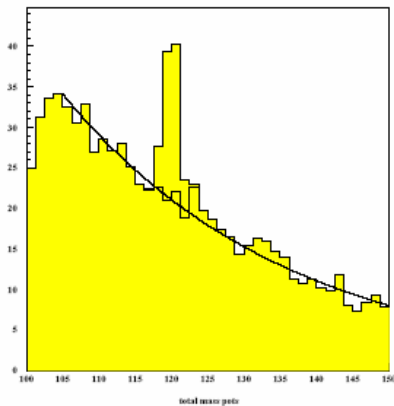


Experimental
check: L. Rurua

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.

Detailed Simulation Studies

Signals and background for different Higgs masses



100 fb⁻¹

Detailed studies ongoing
Fast detector simulation

Boonekamp/ATLAS
Royon, Tasevsky/CMS

Include exclusive and inclusive bb
background

Include missing mass resolution
from the tagged protons

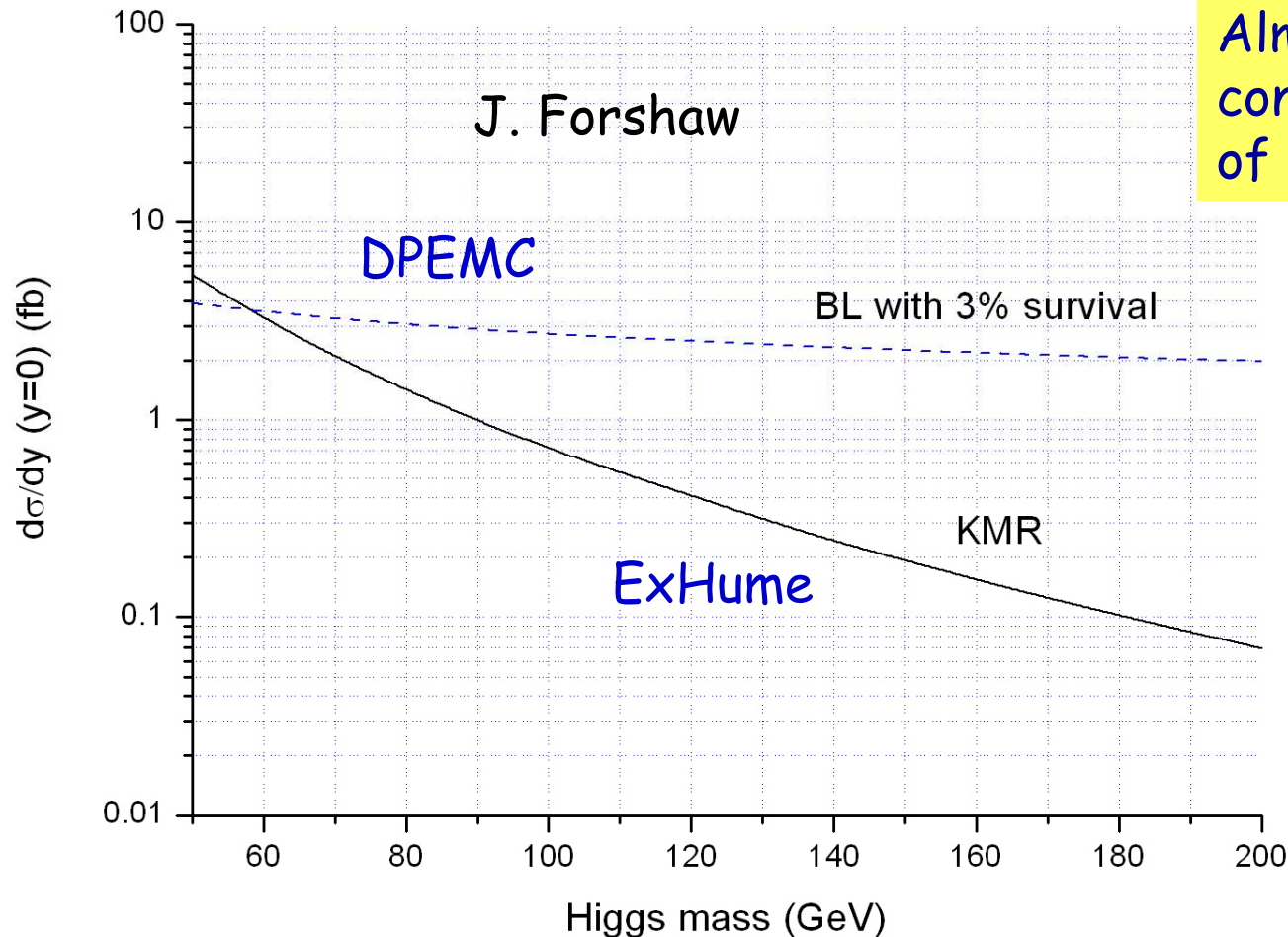
First look/needs to be optimized

Models...

Different models give different predictions for

- The cross sections
- The mass/energy dependence of the cross sections

Almost all calculations now converge to a cross section of 2-10 fb for a light Higgs



BL Bialas Landshof
(soft Pomeron)

KMR: Khoze Martin
Ryskin

Tevatron can test
these models

Test at the Tevatron

Test for exclusive production at the Tevatron
⇒ Energy in the two-jets/all energy for DPE events

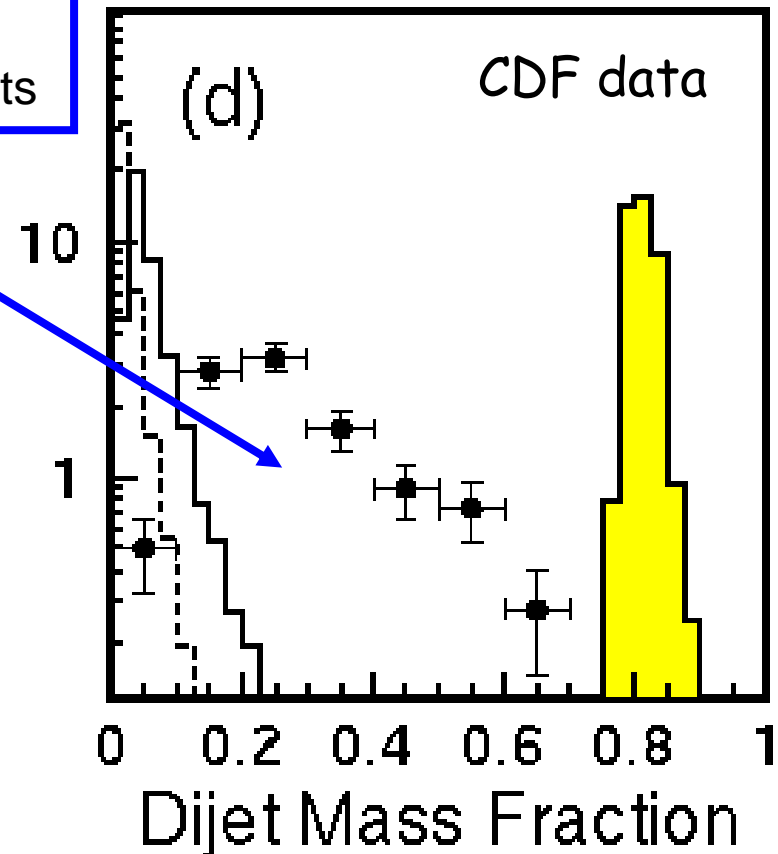
CDF di-jets in DPE
upper limit 3.7 nb

Generally old predictions of
>O(100) pb for the Higgs
overshoot this predictions
by a factor 10-100

Hence → ruled out!

CDF and D0 should find &
measure a signal with run IIa

Needs optimal jet finder
Cone algorithm not the best

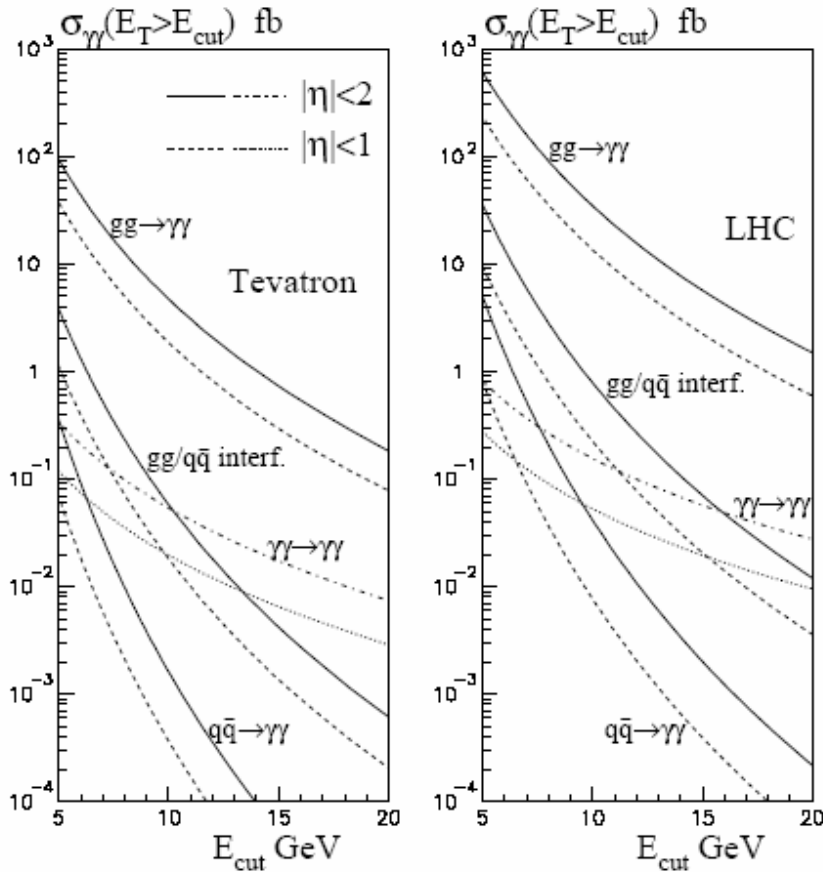


Smooth decrease of the cross section.
Can exclusive processes be seen on top
of the non-exclusive background?

More Information from Tevatron!

Study of central exclusive processes

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



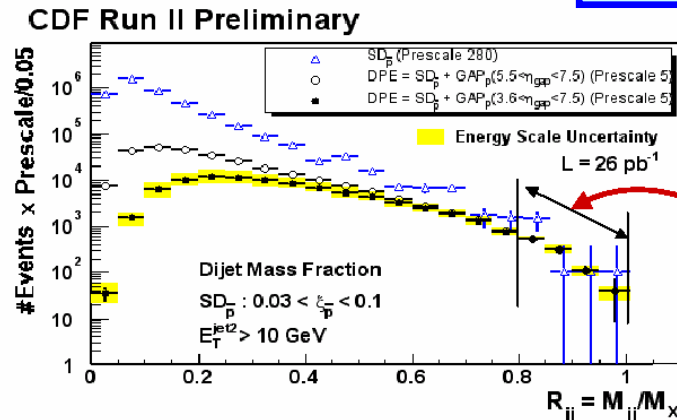
$pp \rightarrow p + \gamma\gamma + p$

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

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

$pp \rightarrow p + \chi_c + p$

$pp \rightarrow p + \text{dijets} + p$



No exclusive dijet bump observed

D. Goulianos

$|\eta_{\text{jet}1,2}| < 2.5, 0.03 < \xi_{\bar{p}} < 0.1, 3.6 < \eta_{\text{gap}} < 7.5, R = 0.7$
 Minimum $E_T^{\text{jet}1}$ Cross Section: $\sigma_{\text{DPE}}^{\text{excl}}(R_{jj} > 0.8)$
 10 GeV $970 \pm 65(\text{stat}) \pm 272(\text{syst})$ pb
 25 GeV $34 \pm 5(\text{stat}) \pm 10(\text{syst})$ pb

Central Exclusive Dijet Production

Tevatron prospects

Cox and Pilkington

CDF runII analysis cuts

$$E_T^{jets1,2} > 10 \text{ GeV}$$

$$|\eta_{jets1,2}| < 2.5$$

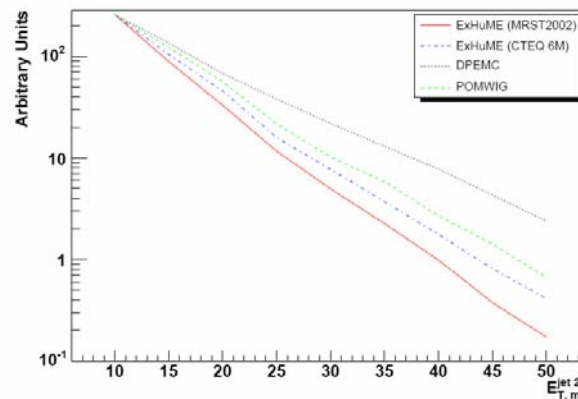
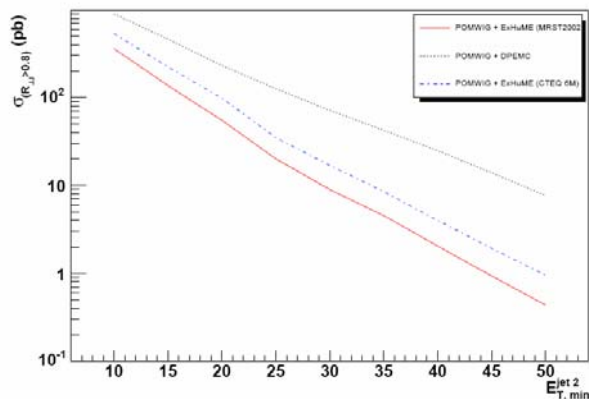
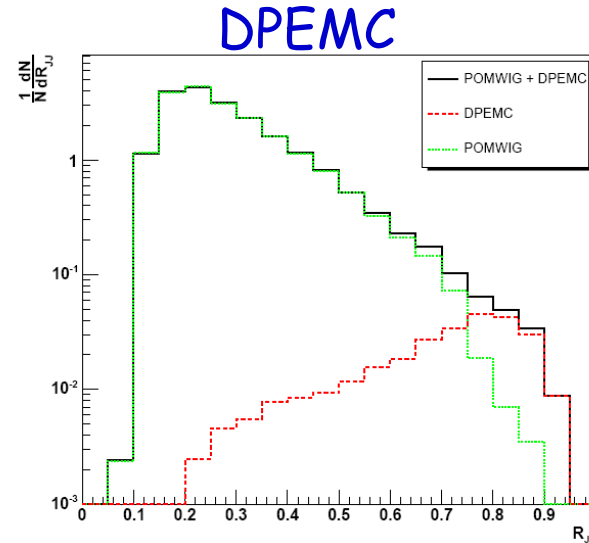
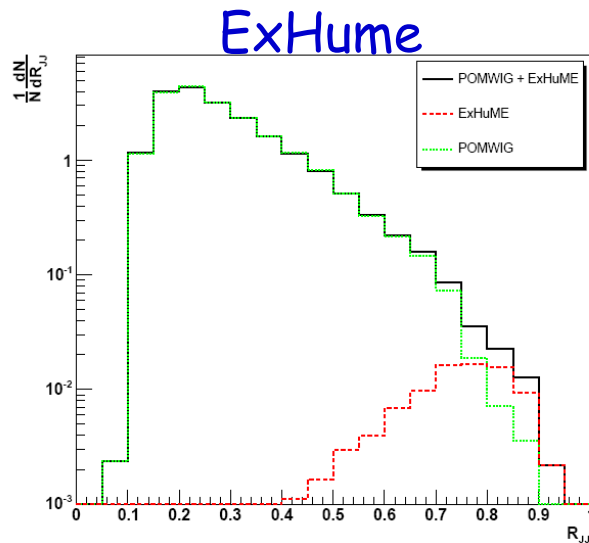
$$0.03 < \xi_{\bar{p}} < 0.1$$

$$\xi_p < 0.1$$

$$\sigma_{R_{jj}} > 0.8 \Rightarrow 20-120 \text{ pb}$$

Models predict a different pt spectrum for the jets

Dedicated analyses to detect central exclusive production would be useful (other jet algos)

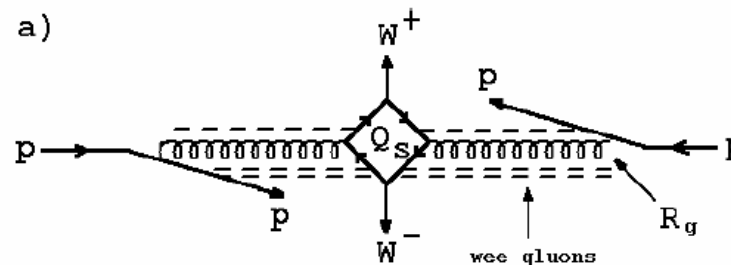


Anomalous WW Production

Alan White: theory of supercritical pomeron \rightarrow reggeized gluon + many (infinite) wee gluons

- color sextet quarks required by asymptotic freedom, have strong colour charge, (at least) few 100 GeV constituent mass
- Sextet mesons \rightarrow EWSB
- UDD neutron dark matter candidate
- Explain high energy cosmic rays, Knee?
- Color sextet quarks couple strongly to W and Z and to the pomeron
- Phenomenology: Anomalous production of WW when above threshold ie. At the LHC (with possibly some onset already detectable at the Tevatron)

color triplets	color sextets
u c t	U
d s b	D

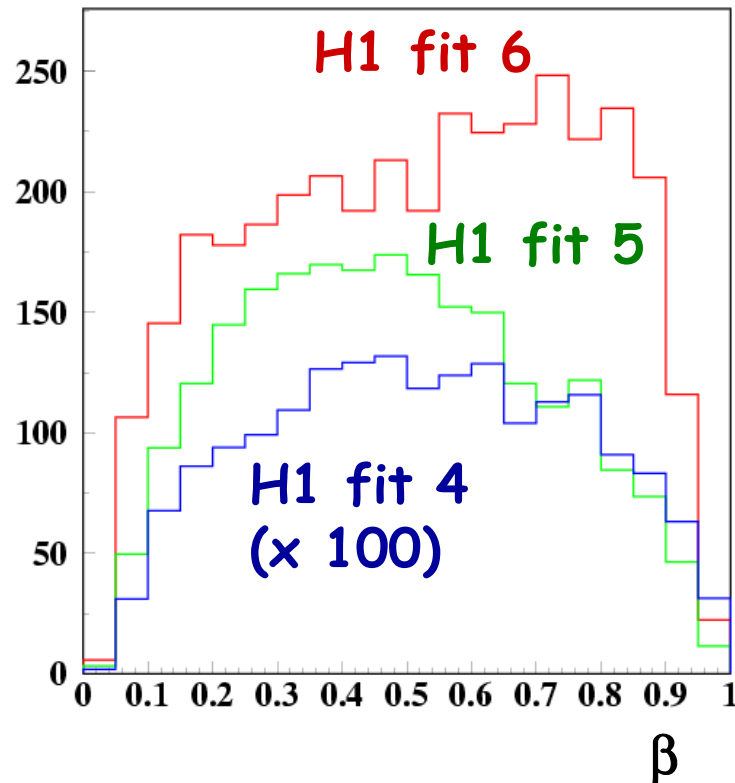


\Rightarrow Measure exclusive WW, ZZ cross sections in DPE at the LHC
Expected Cross section orders of magnitude larger than in SM

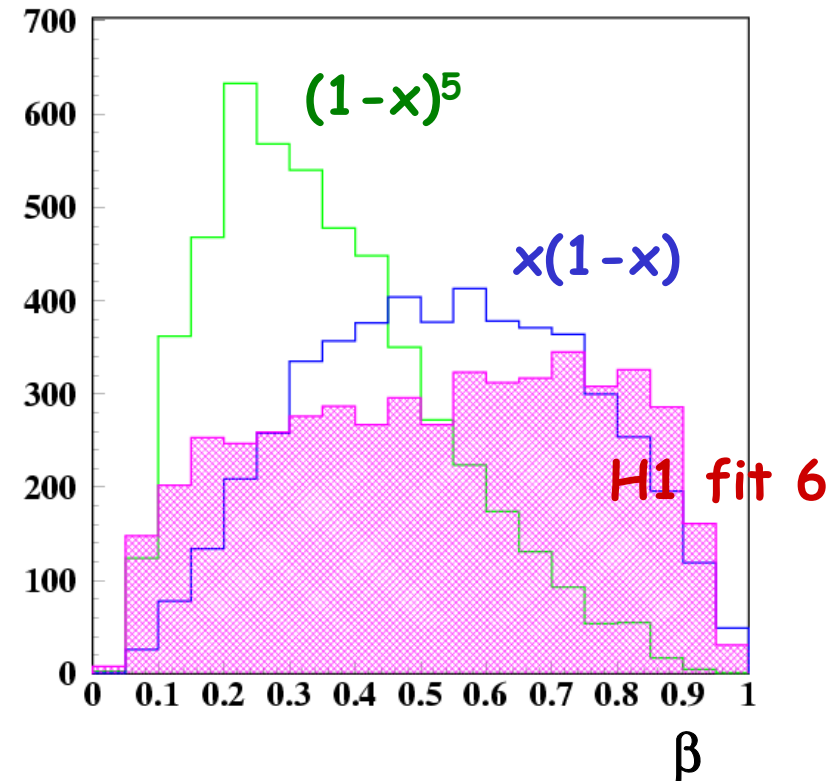
QCD: β from Di-jet events

$P_{\tau} > 100 \text{ GeV}/c$ for different structure functions

$d\sigma$ (pb)



events



$\beta = \sum_{\text{jets}} E_T e^{-\eta} / (\sqrt{s} \xi)$; ξ from Roman Pots; E_T and η from CMS

High β region probed/ clear differences between different SFs

The FP420 Project

CERN-LHCC-2005-025
LHCC-I-015

FP420 : An R&D Proposal to Investigate the Feasibility of Installing Proton Tagging Detectors in the 420m Region at LHC

M. G. Albrow, T. Anthonis, M. Arneodo, R. Barlow, W. Beaumont, A. Brandt, P. Bussey, C. Buttar, M. Capua, J. E. Cole, B. E. Cox,* , C. DaVià, A. DeRoeck,* , E. A. De Wolf, J. R. Forshaw, J. Freeman, P. Grafstrom,+ , J. Gronberg, M. Grothe , J. Hasi, G. P. Heath, V. Hedberg,+ , B. W. Kennedy, C. Kenney, V. A. Khoze, H. Kowalski, J. Lamsa, D. Lange, V. Lemaitre, F. K. Loebinger, A. Mastroberardino, O. Militaru, D. M. Newbold, R. Orava¹, V. O'Shea, K. Osterberg, S. Parker, P. Petroff, J. Pinfold, K. Piotrkowski, M. Rijssenbeek, J. Rohlf, L. Rurua, M. Ruspa, M. G. Ryskin, D. H. Saxon, P. Schlein, G. Snow, A. Sobol, A. Solano, W. J. Stirling, M. Tasevsky, E. Tassi, P. Van Mechelen, S. J. Watts, T. Wengler, S. White, D. Wright

LOI submitted to the LHCC end of June

58 authors
29 institutes

FP420 plans

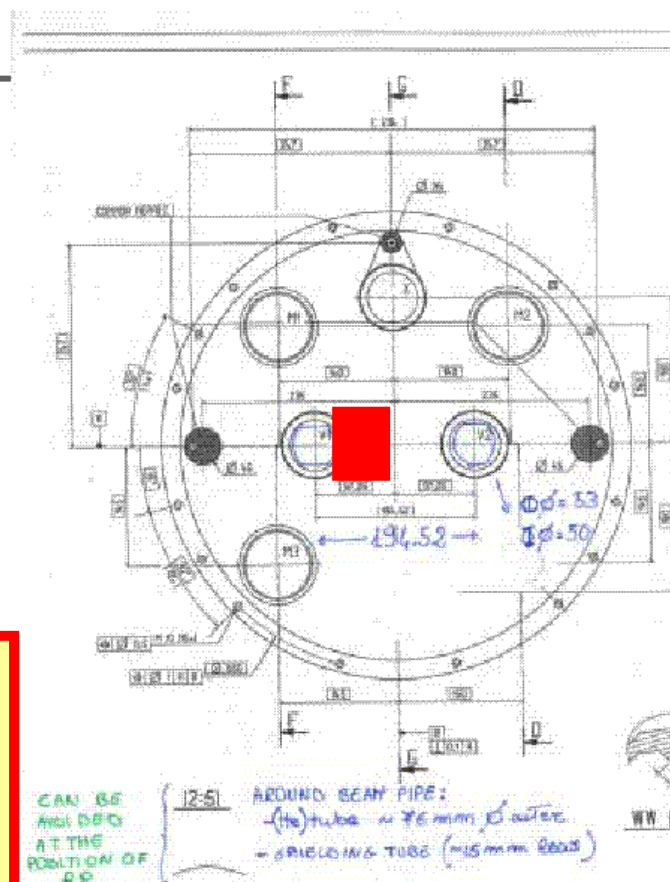
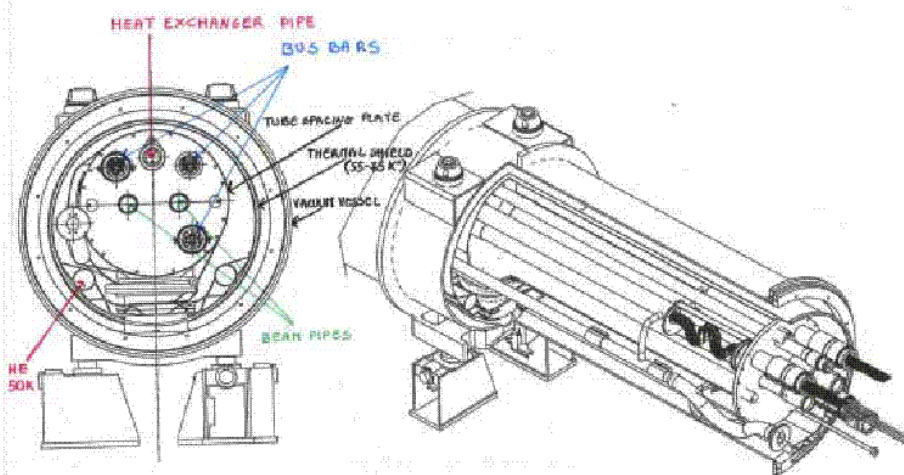
- Feasibility study for the development of detectors to measure protons at 420 m from the IP, during low β optics at the LHC
 - Main physics aim $pp \rightarrow p + X + p$
 - Higgs, New physics
 - QCD studies
 - Photon induced interactions
- First meeting at FNAL April 26 2005
 - Green light for the UK funds
 - Decide to submit a LOI to the LHCC
- Further meetings/collaboration web page
<http://www.fp420.com>
- Next meeting: 11-13 December Manchester

Note: this is an open (proto-)collaboration

Contacts: B. Cox (Manchester), A. De Roeck (CERN)

Detectors at 300/400m

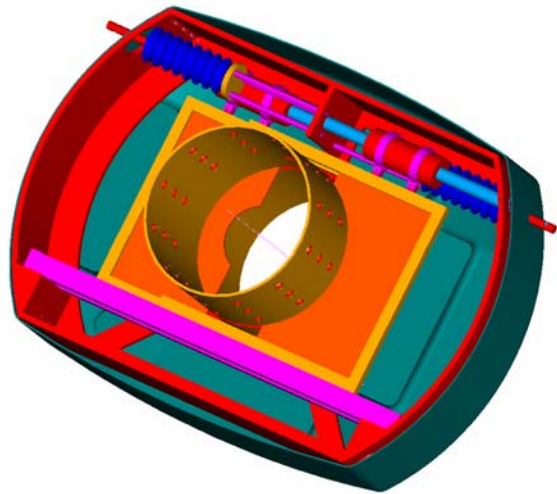
- Cold section: Detectors have to be integrated with cryostat
Several options discussed with the machine
Preferred option: 15m cold-warm transition with the detectors at 'room' temperature.



- Many machine components already ordered, some already delivered
- Machine wants "easy" start-up/no perturbation
⇒ Change means an "LHC upgrade" (phase II)
⇒ aim for 2009 run

Detectors & mechanics

μ -station concept of a compact detectors



..or a moving beampipe as used at HERA

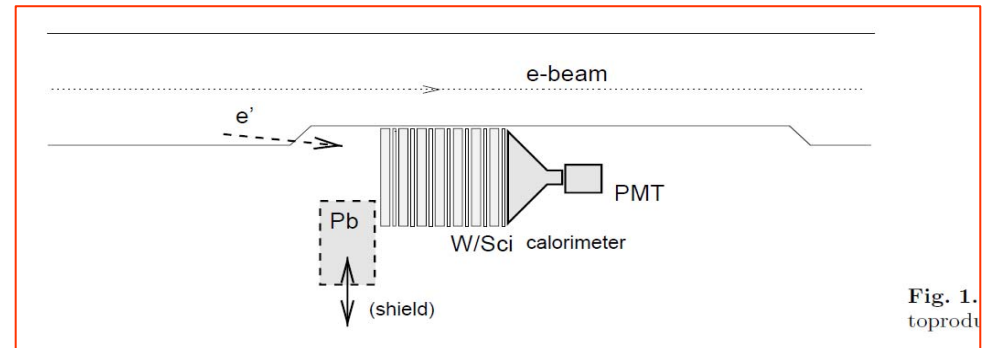


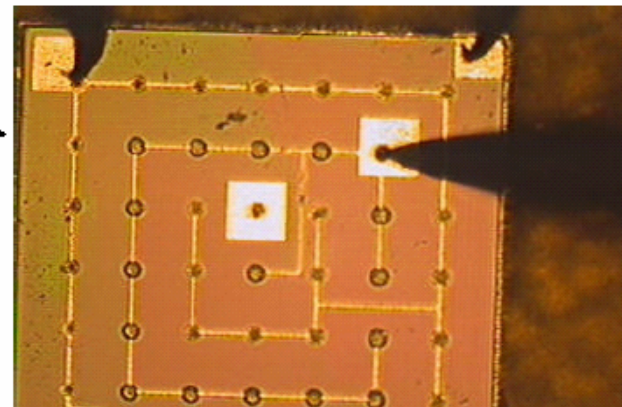
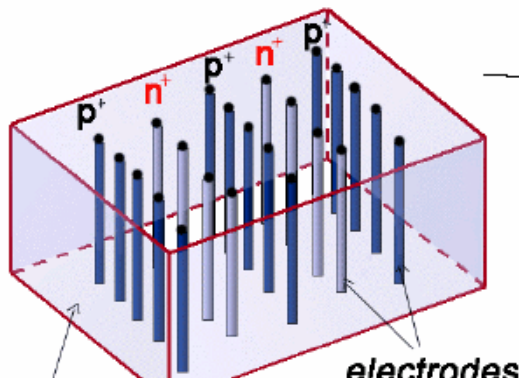
Fig. 1. toprodu

Important will be overall stability and integration with precision beam position monitor to reach $O(10)\mu\text{m}$

Need to approach beam to mm level

3D DETECTORS AND ACTIVE EDGES

Brunel, Hawaii, Stanford

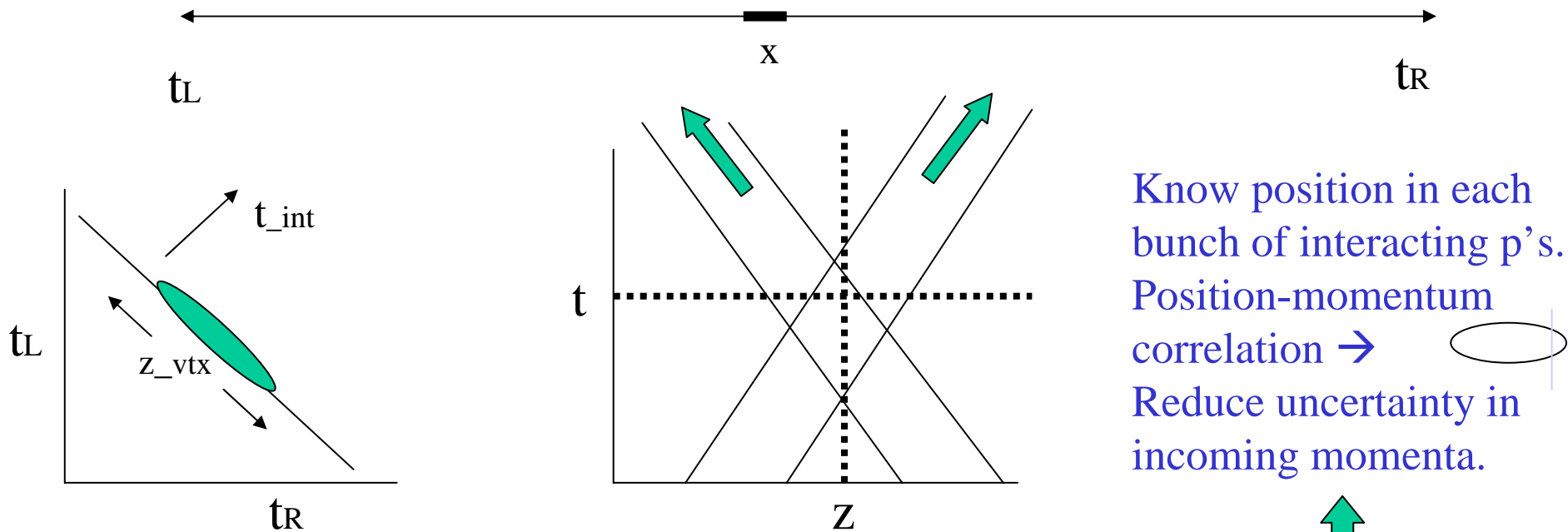



Fast Timing Detectors

Albrow, Brandt, Pinfold, et al.

Put at back of 420m (220m?) tracking high precision timing counters.
Eg. Quartz Cerenkov + ~ Microchannel PMT → tested (Japanese Gp) → **10 ps = 3mm!!**

Check that p's came from same interaction vertex (& as central tracks)



Know position in each bunch of interacting p's.
Position-momentum correlation → 
Reduce uncertainty in incoming momenta.

Potentially valuable e.g. MSSM triplet
(Higher cross section & close states)

MCP-PMT timing property for single photons

M. Akatsu, Y. Enari, K. Hayasaka, T. Hokuue, T. Iijima, K. Inami*, K. Itoh, Y. Kawakami, N. Kishimoto, T. Kubota, M. Kojima, Y. Kozakai, Y. Kuriyama, T. Matsuishi, Y. Miyabayashi, T. Ohshima, N. Sato, K. Senyo, A. Sugi, S. Tokuda, M. Tomita, H. Yanase, S. Yoshino

Department of Physics, High Energy Physics Laboratory, Nagoya University, Furo-Cho, Chikusa, Nagoya 464-8602, Japan

Received 8 January 2004; received in revised form 1 April 2004; accepted 2 April 2004

Abstract

We have measured the performance, especially the timing properties, of micro-channel plate photo-multiplier tubes (MCP-PMTs) by irradiating with single photons with/without a magnetic field. A time resolution of $\sigma = 30\text{--}35$ ps was obtained for single photons under 1.5 T. With an MCP-PMT, a small time-of-flight counter by means of Cherenkov light radiation instead of scintillation light has been prepared, and a time resolution $\sigma \sim 10$ ps was attained for a high-energy π -beam by multiple photons.

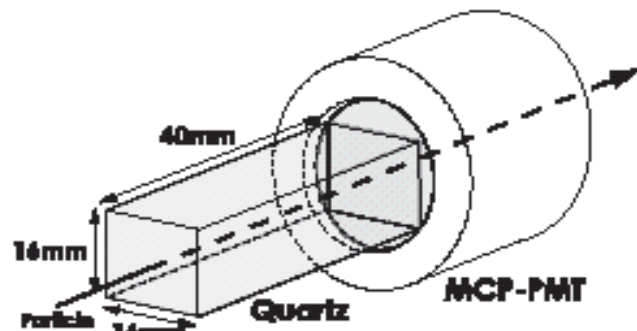


Fig. 12. Schematic drawing of the test TOF counter. HPK10 is used as the MCP-PMT.

It's been done!

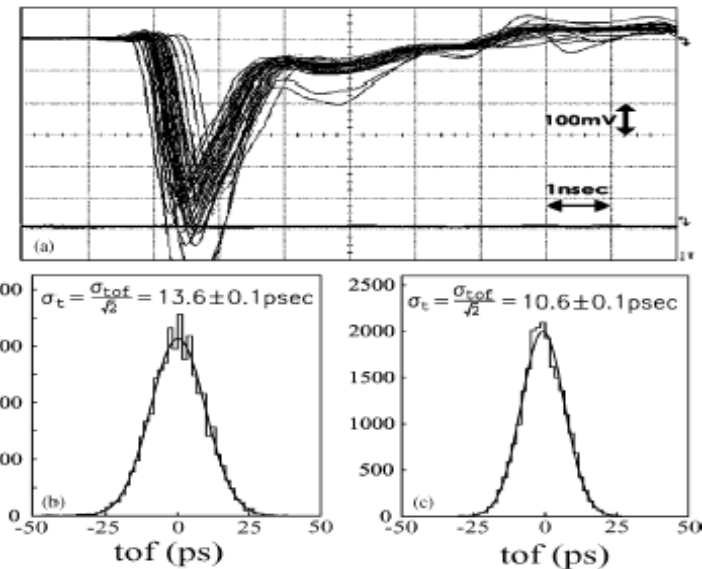


Fig. 13. (a) shows HPK10s output signal for 3 GeV/c pion beam; (b) and (c) are the distributions of the time difference between two test counters without and with a quartz radiator, respectively. Their resulting time resolutions of the single counter are obtained as $\sigma_t = \sigma_{\text{tof}}/\sqrt{2} = 13.6 \pm 0.1$ ps and 10.6 ± 0.1 ps.

Summary

- The Study of central (exclusive) production requires additional detectors at 420m away from the central detectors.
 - Earliest possible installation for 2009 run
- An R&D collaboration has been formed to make a feasibility study for such detectors and the physics. Close collaboration with the LHC machine
- Main physics aim $pp \rightarrow p + X + p$
 - Higgs, New physics
 - QCD studies
 - Photon induced interactions
- Important tests/refereeing on the models can be done at the Tevatron
 - Central exclusive $\chi_c, \chi_b, \gamma\gamma, \text{dijet} \dots$ production
- FP420 is an open collaboration \Rightarrow still growing
 - Room for new people/new ideas...
- \Rightarrow Next important milestone meeting Dec 11-13 Manchester