Project to Install Roman Pot Detectors at 220 m in ATLAS

Christophe Royon [*]

DAPNIA/Service de physique des particules,
CEA/Saclay, 91191 Gif-sur-Yvette cedex

We give a short description of the project to install roman pot detectors at 220 m from the interaction point in ATLAS. This project is dedicated to hard diffractive measurements at high luminosity.

1 Introduction

The motivation to install roman pot detectors at 220 m within ATLAS is quite clear. It extends nicely the project of measuring the total cross sections using roman pots at 240 m [2] by measuring hard diffraction at high luminosity in ATLAS in the LHC. As we will see in the following, it is also complementary to the FP420 project which aims at tagging protons at 420 m.

The physics motivation of this project corresponds to different domains of diffraction:

- A better understanding of the inclusive diffraction mechanism at the LHC by studying in detail the structure of pomeron in terms of quarks and gluons as it was done at HERA [3]. Of great importance is also the measurement of the exclusive production of diffractive events [4] and its cross section in the jet channel as a function of jet transverse momentum. Its understanding is necessary to control the background to Higgs signal.
- Looking for Higgs boson diffractive production in double pomeron exchange in the Standard Model or supersymmetric extensions of the Standard Model [5]. This is clearly a challenging topic especially at low Higgs boson masses where the Higgs boson decays in $b\bar{b}$ and the standard non-diffractive search is possible. We will detail in the following the trigger strategy.
- Sensitivity to the anomalous coupling of the photon by measuring the QED production cross section of W boson pairs. This might be the best way to access the anomalous coupling before the start of the ILC.
- Photoproduction of jets
- Other topics such as looking for stop events or measuring the top mass using the threshold scan method [6] which will depend strongly on the production cross section.

2 Roman pot design and location

We propose to install roman pots in ATLAS at 216 and 224 m on each side of the main ATLAS detectors. The project is a collaboration between the physics institutes and universities of Prague, Cracow, Stony Brook, Michigan State University, LPNHE (Paris 6), Giessen, and

[*]On behalf of the RP220 Collaboration

in addition the University of Chicago and the Argonne National Laboratory for the timing detectors.

The roman pot design follows as close as possible the design which is currently used by the TOTEM collaboration and the Luminosity group of the ATLAS collaboration which aims at measuring the total cross section using roman pots at 240 m. The only difference is that we only need the horizontal arms and not the vertical arms since hard diffractive protons are scattered horizontally. We will follow the TOTEM experience to build the roman pots in Vakuum Praha and to use the same technics for the step motors and the LVDT system.

Assuming one can go down to 10 (resp. 15) σ from the beam center, it is possible to measure protons with $\xi > 0.01$, and $\xi > 0.012$ on each side of ATLAS (resp. $\xi > 0.014$, $\xi > 0.016$) where ξ is the momentum fraction of the initial proton carried away by the Pomeron [7]. This can be translated in missing mass acceptance as illustrated in Fig 1. The missing mass acceptance using only the 220 m pots starts at 135 GeV, but increases slowly as a function of missing mass. It is clear that one needs both FP420 and RP220 projects, or in other words the possibility to detect scattered protons at 220 and 420 m to obtain a good acceptance on a wide range of masses since most events are asymmetric (one tag at 220 m and another one at 420 m). The precision on mass reconstruction using either two tags at 220 m or one tag at 220 m and another one at 420 m is of the order of 2-3 % on the full mass range. This shows the advantage of this measurement which allows to give a very good mass resolution on a wide range of masses, and thus to detect Higgs bosons at low masses decaying into $b\bar{b}$. The idea is to enhance the signal over background ratio by benefitting from the good resolution of the detectors and the suppression of the b jet background due to the $J_z = 0$ suppression rule for b jet exclusive production.

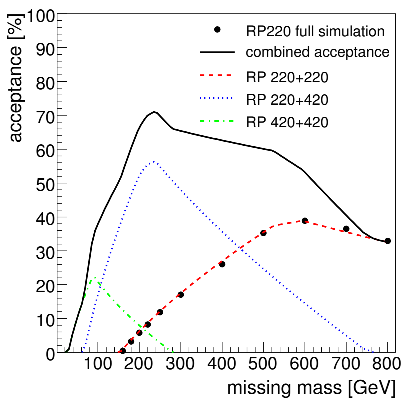

Figure 1: Roman pot detector acceptance as a function of missing mass assuming a 10σ operating positions, a dead edge for the detector of 50 μm and a thin window of 200 μm.

3 Detector inside roman pots

We propose to put inside the roman pots two kinds of detectors, namely Silicon detectors to measure precisely the position of the diffracted protons, and the mass of the produced object, such as the Higgs boson, and ξ, and precise timing detectors.

The position detectors will consist in either five layers of Silicon strips of 50 μm and two additional layers used for triggering, or 3D Silicon detectors if they are available industrially by the time we need to instal the roman pots. If the Silicon strip option is chosen, there will be four different orientations, namely X, Y, U, and V (U and V being orientated within 45 degrees with respect to X and Y). The strip size will be 50 μm and the detector size about 2 cm, which allows a measurement up to $\xi \sim 0.15$. The Silicon strip detectors will be edgeless which means that the dead edge will be of the order of 30-50 μm so that we can move the detector as close to the beam as possible without losing some acceptance due to the dead edge. The detectors will be read out by the standard ABCNext chip being developped in Cracow for the Silicon detector of ATLAS. The latency time of the ABCNext chip is of the order of 3.5 μs which gives enough time to send back the local L1 decision from the roman pots to ATLAS (see the next paragraph about trigger for more detail), and to receive the L1 decision from ATLAS, which means a distance of about 440 m. It is also foressen to perform a slight modification of the ABCNext chip to include the trigger possibilities into the chip. The other option is to use 3D Silicon detectors using the same readout system as before (ABCNext chip). These detectors use a lateral electric field, instead of vertical in conventional planar techniques. Holes of the order of 10 μm crossing the full thickness of the detector are filled with a conductive medium in order to collect the ionisation (electrons or holes) depending on the applied bias. Both kinds of options will be tested in Prague and in Saclay using the full electronics chain (including the ABCNext chip) and a laser or a radioactive source. Beam tests at DESY or CERN are also foreseen. It is planed to install the roman pot together with the Silicon detectors during a shut down of the LHC in 2009-2010.

The timing detectors are necessary at the highest luminosity of the LHC to identify from which vertex the protons are coming from. It is expected that up to 35 interactions occur at the same bunch crossing and we need to identify from which interaction, or from which vertex the protons are coming from. A precision of the order of a few mm or 5-10 ps is required to distinguish between the different vertices and to make sure that the diffracted protons come from the hard interactions. Picosecond timing detectors are still a challenge and are developped in a collaboration between Saclay, Stony Brook, the University of Chicago and Argonne National Laboratory for medical and particle physics applications. The proton timings will be measured in a crystal of about 2.5 cm located inside the roman pots, and the signal will be read out by Micro-Channel Plates Photomultipliers developped by Photonis. The space resolution of those detectors should be of the order of a few mm since at most two protons will be detected in those detectors for one given bunch crossing at the highest luminosity. The detectors are read out with a Constant Fraction Discriminator which allows to improve the timing resolution significantly compared to usual electronics. A first version of the timing detectors is expected to be ready in 2009-2010 with a worse resolution of 40-50 ps, and the final version by 2012 with a resolution of 5-10 ps.

4 Trigger principle and rate

In this section, we would like to give the principle of the trigger using the roman pots at 220 m as well as the rates obtained using a simulation of the ATLAS detector and trigger framework.

The principle of the trigger is shown in Fig. 2 in the case of a Higgs boson decaying into $b\bar{b}$ as an example. The first level trigger comes directly from two different Silicon strip layers in each roman pot detector. It is more practical to use two dedicated planes for triggering only since it allows to use different signal thresholds for trigger and readout. The idea is to send at most five strip addresses which are hit at level 1. A local trigger is defined at the roman pot level on each side of the ATLAS experiment by combining the two trigger planes in each roman pot and the roman pots as well. If the hits are found to be compatible (not issued by noise but by real protons), the strip addresses are sent to ATLAS, which allows to compute the ξ of each proton, and the diffractive mass. This information is then combined with the information coming from the central ATLAS detector, requesting for instance two jets above 40 GeV in the case shown in Fig. 2. At L2, the information coming from the timing detectors for each diffracted proton can be used and combined with the position of the main vertex of ATLAS to check for compatibility. Once a positive ATLAS trigger decision is taken (even without any diffracted proton), the readout informations coming from the roman pot detectors are sent to ATLAS as any subdetector.

The different trigger possibilities for the roman pots are given below:

- **Trigger on DPE events at 220 m:** This is the easiest situation since two protons can be requested at Level 1 at 220 m. Three different options are considered:
  - trigger on high mass Higgs ($M > 160$ GeV) given by ATLAS directly (decay in WW, ZZ),
  - inclusive trigger on high mass object by requesting two high p_T jets and two positive tags in roman pots,
  - trigger on jets (high p_T jets given directly by ATLAS, and low p_T jet special trigger for QCD studies highly prescaled).
  This configuration will not rise any problem concerning the L1 rate since most of the events will be triggered by ATLAS anyway, and the special diffractive triggers will be for QCD measurements and can be highly prescaled.
- **Trigger on DPE events at 220 and 420 m** This is the most delicate scenario since the information from the 420 m pots cannot be included at L1. The strategy is the following (see Table 1):
  - trigger on heavy objects (Higgs...) decaying in $b\bar{b}$ by requesting a positive tag (one side only) at 220 m with $\xi < 0.05$ (due to the 420m RP acceptance in ξ, the proton momentum fractional loss in the 220m roman pot cannot be too high if the Higgs mass is smaller than 140 GeV) , and topological cuts on jets such as the exclusiveness of the process ($(E_{jet1} + E_{jet2})/E_{calo} > 0.9$, $(\eta_1 + \eta_2) \cdot \eta_{220} > 0$, where $\eta_{1,2}$ are the pseudorapidities of the two L1 jets, and η_{220} the pseudorapidity of the proton in the 220m roman pots). This trigger can hold without prescales to a luminosity up to 2.10^{33} cm^{-2}s^{-1},
  - trigger on jets (single diffraction, or double pomeron exchange) for QCD studies: can be heavily prescaled,
  - trigger on W, top... given by ATLAS with lepton triggers.
  Let us note that the rate will be of the order of 1 Hz at L2 by adding a cut on a presence of a tag in the 420 pots, on timing, and also on the compatibility of the rapidity of the central object computed using the jets or the protons in roman pots.

$\mathcal{L}$ $E_T > 40$ GeV	n_{pp} per bunch crossing	2-jet rate [kHz] [cm$^{-2} \cdot$ s^{-1}]	RP200 reduction factor	$\xi < 0.05$ reduction factor	Jet Prop.
1×10^{32}	0.35	2.6	120	300	1200
1×10^{33}	3.5	26	8.9	22	88
2×10^{33}	7	52	4.2	9.8	39.2
5×10^{33}	17.5	130	1.9	3.9	15.6
1×10^{34}	35	260	1.3	2.2	8.8

Table 1: L1 rates for 2-jet trigger with $E_T > 40$ GeV and additional reduction factors due to the requirement of triggering on diffractive proton at 220 m, and also on jet properties.

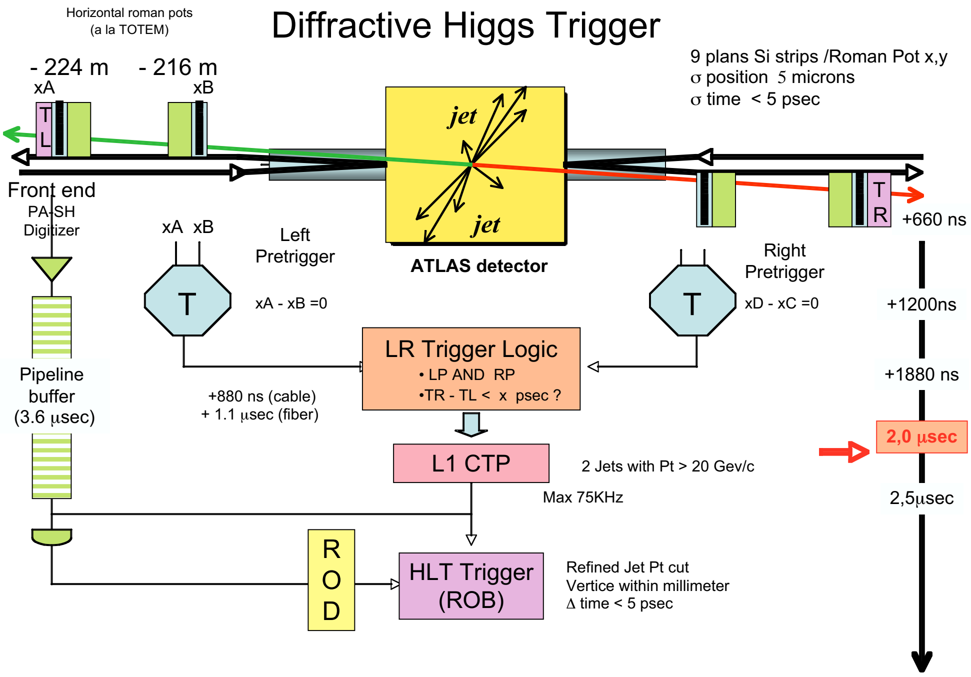

Figure 2: Principle of the L1 trigger using roman pot detectors at 220 m in the case of a Higgs boson decaying into $b\bar{b}$.

In this short report, we described the main aspects of the project to install roman pots at 220 m within ATLAS: Silicon detectors, measurement of the proton timings, and the trigger properties. This project is aimed to be proposed to ATLAS and the LHCC together with the FP420 one.

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