FP420: fisica in avanti a LHC

Studio della fattibilità di equipaggiare con rivelatori una zona a ±420 m dal punto di interazione di ATLAS/CMS per rivelare protoni che hanno perso tra 0.2% e 2% del loro impulso (parte centrale dell’evento misurata in ATLAS/CMS e protone/i in FP420). Complementare a TOTEM.

1. Motivazione fisica
   "discovery physics": SM Higgs, MSSM Higgs
   QCD
   $\gamma\gamma$

2. Aspetti tecnici

3. Tempi

4. Partecipazione di Torino

M. Arneodo (Univ. Piemonte Orientale e INFN-Torino) Frascati, Comm. I, 14 Nov 2005
Proposal submitted to the LHCC in June

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


58 authors
29 institutes

Authors from:
ATLAS, CMS, TOTEM
CDF, D0, LHC

Close collaboration with
ATLAS and CMS

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

http://www.fp420.com
1) Central exclusive Higgs: \( pp \rightarrow pHp \)

- For light Higgs (\( \approx 120 \text{ GeV} \)), \( gg \rightarrow H, H \rightarrow b\bar{b} \) mode has highest branching ratio, but signal swamped by \( gg \rightarrow b\bar{b} \)

- Signal-to-background ratio improves dramatically for central exclusive production: \( S/B \sim 1 \) [Khoze, Martin, Ryskin, 2000]
  Expect 11 signal events (after detector cuts) for 30 fb\(^{-1}\)

- Reconstruct \( M_H \) from \( b\bar{b} \) (central detector)
  - and/or from scattered protons with missing mass method
  - 1-2 GeV resolution

- \( H \rightarrow WW \) also OK if \( M_H = 140 \text{ GeV} \)
  - 8 signal / O(3) background in 30 fb\(^{-1}\)

- High S/B ratio thanks to \( J_z \) selection rule: to accuracy (\( m_b/E_T \))^2, only \( J^{PC} = 0^{++} \) states can be produced

- Models can be tested at Tevatron run II – cf HERA-LHC workshop for pheno
Necessary ingredients

1) Central apparatus to measure the $b\bar{b}$ jets (ATLAS/CMS)

2) Spectrometers to measure the scattered protons in the tunnel:

   For 120 GeV Higgs, typical proton momentum loss is $\xi \approx 1\%$

   Best place to catch these protons is at 420m from the interaction point (they have to emerge from the 10 sigma beam envelope)

   NB 2-arm spectrometer, at + 420m and at - 420m
Necessary ingredients, cont’d

FP420

TOTEM (or corresponding ATLAS detectors)

High lumi running ($\beta^* = 0.5m$)
$10^{33}-10^{34}$cm$^{-2}$s$^{-1}$:

- TOTEM $0.02 < \xi < 0.2$
- 420m $0.002 < \xi < 0.02$

$$M^2 = \xi_1 \xi_2 S$$
Where $\xi_{1,2}$ are the fractional momentum losses of the outgoing protons
Necessary ingredients, cont’d

Challenging:

- 420m is in the cold region of LHC
- 420m too late for CMS/ATLAS L1 trigger
- pile-up! 35 events at $10^{34}$, of which 30% diffractive

$M^2 = \xi_1 \xi_2 S$

Where $\xi_{1,2}$ are the fractional momentum losses of the outgoing protons
2) MSSM: proton tagging friendly

- b-jet channel very important in ‘intense coupling regime’ of MSSM ($M_h \sim M_A \sim M_H \sim O(100 \text{ GeV}))$: couplings of the Higgs to $\gamma\gamma$, $WW^*$, $ZZ^*$ are strongly suppressed → discovery challenging by conventional means.

- Rates for central exclusive production of the two scalar (0+) MSSM Higgs bosons (h,H) large.

- Pseudo-scalar (0-) Higgs (A) practically not produced in the central exclusive channel → clean separation of the scalar and pseudo-scalar Higgs bosons, impossible in conventional channels.

- Missing mass resolution allows to resolve h, H and, if enough statistics, measure widths.

- Discovery channel?

$M_A=130$ GeV, $\tan \beta=30$

$M_h=124$ GeV: 71 ev/9 background (30 fb$^{-1}$)

$M_H=135$ GeV: 124 ev/6 background (30 fb$^{-1}$)

$M_A=130$ GeV: 3 ev/6 background (30 fb$^{-1}$)

Kaidalov et al., hep-ph/0307064
2) MSSM: proton tagging friendly

- Azimuthal angle between outgoing protons sensitive to Higgs spin-parity: $J^P=0^+ \text{ vs } J^P=0^-$ (recall $J_Z$ selection rule only approximate)

Kaidalov et al., hep-ph/0307064
2) MSSM: CP violation in Higgs sector

- “3-way mixing” scenario of CP-violating MSSM: the 3 neutral Higgs bosons are nearly degenerate, mix strongly and have masses close to 120 GeV

- Central exclusive production very promising: good mass resolution via the scattered protons allows disentangling the Higgses by studying the production lineshape

- Explicit CP-violation in the Higgs sector shows up as asymmetry in azimuthal distributions of tagged protons (interference of P-even and P-odd amplitudes) – a measurement unique at the LHC (Khoze et al., hep-ph/0401078)

J. Ellis et al., hep-ph/0502251
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.
3) QCD and the structure of the proton

FP420 acceptance covers $0.002 < \xi < 0.02$ – the so-called diffractive peak

Explore hard-diffractive interactions at high lumi – follow path of HERA and Fermilab

i) low-x structure of the proton through diffractive PDFs and generalised parton densities (GPDs)

ii) QCD in the high density regime (saturation, RHIC physics…)

iii) Rapidity gap survival – multi-parton interactions
3) QCD: diffr PDFs and GPDs

- **Diffractive PDFs**: probability to find a parton of given $x$ in the proton under condition that proton stays intact – sensitive to low-$x$ partons in proton, complementary to standard PDFs

- **Generalised Parton Distributions (GPD)**
  - quantify correlations between parton momenta in the proton; $t$-dependence sensitive to parton distribution in transverse plane
  - When $x' = x$, GPDs are proportional to the square of the usual PDFs
4) Photon-photon interactions

• Tag two protons → $\gamma\gamma$ interactions (K. Piotrzkowski, PRD 63 071502)
  
  $\sigma=110$ fb with $<M_{\gamma\gamma}> > 300$ GeV → approx 1000 events in semi/fully leptonic channels (30 fb$^{-1}$)
  
  Sensitivity to anomalous quartic couplings significantly better than LEP2 limits (no other way at LHC to have such sensitivity)
  
• 2-$\gamma$ production of $W$ pairs: studies of quartic gauge couplings $\gamma\gamma WW$

• Tag a single proton → $\gamma p$ interactions
  Eg $W$ boson production at high transverse momentum
top pair production via photon-gluon fusion
Summary of the physics potential

• A glue-glue collider where the energy of the gluons is known
• Selection rules mean that central system is (to a good approx) 0\(^{++}\)
  (if see a new particle produced exclusively with proton tags, its quantum numbers are known)
• Tagging the protons means excellent mass resolution \(\sim\) GeV
• Light standard model Higgs can be seen with S/B > 1
• In certain regions of MSSM parameter space, S/B > 20, and double tagging may be the discovery channel
• Explicit CP violation in the Higgs sector shows up as azimuthal asymmetry in the tagged protons \(\rightarrow\) 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.
• Unique access to a host of interesting QCD processes – p structure, low-x...
• Rich program of \(\gamma\gamma\) and \(\gamma p\) physics
Technical aspects

Distance between pipes ~20 cm

Need edgeless detectors, radiation hard

3D Si pixel detectors?

Cold section: detectors have to be integrated with cryostat

Preferred option: 15m cold-warm transition with the detectors at ‘room’ temperature

→ modified cryostat
Aim of the project, timeline

Establish the feasibility of:

• Modifying the cryostat at 420m – ie come up with a design that satisfies the machine and allows insertion of detectors with appropriate mechanics (moving beam pipe, microstations, roman pots…)

• Operating edgeless detectors (eg 3D Si pixel detectors)

• Being able to trigger and have sufficient acceptance

All above, with no interference with LHC, ATLAS, CMS, TOTEM

Estimated time for this: early 2007

Once/if feasibility established:

• ATLAS and CMS members of FP420 will go back to their collaborations, propose the addition – then, if all OK, collaboration(s) will submit TDR

• Installation: not before the first long LHC break – ie do not interfere with machine startup
Work in progress

• First meeting at FNAL in April 2005

• Green light for UK funding (100 k£ seedcorn)

• Submitted proposal to the LHCC in June; LHCC appointed Mario Martinez as referee

• LHCC (closed) discussion in October:
  “The LHCC acknowledges the scientific merit of the FP420 physics programme and the interest in exploring its feasibility” (from the public minutes on the web, not yet approved)

• Accelerator interface issues, including redesign of 420m cryostat, funded by UK (Cockroft Institute)

• Funding of other groups (B, US…) being discussed

• New funding bid in UK in March 2006: design and construction of prototype cryostat, development of the 3D detectors and electronics

• Test beams in spring and summer 2006 at Fermilab and CERN (mechanics, detectors)
Contributo di Torino

- M. Grothe (Univ. To, rientro dei cervelli), M. Ruspa (Univ. Piemonte Orientale), A. Solano (Univ. To), M.A. (Univ. Piemonte Orientale)

MG: rientro cervelli dedicato alla fisica in avanti a LHC;
MA, MR, AS in transizione da ZEUS a CMS (ex-Leading Proton Spectrometer)

- Torino ha contribuito alla proposta (e continua a contribuire) con gli studi di trigger e simulazione di pile-up diffrattivo

- Un progettista di Torino sta lavorando (20%) sull’interfacciamento meccanico criostato-rivelatori

- Possibili sviluppi: elettronica?

- Possibile richiesta di fondi l’anno prossimo

- Il tutto senza interferire con le altre attività CMS in Sezione
RESERVE
**SM Higgs -> WW**

<table>
<thead>
<tr>
<th>Selection cuts</th>
<th>Higgs Mass (GeV)</th>
<th>Efficiency</th>
<th>Signal $\sigma$ (fb)</th>
<th>Events / 30 fb$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$H \rightarrow WW$</td>
<td>120</td>
<td>100%</td>
<td>0.403</td>
<td>12.1</td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>100%</td>
<td>0.933</td>
<td>28.0</td>
</tr>
<tr>
<td></td>
<td>160</td>
<td>100%</td>
<td>1.164</td>
<td>34.9</td>
</tr>
<tr>
<td></td>
<td>180</td>
<td>100%</td>
<td>0.843</td>
<td>25.3</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>100%</td>
<td>0.483</td>
<td>14.5</td>
</tr>
<tr>
<td>Acceptance of proton taggers (420m + 220m)</td>
<td>120</td>
<td>61%</td>
<td>0.246</td>
<td>7.4</td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>67%</td>
<td>0.625</td>
<td>18.8</td>
</tr>
<tr>
<td></td>
<td>160</td>
<td>71%</td>
<td>0.826</td>
<td>24.8</td>
</tr>
<tr>
<td></td>
<td>180</td>
<td>74%</td>
<td>0.624</td>
<td>18.7</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>77%</td>
<td>0.372</td>
<td>11.2</td>
</tr>
<tr>
<td>Single lepton trigger: an electron with $p_T &gt; 25$ GeV or a muon with $p_T &gt; 20$ GeV within $</td>
<td>\eta</td>
<td>&lt; 2.5$</td>
<td>120</td>
<td>8.7%</td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>12.8%</td>
<td>0.119</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>160</td>
<td>16.6%</td>
<td>0.194</td>
<td>5.8</td>
</tr>
<tr>
<td></td>
<td>180</td>
<td>18.3%</td>
<td>0.154</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>19.8%</td>
<td>0.096</td>
<td>2.9</td>
</tr>
<tr>
<td>2 or more jets within $</td>
<td>\eta</td>
<td>&lt; 2.5$</td>
<td>120</td>
<td>7.0%</td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>10.2%</td>
<td>0.096</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>160</td>
<td>13.6%</td>
<td>0.158</td>
<td>4.7</td>
</tr>
<tr>
<td></td>
<td>180</td>
<td>15.1%</td>
<td>0.127</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>16.6%</td>
<td>0.080</td>
<td>2.4</td>
</tr>
<tr>
<td>Mass window around hadronically decaying $W$ $70$ GeV $&lt; M_W &lt; 90$ GeV</td>
<td>120</td>
<td>0.51%</td>
<td>0.002</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>2.0%</td>
<td>0.019</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>160</td>
<td>7.2%</td>
<td>0.084</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>180</td>
<td>9.5%</td>
<td>0.080</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>10.8%</td>
<td>0.052</td>
<td>1.6</td>
</tr>
<tr>
<td>$p_T$(protons) &gt; 100 MeV</td>
<td>160</td>
<td>6.6%</td>
<td>0.077</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>180</td>
<td>8.6%</td>
<td>0.073</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>9.8%</td>
<td>0.047</td>
<td>1.4</td>
</tr>
<tr>
<td>$p_T$(protons) &gt; 200 MeV</td>
<td>160</td>
<td>5.2%</td>
<td>0.061</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>180</td>
<td>6.7%</td>
<td>0.057</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>7.7%</td>
<td>0.037</td>
<td>1.1</td>
</tr>
</tbody>
</table>

WW channel @ 160 GeV:

5 semi-leptonic + 1 fully leptonic event in 30 fb$^{-1}$ with standard triggers, double that if single leptonic trigger threshold reduced to 15 GeV

(hep-ph 0505240)
Diffractive Higgs at Tevatron/LHC

- Proton diffractive PDFs essential for prediction
- Understanding of factorisation breaking ep vs pp, $p\bar{p}$ essential, including $\sqrt{s}$ dependence

- Wide range of theoretical predictions – consensus?
  Bialas and Landshoff, Cudell and Hernandez; Levin; Kharzeev, Levin; Khoze, Martin and Ryskin; Cox, Forshaw and Heinemann, Boonekamp et al, Enberg et al, Godizov et al, …
  [some ruled out by Tevatron data]

- A very promising field – lots more theoretical and experimental work necessary
Diffractive dijets at Tevatron

On the way to diffractive Higgs:

• Helps constraining theory
• Exclusive dijet production would appear as a peak at \( R_{jj} = \frac{M_{jj}}{M_X} = 1 \)
• Very large values \( M_{jj} \) (up to 250 GeV !)
• No peak observed in the data (yet...)

\[ p \rightarrow M_{jj} \rightarrow M_X \]

CDF Run II Preliminary
Diffractive $\chi_c$ at Tevatron

On the way to diffractive Higgs production:

$\begin{align*}
\text{p} & \rightarrow \chi_c \\
\chi_c & \rightarrow J/\psi \gamma
\end{align*}$

• $H$ proceeds via the same diagram but t-loop instead of c-loop

• Important for calibrating models on diffractive Higgs

10 candidate events (but unknown background)

$\sigma < 49 \pm 18 \text{ (stat)} \pm 39 \text{ (syst)} \text{ pb}$

for exclusive $\chi_c$ production for $|y|<0.6$
9.4.1 Tunnel Cross-Sections

- Cable trays (controls, DC and AC power)
- Piping (helium, air, water)
- QRL
- Racks
- Jacks
- Volume reserved for transport
- Volume reserved for survey
- Cryodipole or SSS without jumper

Figure 9.1: Standard Tunnel Cross section
Figure 9.3: Enlarged tunnel cross section (RA) with DFBA
Detectors & mechanics

μ-station concept of a compact detector

..or a moving beampipe as used at HERA

Important will be overall stability and integration with precision beam position monitor to reach O(10)μm

Need to approach beam to mm level
Detectors & mechanics

3D DETECTORS AND ACTIVE EDGES

- Edge sensitivity: <10 μm
- Collection paths: ~50 μm
- Spatial resolution: 10-15 μm
- Depletion voltages at 10^{15} n/cm^2:
  - < 10 V
  - ~105 V
- Speed at RT: 3.5 ns
- Area coverage: 3x3 cm^2
- Signal amplitude before irradiation: 24 000 e^-
- Signal amplitude at 10^{15} n/cm^2: 15 000 e^-

15 μm InfraRed beam spot
FWHM = 772 μm
Edge Al strip width = 16 μm

INSENSITIVE EDGE (INCLUDING 16 μm AL STRIP):
(813 - 772) / 2 = 21 μm

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


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 without a magnetic field. A time resolution $\sigma_t \sim 30-25$ 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 $\sigma_t = 10$ ps was attained for a high-energy $\pi$-beam by multiple photons.

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

Fig. 13. (a) shows HPK10's 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 $\sigma_t = 30.6 \pm 0.1$ ps and $10.6 \pm 0.1$ ps.
TRIGGER STUDIES
Forward detectors

TOTEM detectors:
**T1** (CSC) in CMS endcaps
**T2** (GEM) in shielding behind HF
T1 + T2: $3 \leq |\eta| \leq 6.8$

**Roman pots** (Si) on 2 sides at up to **220 m**
Acc. for nominal LHC optics: $0.02 < \xi < 0.2$

Under discussion: **RPs at 420 m**
Acc. for nominal LHC optics: $0.002 < \xi < 0.02$

**CMS**: **Castor calorimeter**, downstream of T2
The challenge: central exclusive diffractive production of low mass Higgs

Our poster-child process: \( H (120 \text{ GeV, DPE prod}) \rightarrow b \ b\bar{b} \)

L1 signature without fwd detectors: 2 jets in CMS Cal, each with \( E_T < 60 \text{GeV} \)

- Measured L1 jet \( E_T \) on average only \( \sim 60\% \) of true jet \( E_T \)
- L1 trigger applies jet \( E_T \) calibration and cuts on calibrated value
- Thus: 40 GeV (calibrated) \( \sim 20\) to 25 GeV measured
- Cannot go much lower because of noise

\( \rightarrow \) **Use rate/efficiency @ L1 jet \( E_T \) cutoff of 40 GeV as benchmark**

With current software:
L1 2-jet rate for central jets (\( |\eta| < 3 \)) @ L1 jet \( E_T \) cutoff of 40 GeV for Lumi \( 2 \times 10^{33} \text{ cm}^{-2} \text{s}^{-1} \): \( \sim 50 \text{ kHz} \), while considered acceptable: \( O(1 \text{ kHz}) \)

**Need additional conditions to trigger a 120 GeV Higgs with L1:** Forward detectors!
The program completed so far

Answered:

A) What can be done with **central CMS L1 condition** alone
B) What can be won by **adding T1/T2** as veto condition on L1
C) What can be done with (central CMS + RP at 220 m) L1 cond.
D) What could be achieved with RPs at 420m at HLT, if not at L1

With respect to:

1) **L1 rates**
2) **L1 signal efficiency**
3) **Pile-up events**

Reference luminosities:

i) No pile-up case (e.g. for $L=10^{32}\text{ cm}^{-2}\text{ s}^{-1}$)
ii) $L = 10^{33}\text{ cm}^{-2}\text{ s}^{-1}$
iii) $L = 2\times 10^{33}\text{ cm}^{-2}\text{ s}^{-1}$
iv) $L = 10^{34}\text{ cm}^{-2}\text{ s}^{-1}$

a) for signal:
   EDDE and Exhume generators
b) for QCD background:
   Pythia
Caveat: Work in progress!

All results shown in the following are preliminary!
Central detector jet trigger alone

- 4x4 trigger towers = region
- Search for jets with a sliding 3x3 regions window
- Jet = 3x3 region with local energy max in middle
- Reconstructed L1 jet $E_T$ on average ~ 60% of real jet $E_T$, thus need for jet $E_T$ calibration
- A jet = 144 trigger towers, with typical jet dimensions: $\Delta\eta \times \Delta\phi = 1 \times 1$

L1 condition closest to rap gap trigger in calorimeter (rap gap >2):
2 jets in central Cal ($|\eta|<3$) with $\Sigma(E_T$ 2 jets)/HT > given threshold
$H_T$ = scalar sum of $E_T$ of all jets in the event with $E_T$(jet)>threshold

--> Provides factor ~2 rate reduction

Creighton Hogg
Use T1, T2 as vetoes (to require rap gap)

Exploit the fact that signal events have rapidity gaps

- Lack of activity in T1, T2 used to require presence of rapidity gap
- Excellent suppression of QCD background (factors 100 or more)
- However, useless as soon as pile-up becomes significant because then also signal events are vetoed

**Useful only for no pile-up case**

Probability that event survives the veto condition vs # of pileup events:
Require hits in 220 m Roman Pots (I)

Richard Croft
- single-arm 220 m condition
- $L = 10^{32}$, i.e. case with no pile-up

- Excellent suppression of QCD background: rate reduction $\sim 350$ at 40 GeV for $L=10^{32}$
- However...
However, rejection factor becomes small when pileup (contains diffractive component) is included:

<table>
<thead>
<tr>
<th>Luminosity ( [cm^{-2}s^{-1}] )</th>
<th># Pile-up events per bunch crossing</th>
<th>L1 2-jet rate ( [kHz] ) for ( E_T &gt; 40\text{GeV} ) per jet</th>
<th>Total reduction needed</th>
<th>Reduction when requiring track in RP detectors at 220 m ( -\xi &lt; 0.1 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 1 \times 10^{32} )</td>
<td>0</td>
<td>2.6</td>
<td>2</td>
<td>370</td>
</tr>
<tr>
<td>( 1 \times 10^{33} )</td>
<td>3.5</td>
<td>26</td>
<td>20</td>
<td>7, 15</td>
</tr>
<tr>
<td>( 2 \times 10^{33} )</td>
<td>7</td>
<td>52</td>
<td>40</td>
<td>4, 10</td>
</tr>
<tr>
<td>( 5 \times 10^{33} )</td>
<td>17.5</td>
<td>130</td>
<td>100</td>
<td>3, 5</td>
</tr>
<tr>
<td>( 1 \times 10^{34} )</td>
<td>35</td>
<td>260</td>
<td>200</td>
<td>2, 3</td>
</tr>
</tbody>
</table>

Table 1: Reduction of rate from standard QCD processes for events with at least 2 central L1 jets with \( E_T > 40 \text{GeV} \), achievable with requirements on tracks in RP detectors. Additional QCD rate reductions can be achieved with the \( H_T \) condition and a topological condition (see text). Each of them yields, for all luminosities listed, an additional reduction by a factor 2.
Require hits in 220 m Roman Pots (III)

- **Topological condition**
  Can win additional factor \(\sim 2\) in rejection when requiring that the 2 jets are in the same \(\eta\) hemisphere as the RP

- **Possibility of setting a \(\xi\) cut in the RPs**, e.g. \(\xi < 0.1\) (recall acc is \(0.02 < \xi < 0.2\)) to reduce contribution from outside diffractive peak

For H (120 GeV, DPE prod) \(\rightarrow b\ b\bar{b}\), adding L1 conditions on the RPs at 220m is likely to provide a rate reduction sufficient to meet the CMS L1 bandwidth limits at luminosities up to \(2 \times 10^{33}\ cm^{-1}\ s^{-1}\)
Require hits in 220 m and 420 m RPs

Probably not possible on L1 - cannot beat the speed of light
Still - require hits on one side in 220m RPs and on one side in 420m RPs
(in effect means on opposite side - events where \( \xi \) values of 2 protons are very different, i.e. “asymmetric” events)

<table>
<thead>
<tr>
<th>Luminosity ([\text{cm}^{-2}\text{s}^{-1}])</th>
<th># Pile-up events per bunch crossing</th>
<th>L1 2-jet rate ([\text{kHz}]) for ( E_T &gt; 40\text{GeV} ) per jet</th>
<th>Total reduction needed</th>
<th>Reduction when requiring track in RP detectors ( \xi &lt; 0.1 ) at 220 m</th>
<th>Reduction when requiring track in RP detectors ( \xi &lt; 0.1 ) at 420 m</th>
<th>Reduction when requiring track in RP detectors ( \xi &lt; 0.1 ) at 220 m &amp; 420 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1 \times 10^{32})</td>
<td>0</td>
<td>2.6</td>
<td>2</td>
<td>370</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1 \times 10^{33})</td>
<td>3.5</td>
<td>26</td>
<td>20</td>
<td>7</td>
<td>15</td>
<td>27</td>
</tr>
<tr>
<td>(2 \times 10^{33})</td>
<td>7</td>
<td>52</td>
<td>40</td>
<td>4</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>(5 \times 10^{33})</td>
<td>17.5</td>
<td>130</td>
<td>100</td>
<td>3</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>(1 \times 10^{34})</td>
<td>35</td>
<td>260</td>
<td>200</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

Richard Croft

For H (120 GeV, DPE prod) \( \rightarrow b\bar{b}b\bar{b} \), adding L1 conditions on the RPs at 220m and 420m would provide a rate reduction sufficient to meet the CMS L1 bandwidth limits at luminosities up to \(10^{34} \text{ cm}^{-1} \text{ s}^{-1}\)
And how much is left of our signal?
- Signal efficiency results
L1 efficiency studies for diff Higgs

Without RP condition

With various RP conditions

Plots Richard Croft
RP condition for 220m RPs reduces 2-jet L1 trigger signal efficiency by factor \( \sim 2 \)
Result of limited acceptance of RPs in diffractive peak region

Requiring 2-jet trigger threshold of \( ET=40 \text{ GeV} \) and a proton be seen on one side in 220m RPs: signal efficiency for \( H(120 \text{ GeV}) \rightarrow b \overline{b} \) is of the order 20\% (Exhume)

Requiring in addition that a proton be seen in the 420m RPs on the other side results in signal efficiency of about 15\%

Requiring 2-jet trigger threshold of \( ET=40 \text{ GeV} \) and a proton be seen on one side in 420m RPs: signal efficiency for \( H(120 \text{ GeV}) \rightarrow b \overline{b} \) is of the order 30\%
Muon trigger

Looked at by Fredrik Oljemark (for $10^{33}$)

H (120 GeV) $\rightarrow$ b b$\bar{b}$:

- About 20% have a muon in the final state
- With CMS L1 1-muon threshold of $E_T=14$ GeV assumed in CMS DAQ-TDR: retain 6% @ 3kHz rate
- With a 1 muon + 1 jet L1 condition (not yet foreseen in CMS L1 tables): retain an extra 3% @ 3 kHz rate for thresholds $E_T=3/40$ GeV ($\mu$/jet)

H(140GeV) $\rightarrow$ W W*:

- About 23% have muon in final state
- With CMS L1 1-muon threshold of $E_T=14$ GeV assumed in CMS DAQ-TDR: retain 16% @ 3kHz rate
- With a 1 muon + 1 jet L1 condition (not yet foreseen in CMS L1 tables): retain an extra 2.5% @ 3 kHz rate for thresholds $E_T=3/40$ GeV ($\mu$/jet)
Beam-halo/beam-gas levels I’ve seen so far not a problem as soon as central CMS detector condition is used in L1

Find from pythia pile-up sample:
@420m: 0.012 protons per pile-up event on average, i.e. at $10^{34}$: $35 \times 0.012 = 0.42$
@220m: 0.055 protons per pile-up event on average, i.e. at $10^{34}$: $35 \times 0.055 = 1.93$
Summary

To trigger on L1 **H (120 GeV, DPE prod) → b bbar:** Reduce to **O(1 kHz)**
L1 2-jet rate for central jets (|η|<3) @ L1 jet $E_T$ cutoff of **40 GeV**

→ Triggering in absence of pile-up no problem
→ By including RPs at 220m a QCD rate of a few kHz achievable at
  2x $10^{33}$ cm$^{-1}$s$^{-1}$, i.e. consistent with CMS L1 bandwidth restrictions
→ Signal efficiency of order 20%
→ Using muon trigger increases signal efficiency by at most 10%

**Important side effect of present studies:** improvement of tools –
eg Pythia (used for pile-up) does not reproduce HERA diffractive/leading
proton data: needs re-weighting and being complemented by Phojet
(M. Ruspa, see CMS-Totem LOI meeting and HERA-LHC workshop)

A write-up of most of the results presented here has been contributed to the
HERA-LHC workshop proceedings, can be found at
[www.cern.ch/grothe/heralhc/heralhc.ps](http://www.cern.ch/grothe/heralhc/heralhc.ps)
Further plans

Notes in preparation:
- R. Croft (CMS) on efficiency and rate studies for the diffractive Higgs
- V. Avati, K. Oesterberg (Totem) on the RP acceptance calculations
- F. Oljemark (Totem) on L1 jet calibration and diffractive Higgs Muon trigger studies - will be his Master’s thesis
- F. Ferro (Totem) on T1/T2 track reco and trigger generation

Need in addition for LOI:
Trigger table for a number of diffractive processes beyond the diff Higgs:
- Diffractive production of Jets, of W, Z, t, b
Currently about to start MC production with Pomwig in Wisconsin
RESERVE
Pile-up studies

Soft diffractive & elastic events contribute substantially to pile-up

**Crucial to study impact of pile-up on RP L1 condition**

Prerequisite:
Realistic MC simulation of diffractive events in pile-up

**Pile-up in CMS generated with Pythia, compare to HERA and pp leading proton data**
Pile-up studies (II)

- Pythia too low outside diff peak (~ factor 2-3)
- Pythia approx ok in diffractive peak after taking shrinkage 
  \[ b = b_0 + 4 \alpha_1 \ln s \] 
  into account

Pythia wrong in shape & normal. outside diff peak

Plots Marta Ruspa