Forward detectors in the CMS L1 Status of studies

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Forward detectors offer new physics opportunities for CMS
Put them to use in L1 - new area that is not covered in the L1 TDR
Near-term aim of studies is CMS/TOTEM diff & fwd physics LOI
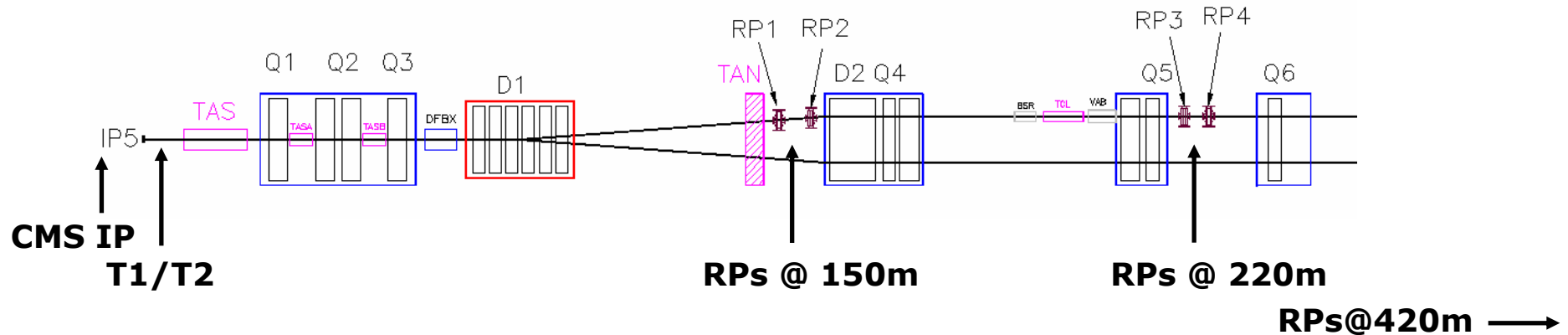
Directly involved in studies:
CMS:
❖Wisconsin (Sridhara Dasu, Creighton Hogg, MG)
❖Turin (Marta Ruspa, MG)
❖Bristol (Richard Croft, Dave Newbold)
Totem:
❖Helsinki (Ken Oesterberg, Fredrik Oljemark)
❖Genova (Fabrizio Ferro)

Forward detectors

CMS IP

T1/T2

RPs @ 150m **RPs @ 220m**

RPs@420m ⟶

TOTEM detectors:
T1 (CSC) in CMS endcaps
T2 (GEM) in shielding behind HF
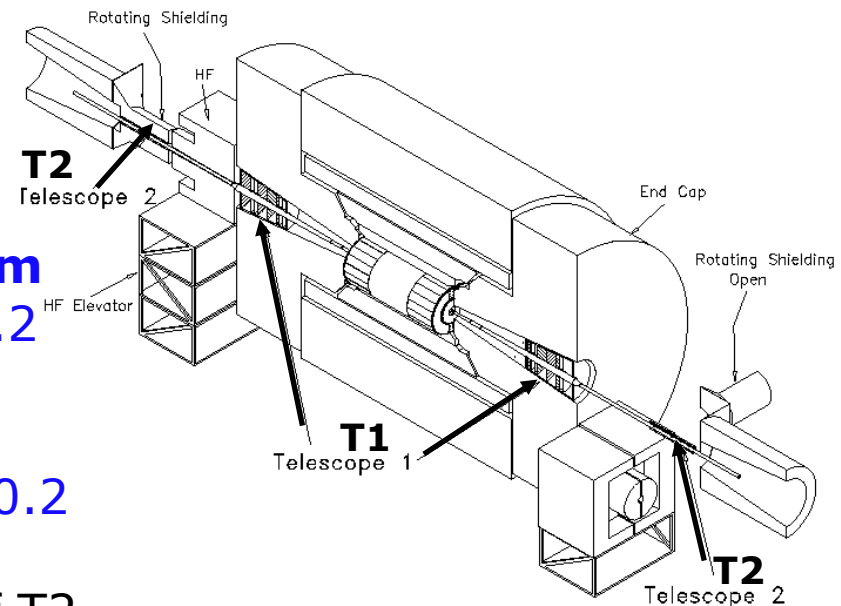T1 + T2: $3 \leq |\eta| \leq 6.8$
Roman pots (Si) on 2 sides at up to **220 m**
Acc. for nominal LHC optics: $0.02 < xi < 0.2$

Under discussion: **RPs at 420 m**
Acc. for nominal LHC optics: $0.002 < xi < 0.2$

CMS: **Castor calorimeter**, downstream of T2

The challenge: Double-diffractive production of low mass Higgs

Our poster-child process:
H (120 GeV, DD prod) → b bbar

L1 signature without fwd detectors:
2 jets in CMS cal, each E_T < 60 GeV

Calibrated L1 jet E_T cut and
resulting L1 2-jet rate:
110 GeV -- 1 kHz
60 GeV -- 10 kHz
Target L1 output rate 75 kHz

Need additional conditions to trigger a 120 GeV Higgs with L1: Forward detectors !

2 x 10^{33} cm^{-2} s^{-1} jet trigger rates

CMS UW-Madison
CMSIM 120 ORCA 4
(With minimum bias)
L = 2×10^{33} cm^{-2} s^{-1}

- ● 1-Jet
- ■ 2-Jet
- ▲ 3-Jet
- ▼ 4-Jet

Rate (kHz) vs Calibrated Trigger E_T Cutoff (GeV)

Note: Importance of studies goes beyond DD Higgs case to more general question of how to trigger with L1 on states with comparatively low E_T
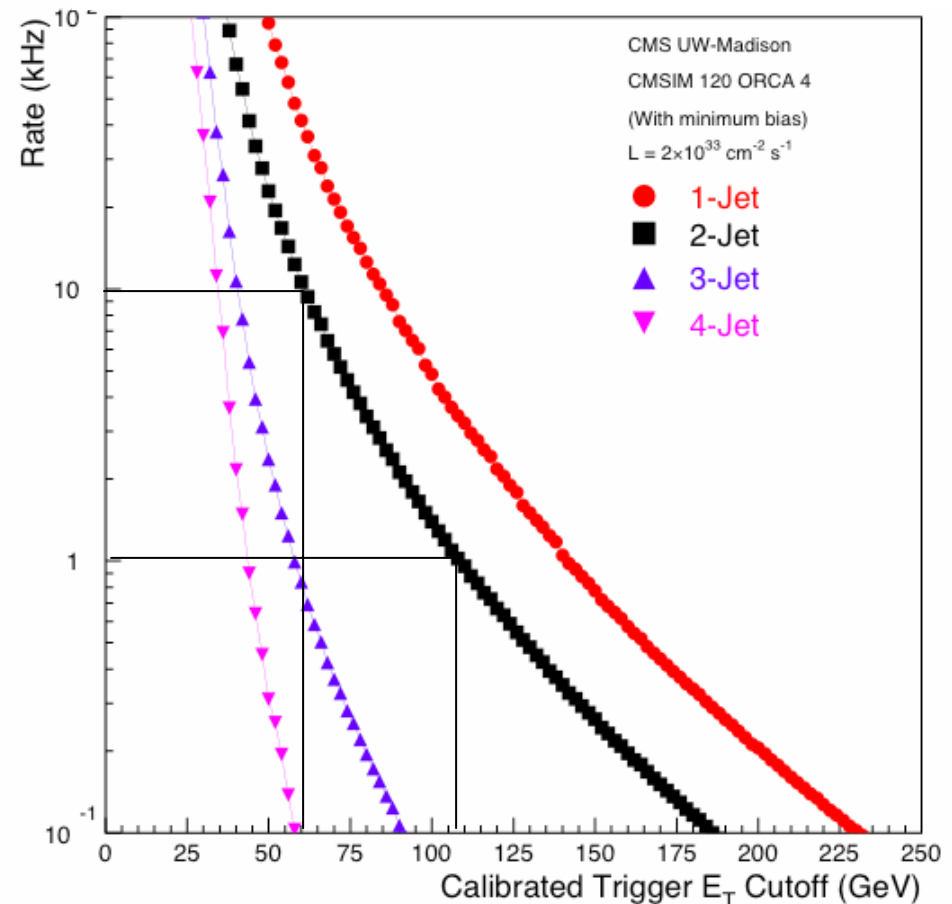
On-going studies and their goals

To answer:
A) What can be done with **central CMS L1 condition** alone
B) What can be done with **(central CMS + RP at 220/420m)** L1 cond.
C) What can be won by **adding T1/T2**
- as veto condition on L1
- as minimum bias trigger on L1
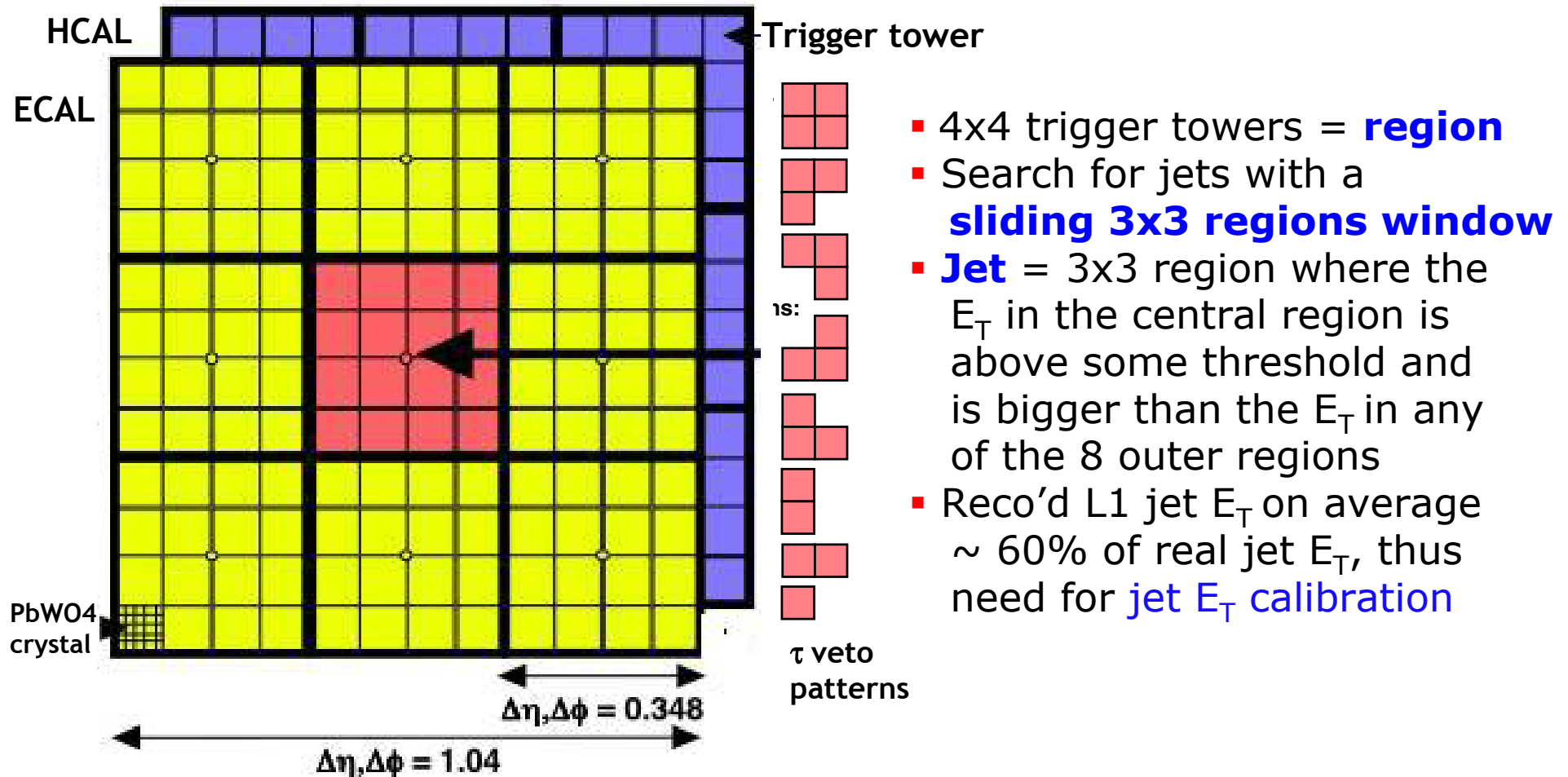- to differentiate between single and double diffraction

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})
ii) L = 10^{33}
iii) L = $2x\ 10^{33}$
iv) L = 10^{34}

a) for signal events (EDDE and Exhume generators)
b) for QCD background events (pythia)

Reminder: Level-1 Jets

HCAL ← Trigger tower

ECAL

PbWO4 crystal

$\Delta\eta, \Delta\phi = 0.348$

$\Delta\eta, \Delta\phi = 1.04$

τ veto patterns

- 4x4 trigger towers = **region**
- Search for jets with a **sliding 3x3 regions window**
- **Jet** = 3x3 region where the E_T in the central region is above some threshold and is bigger than the E_T in any of the 8 outer regions
- Reco'd L1 jet E_T on average ~ 60% of real jet E_T, thus need for jet E_T calibration
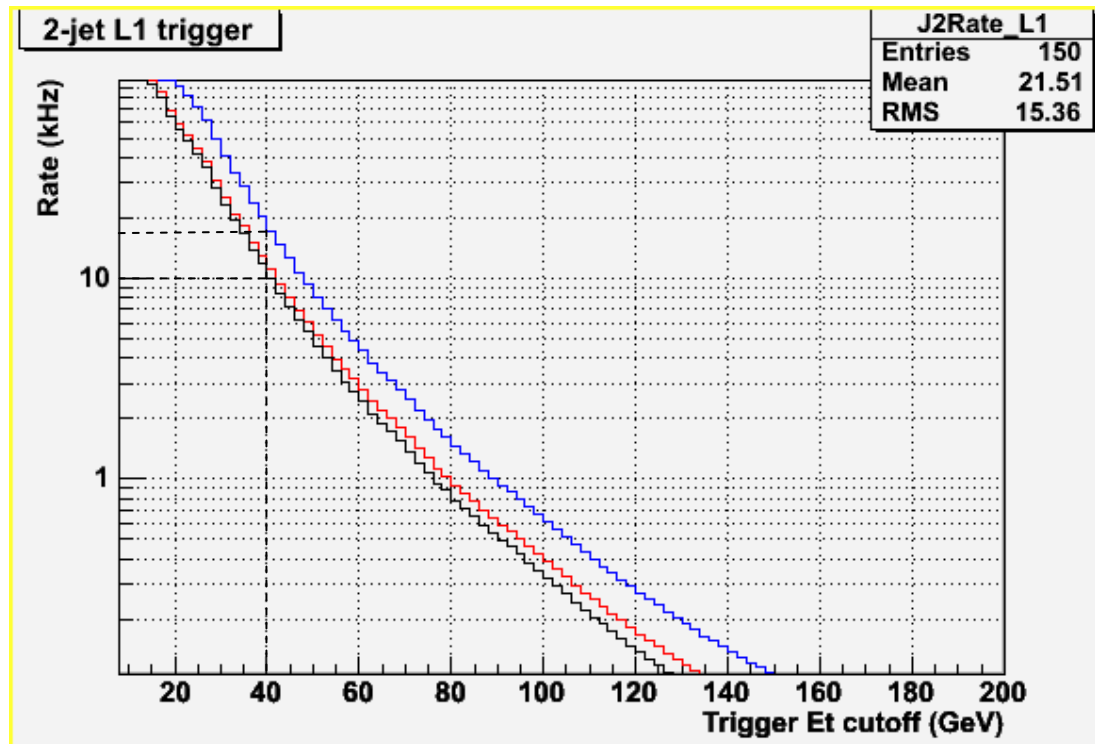
A jet = 144 trigger towers, with typical tower dimensions $\Delta\eta \times \Delta\phi = 0.09 \times 0.09$
Hence typical jet dimensions: $\Delta\eta \times \Delta\phi = 1 \times 1$

Caveat: Work in progress !

All result plots shown in the following are preliminary.

L1 rate studies for diff Higgs

L1 rate (integrated) in kHz as function of 2-jet E_T cutoff

$L = 10^{33}$ with full pile-up (including diff and elastics)

L1 jet calibration applied

Blue: no H_T cut
Sum(2-jet E_T)/H_T > 0.9 red
                    > 0.95 black

Plot Creighton Hogg

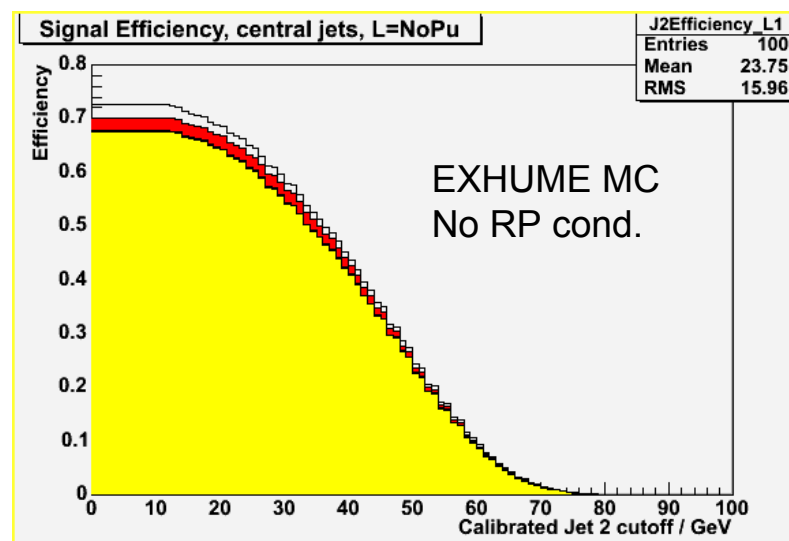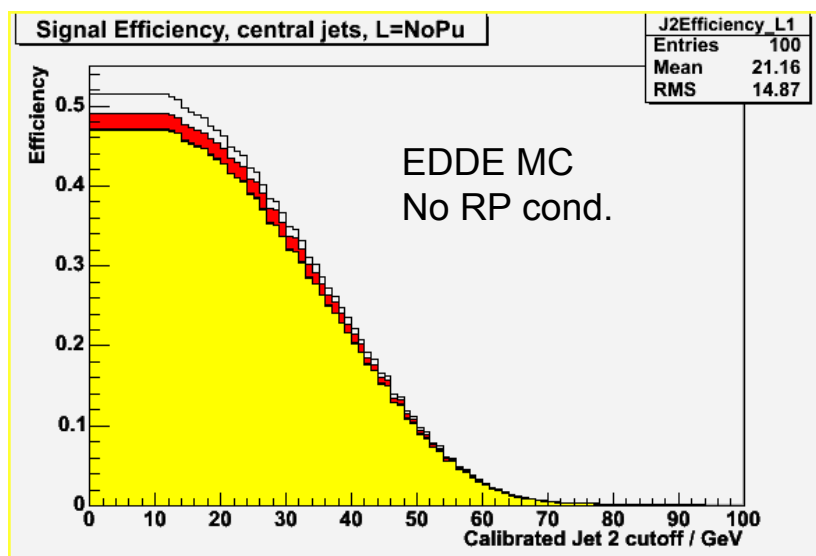Possible L1 condition that comes closest to a rap gap trigger (rap gap > 2):
2 jets in central Cal ($|\eta|$<3) with $\Sigma(E_T$ 2 jets) / H_T > threshold
H_T = sum of the scalar E_T of all jets in the event with E_T(jet)>threshold

Clearly need additional L1 condition for 2-jet E_T cutoff around 40GeV
Note: L1 jet E_T resolution ~30%, b pair from Higgs decay has E_T < 60GeV

L1 efficiency studies for diff Higgs

Plots
Richard
Croft

Signal efficiency (integrated) as function of L1 2-jet E_T cutoff for 2 central jets in CMS
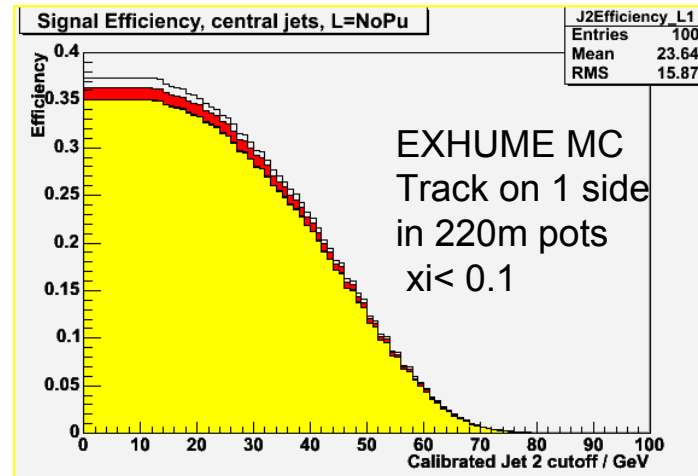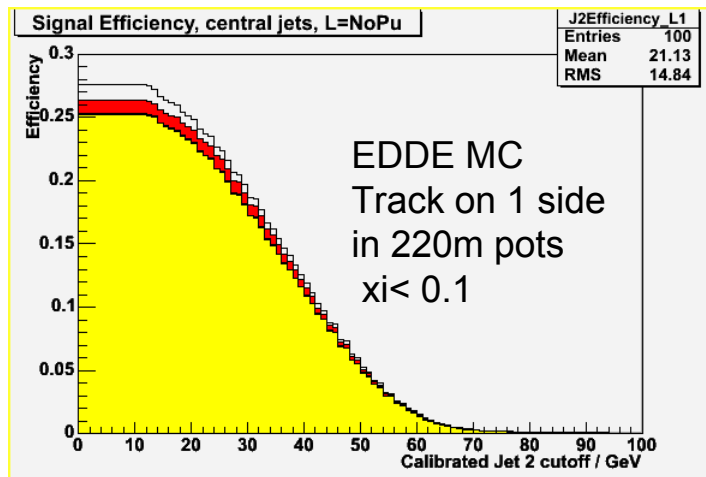L1 jet E_T calibration applied
No pile-up

EDDE and EXHUME MCs as two extreme cases of signal xi distribution
Difference in L1 efficiency reflects difference in xi distribution in 2 MCs:
The two jets are much more central in Exhume than in EDDE
See talk by Creighton Hogg in HERA-LHC diff WG meeting Jan 05

L1 efficiency studies for diff Higgs (II)
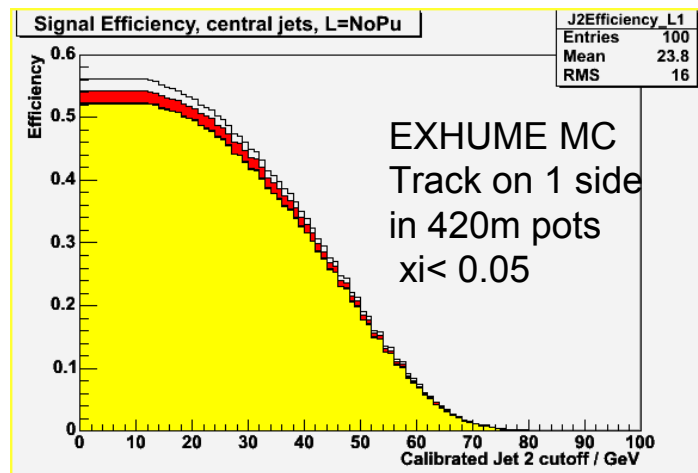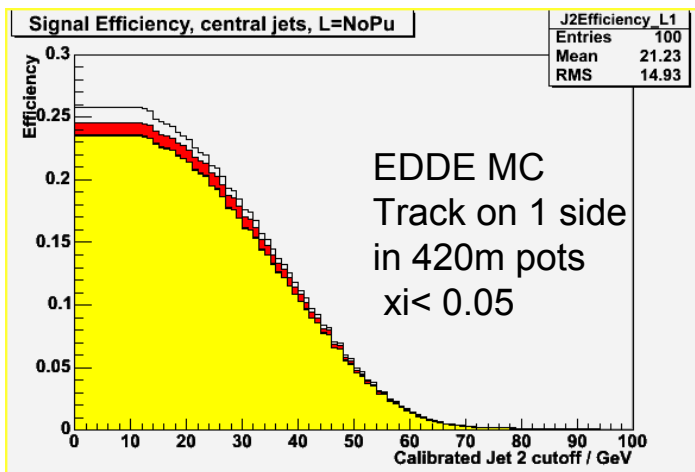

Signal efficiency (integrated) as function of L1 2-jet E_T cutoff for 2 central jets in CMS + RP cond

L1 jet E_T calibration applied
No pile-up

White: no H_T cut
Sum(2-jet E_T)/H_T
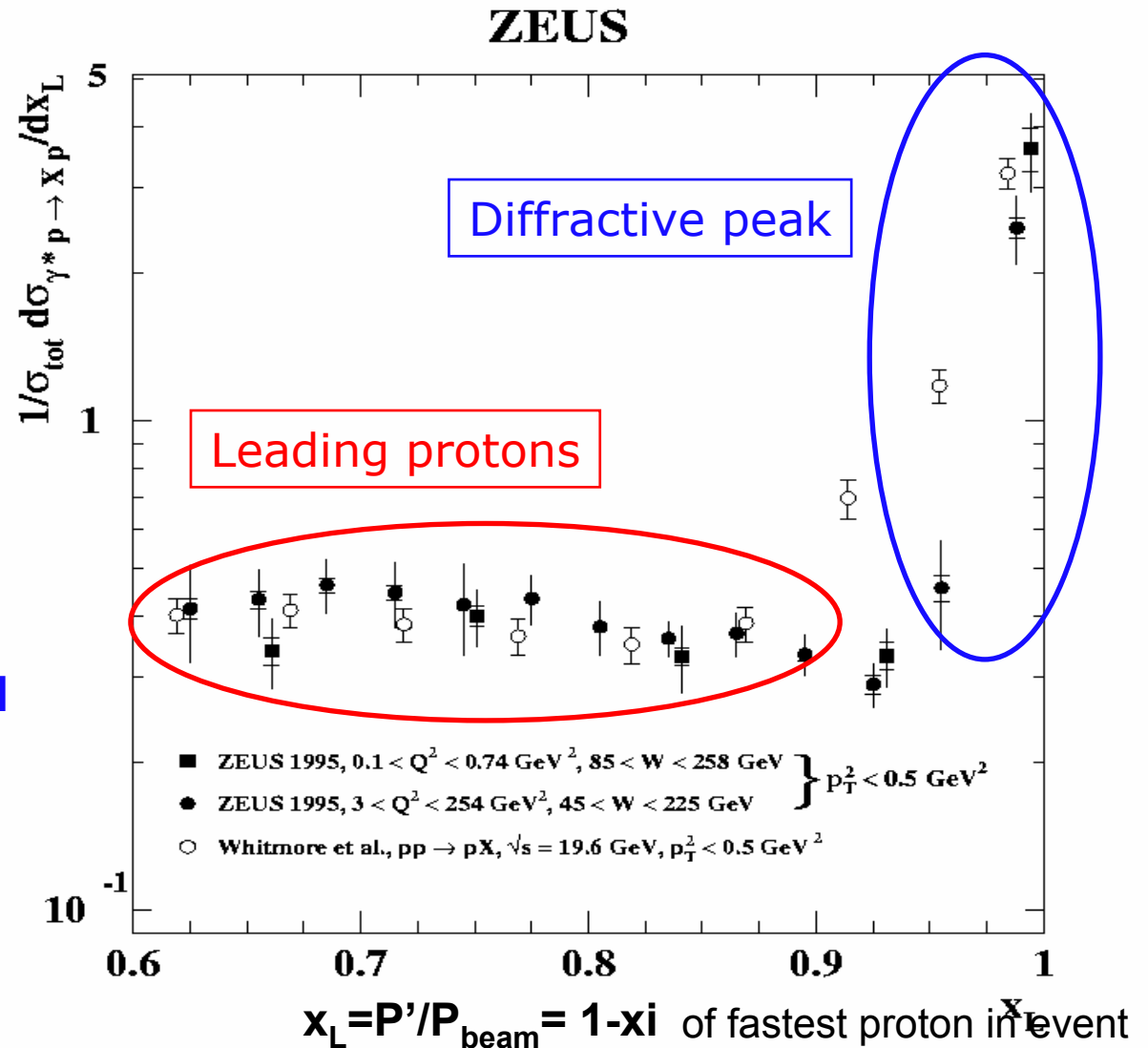   > 0.7 red
    > 0.95 yellow

Plots Richard Croft

RP condition reduces 2-jet L1 trigger signal efficiency by factor ~2
Result of limited acceptance of RPs in diffractive peak region

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

ZEUS

Diffractive peak

Leading protons

$\frac{1}{\sigma_{tot}} \, d\sigma_{\gamma^* p \to x p} / dx_L$

- ■ ZEUS 1995, $0.1 < Q^2 < 0.74$ GeV^2, $85 < W < 258$ GeV } $p_T^2 < 0.5$ GeV^2
- ● ZEUS 1995, $3 < Q^2 < 254$ GeV^2, $45 < W < 225$ GeV
- ○ Whitmore et al., $pp \to pX$, $\sqrt{s} = 19.6$ GeV, $p_T^2 < 0.5$ GeV^2

$x_L = P'/P_{beam} = 1 - xi$ of fastest proton in event

Pile-up studies (II)

$\frac{1}{\sigma_{tot}} \frac{d\sigma}{dx_L}$

- ZEUS
- PYTHIA

$x_L = P'/P_{beam} = 1-xi$

p'_z/p_z

ZEUS

$b \ (GeV^{-2})$

- ZEUS 1995, $0.1 < Q^2 < 0.74 \ GeV^2$, $85 < W < 258 \ GeV$
- ZEUS 1995, $3 < Q^2 < 254 \ GeV^2$, $45 < W < 225 \ GeV$ } $p_T^2 < 0.5 \ GeV^2$
- ZEUS 1994, $Q^2 < 0.02 \ GeV^2$, $176 < W < 225 \ GeV$
- Whitmore et al., $pp \rightarrow pX$, $\sqrt{s} = 19.6 \ GeV$, $p_T^2 < 0.5 \ GeV^2$

$x_L = P'/P_{beam} = 1-xi$

❖ Pythia wrong in shape & normal.
   outside diff peak (~ factor 2-3)
❖ Pythia approx ok in diffractive peak
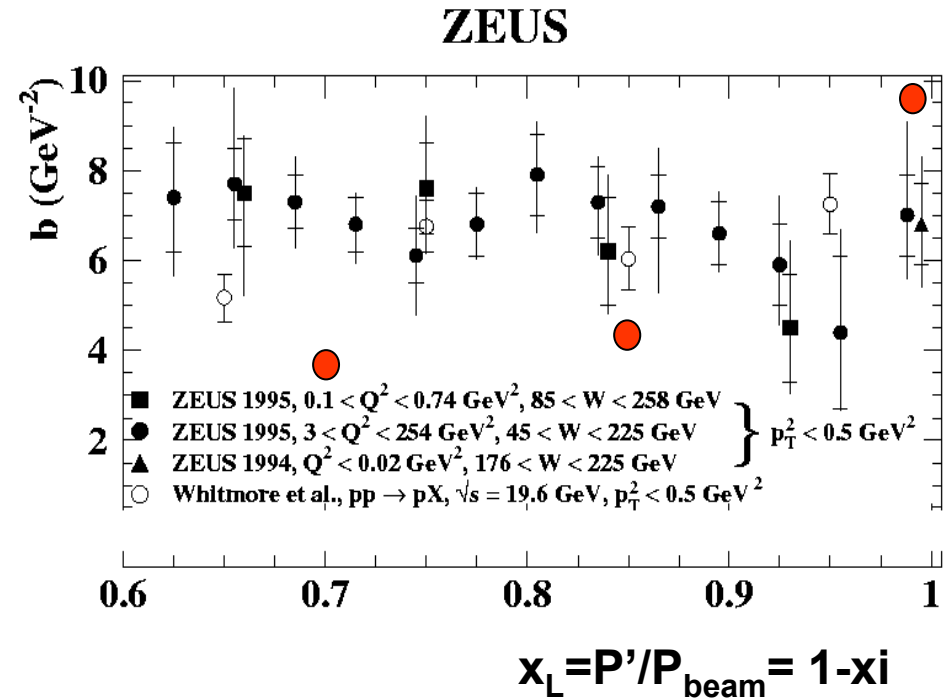
❖ Pythia too low outside diff peak
❖ Pythia approx ok in diff peak
   after taking shrinkage
   $(b = b_0 + 4 \ alpha^I \ln s)$
   into account

Plots Marta Ruspa

Loose ends

❖ Current version of L1 jet calib under-corrects E_T by up to 15% at E_T < 25GeV

❖ Currently used RP acceptance numbers (FAMOS) have only xi-dependence
New calculation with xi- and t-dependence available, need to learn how to use them in on-going studies

❖ L1 signal efficiency studies:
- Expand to EDDE signal MC with full pile-up as soon as available
- Study Exhume as alternative case as well as soon as Exhume 1.0.0 MC samples become available

❖ L1 background rate studies:
- Study QCD background MC sample with full pile-up
- Study effect of adding RP L1 condition

❖ Pile-up:
Produce pile-up efficiency plots
(in zeroth order, protons in RPs for QCD background events always come from overlying pile-up events)

❖ Study possibilities of T1/T2 for L1

So far not addressed at all

❖ So far discussed H (120 GeV) $\rightarrow$ b bbar only
   Another interesting case: H (140 GeV) $\rightarrow$ W W*

❖ So far discussed Cal triggers only:
   Lepton triggers ?

❖ **Alignment trigger** for the RPs at nominal LHC optics and luminosities ?
   In low lumi, special optics runs alignment w.r.t. beam line with elastics
   But even there may need additional method to align w.r.t. CMS

❖ Question of **minimum bias trigger**:
   If request min. $SumE_T$ in Cal:
   How low can one go before noise starts dominating ?
   For no pile-up case could request activity in T1/T2 ?

Summary

Forward detectors are a powerful tool in combination with the CMS L1

- ❖ L1 rate and efficiency studies for our poster-child process
  H (120 GeV) → b bbar well under way

  A number of preliminary results already available
  More results should be forthcoming soon

  MC production will have caught up with studies soon

- ❖ Sufficient number of interesting L1-related questions and their
  associated studies remain as to provide sufficient material for
  at least another year-long workshop

  (Other diff Higgs decay channels, other diffractive processes,
   lepton triggers, alignment triggers for RPs, minimum bias trigger, ...)

Thanks to all contributors !