RP220 Project for ATLAS

6th Small x and Diffraction Workshop

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RP220 Project for ATLAS

- Goal: to propose, build and install forward proton detectors at 220 meters from ATLAS interaction point to study diffractive processes at LHC
- project is complementary to the ATLAS luminosity project which is focused on detection of elastic events and to the RP420 project since it accesses different domain of proton fractional momentum loss ξ
- Institutes:

- CEA Saclay
- LPNHE, Paris
- Stony Brook University
- Michigan State University
- University of Giessen
- AGH-University of Science and Technology, Krakow
- Institute of Nuclear Physics, Krakow
- Institute of Physics, Prague
- Charles University, Prague

Outlook

- Physics motivation
- Acceptance and resolution studies
- Technology:
  - Roman Pots
  - Detectors
  - Electronics
- Trigger
  - background studies
- Timing detector
- Project status

Diffractive physics at LHC

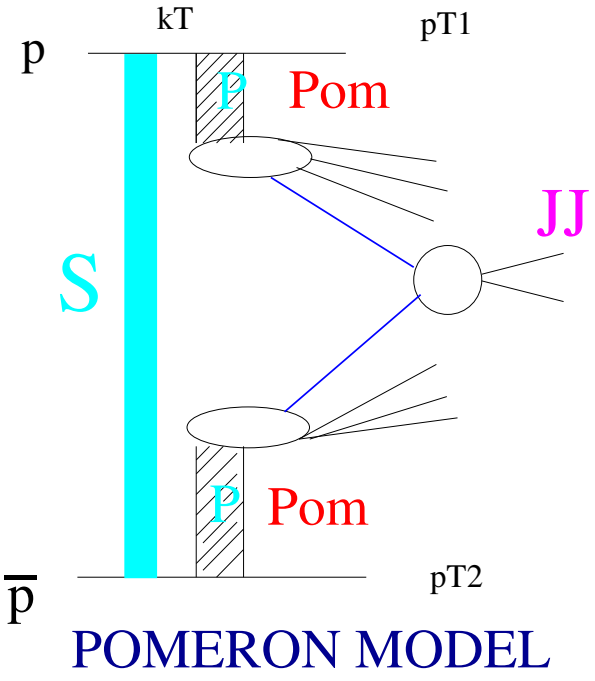
- diffractive proton structure functions, namely gluon density at high values of fractional momenta
- gap survival probability
- photon physics
- Double Pomeron Exchange

$$p + p \to p + X + p$$

- measuring the two scattered protons gives full kinematic constrain on the central object

$$M_X = \sqrt{\xi_1 \xi_2 s}$$

- interesting experimental concept which allows precise mass reconstruction of the central system

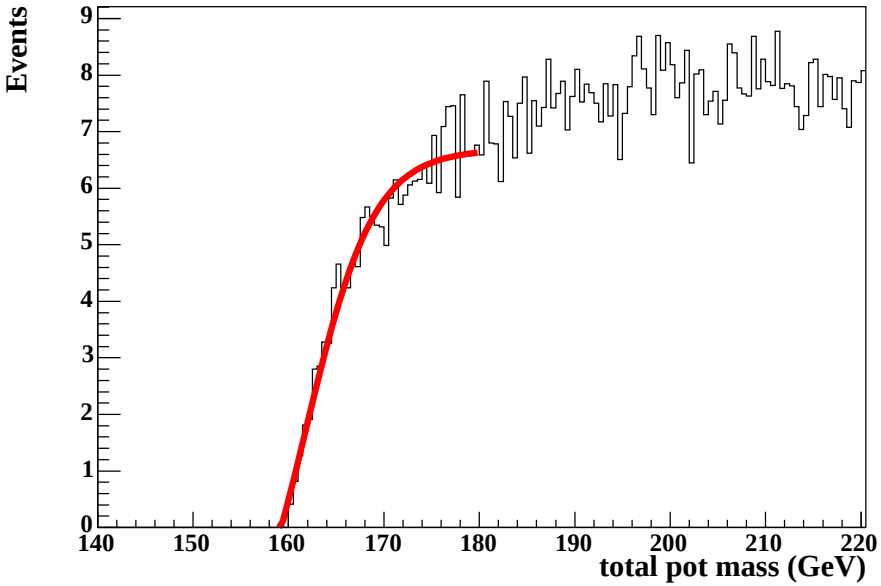


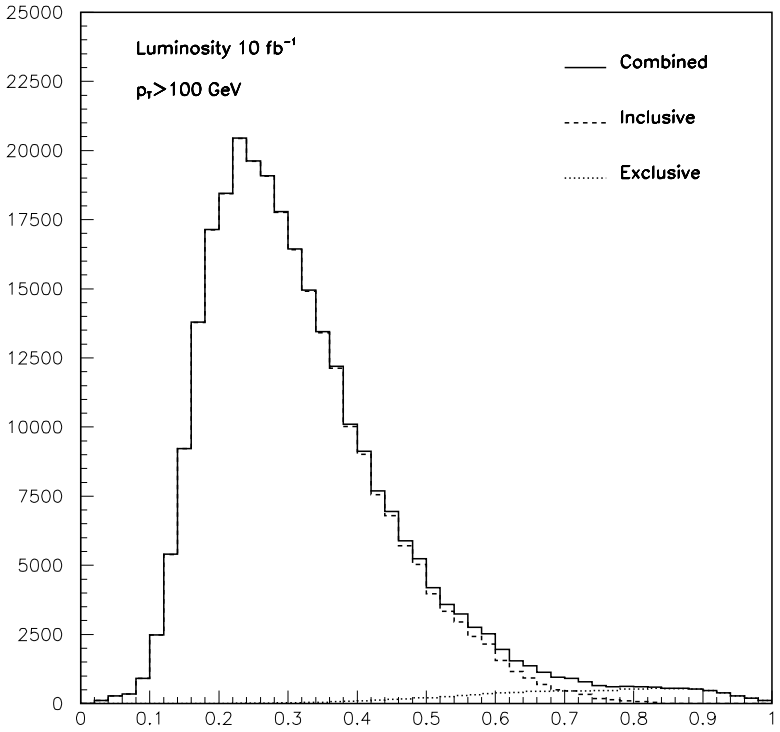
Exclusive DPE production

- study of exclusive jet production

$$R_{jj} = M_{jj}/M_X$$

  - $R_{JJ} > 0.85$ contribution form exclusive events only
  - measurement should help to constrain exclusive models

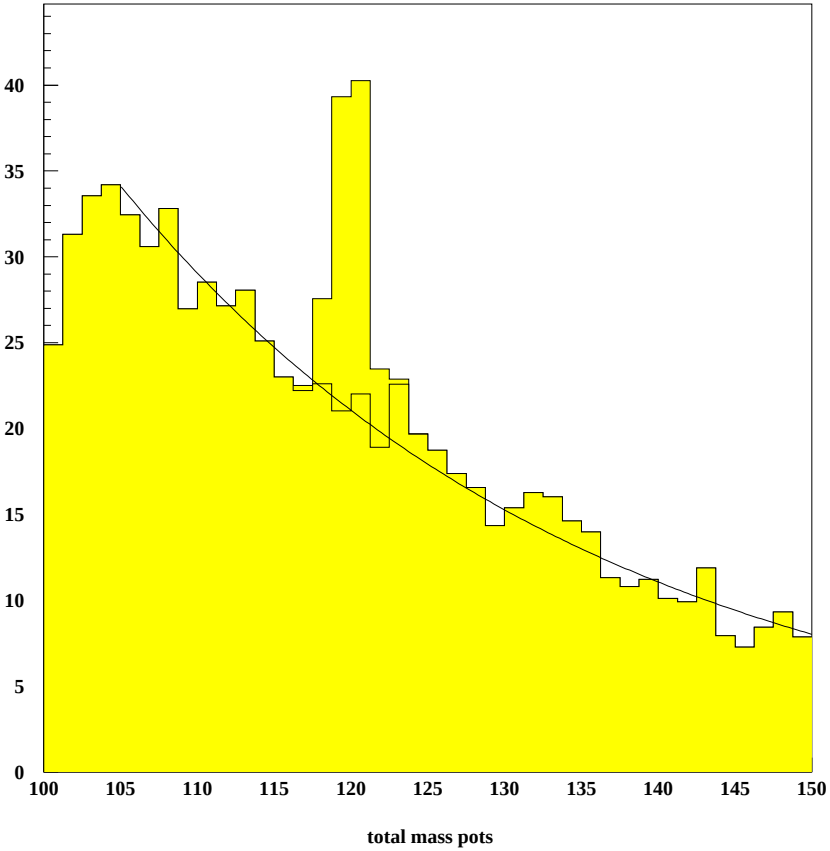




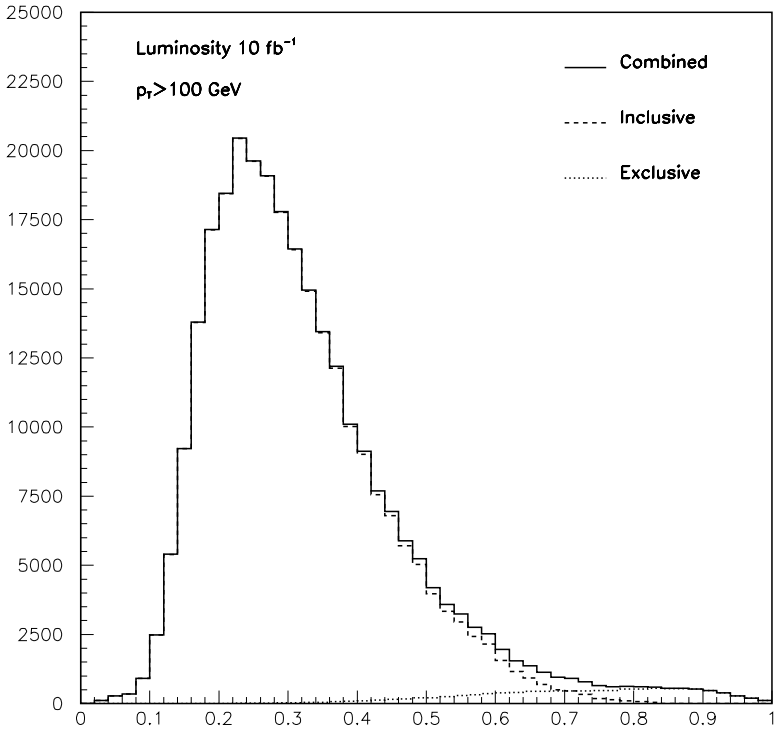
- $pp \to p + WW + p$
  - SM cross section is 56 fb
  - ~ 2000 events per year
  - mass threshold scan (1%)
  - $WW\gamma$ vertex probed with 1%

Exclusive DPE production

- exclusive Higgs production
  - direct access to the $H \to b\bar{b}$



- SUSY searches, ...



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  - SM cross section is 56 fb
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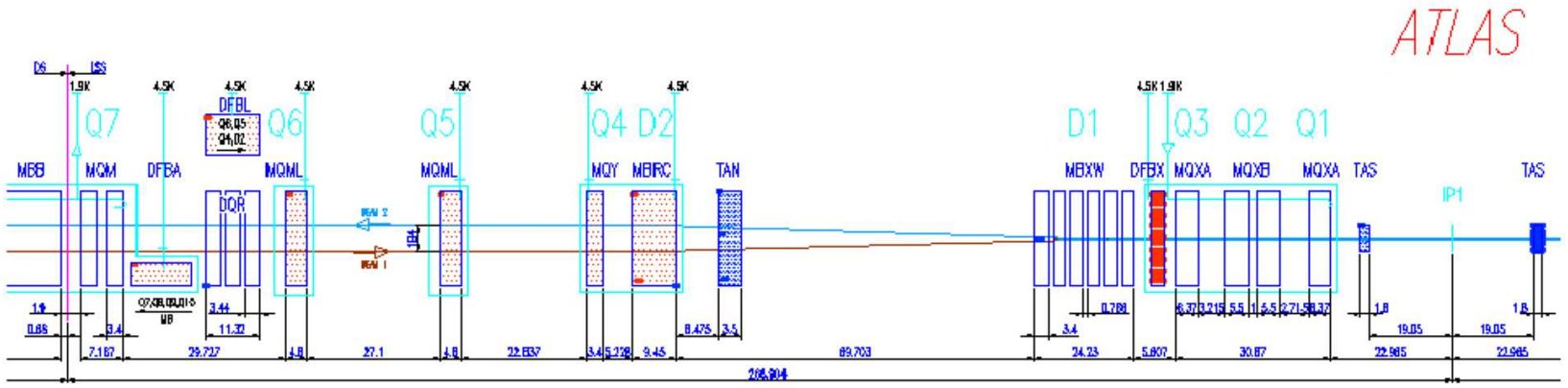
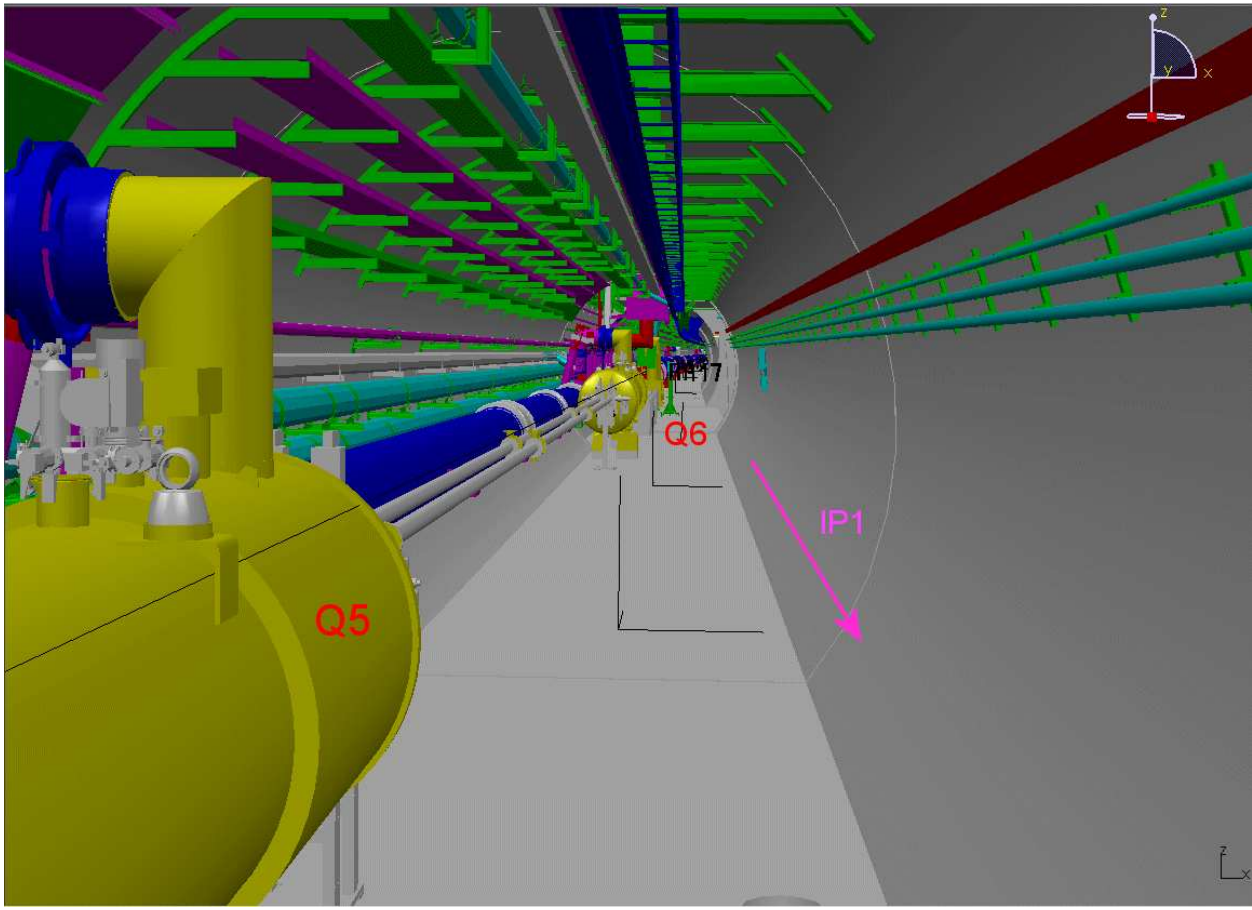
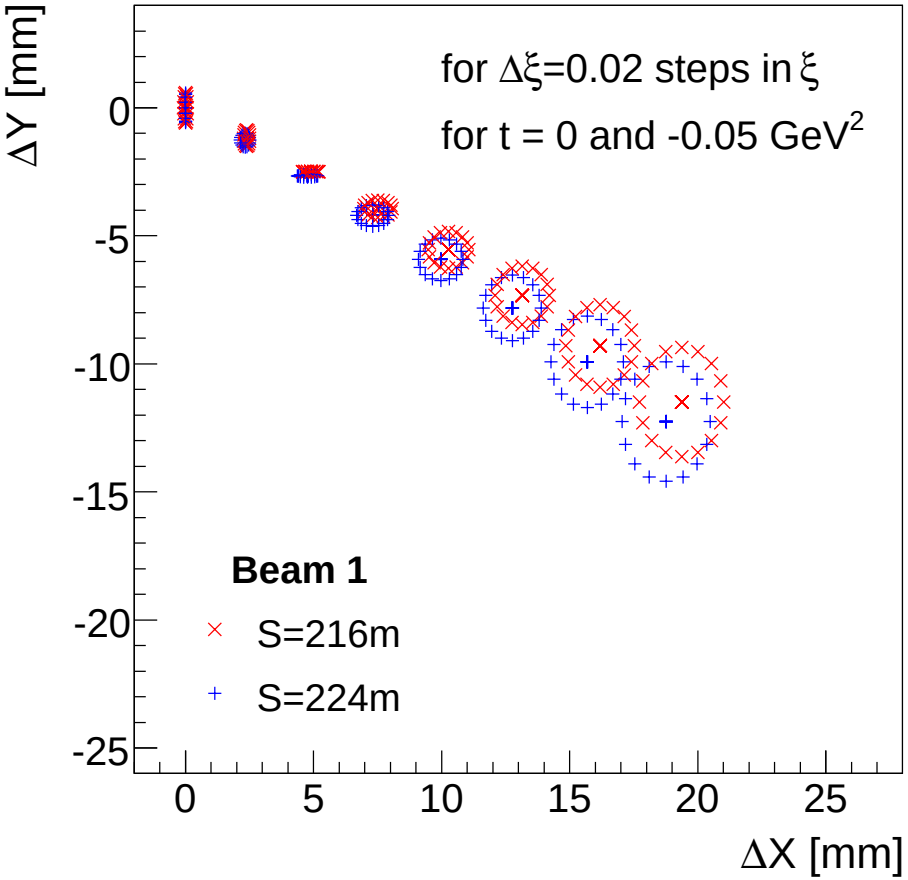
LHC beam-pipe at 220m



- consider space between Q5 (200m) and Q6 (226m)
- try to optimize the performance in terms of acceptance at low values of ξ and in terms of missing mass resolution
- Proposal: two stations at 216 and 224 meters



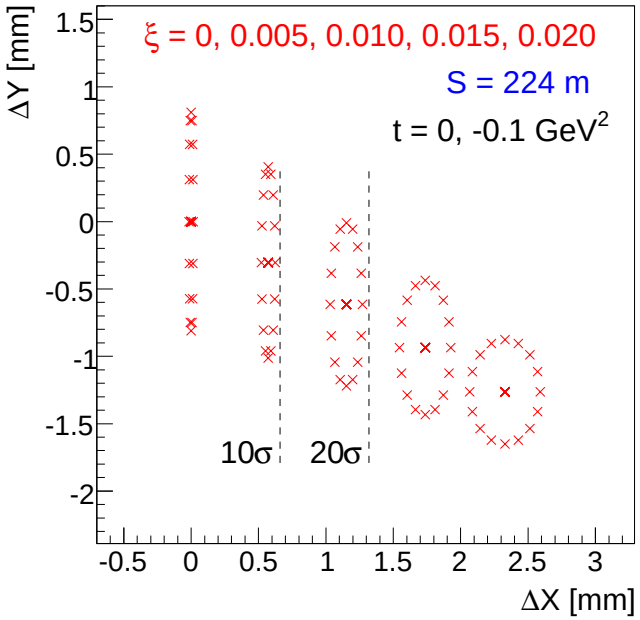
Acceptance in ξ

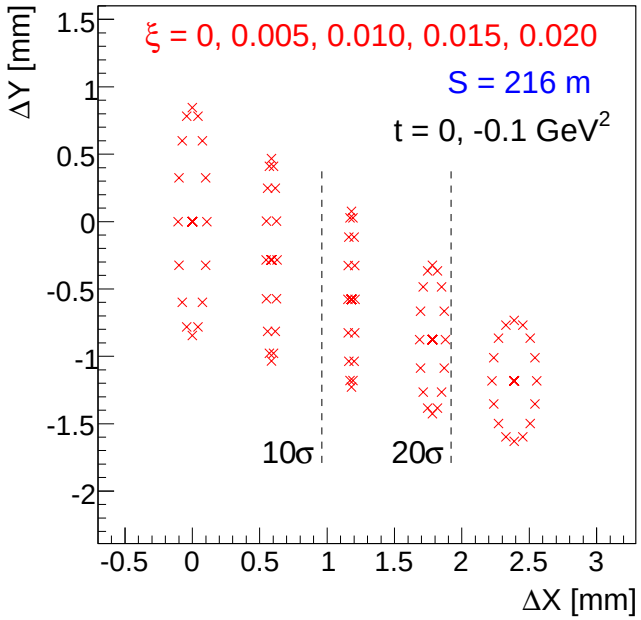


- MadX tracking with LHC6.5 low-β optics
- diffractive protons deflected mostly in the horizontal direction away from the ring center (the best possible configuration)
- similar, for the second beam

- aperture of LHC optics stops protons with $\xi > 0.15 \Rightarrow$ determines the detector size to be about $2 \times 2\,\mathrm{cm}$

Acceptance at low values of ξ





- best acceptance is around Q6 magnet
- spectrometer acceptance is determined by the RP that is closer to the IP
- larger distance between stations means better resolution

- 2×2 cm detector
- $200 + 50\,\mu$m dead edge

10σ

- beam 1: $0.010 < \xi < 0.15$
- beam 2: $0.012 < \xi < 0.14$

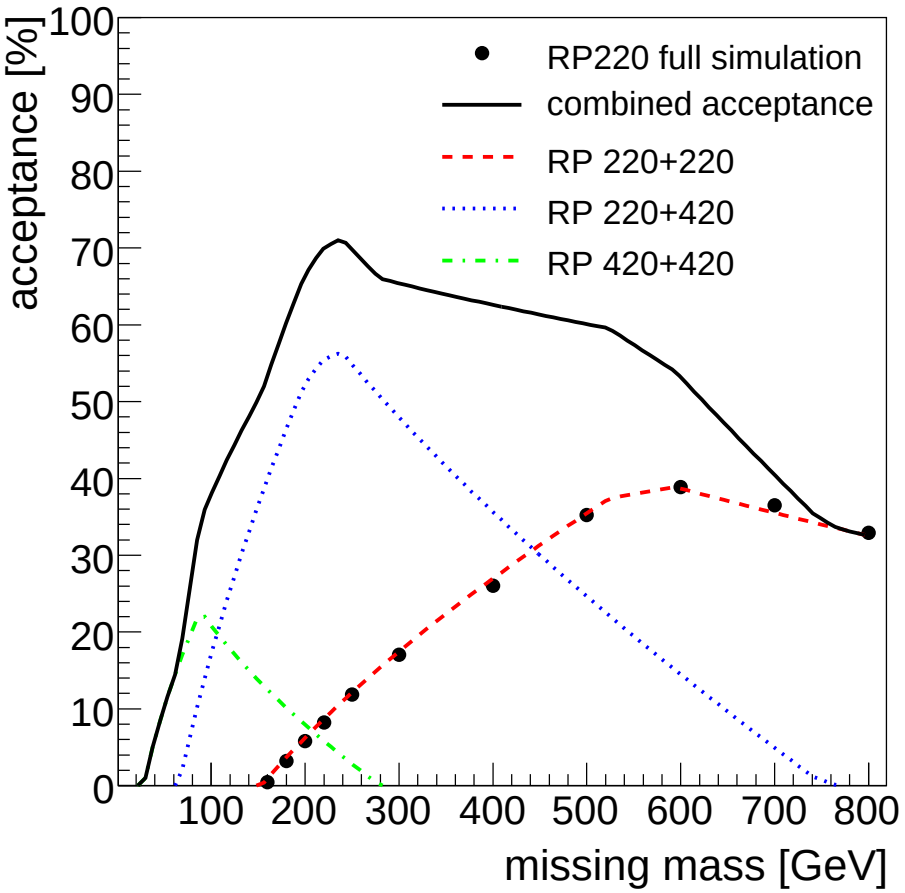
15σ

- beam 1: $0.014 < \xi < 0.15$
- beam 2: $0.016 < \xi < 0.14$

20σ

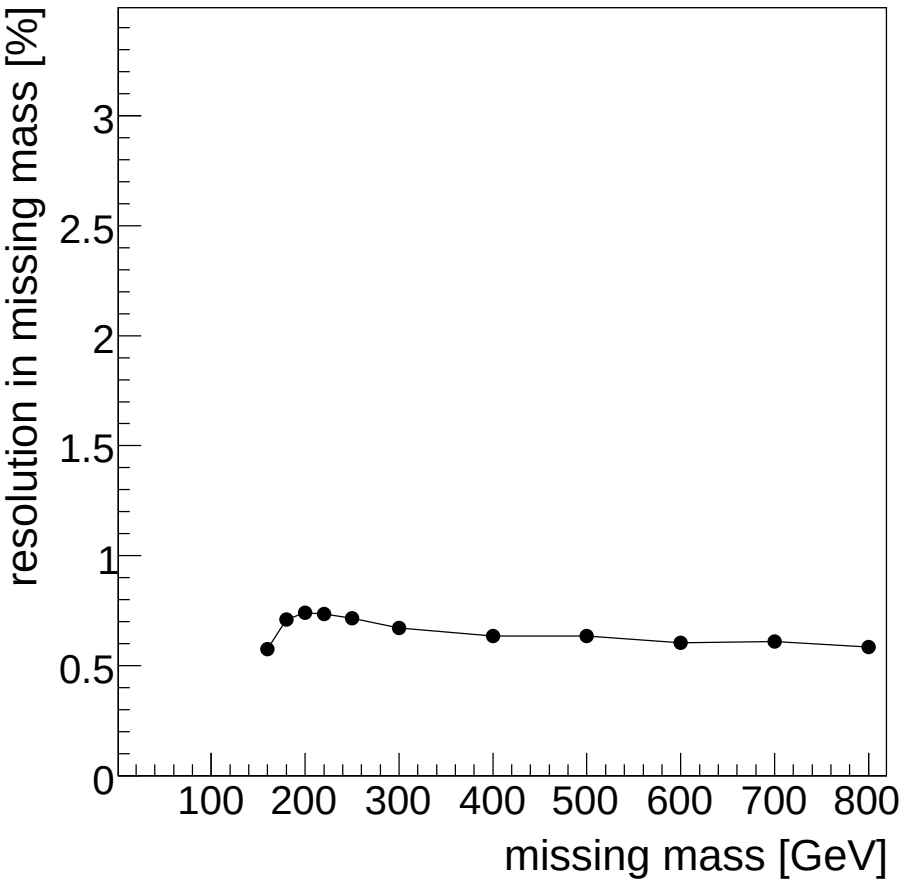
- beam 1: $0.018 < \xi < 0.15$
- beam 2: $0.021 < \xi < 0.14$

Acceptance in M_X



- computed assuming $F(\xi) \propto 1/\xi$ distribution for DPE events
- analytical results in good agreement with full simulation
- RP420 acceptance was assumed to be $0.002 < \xi < 0.02$
- complementarity with RP420 project: combined acceptance covers wide range in M_X

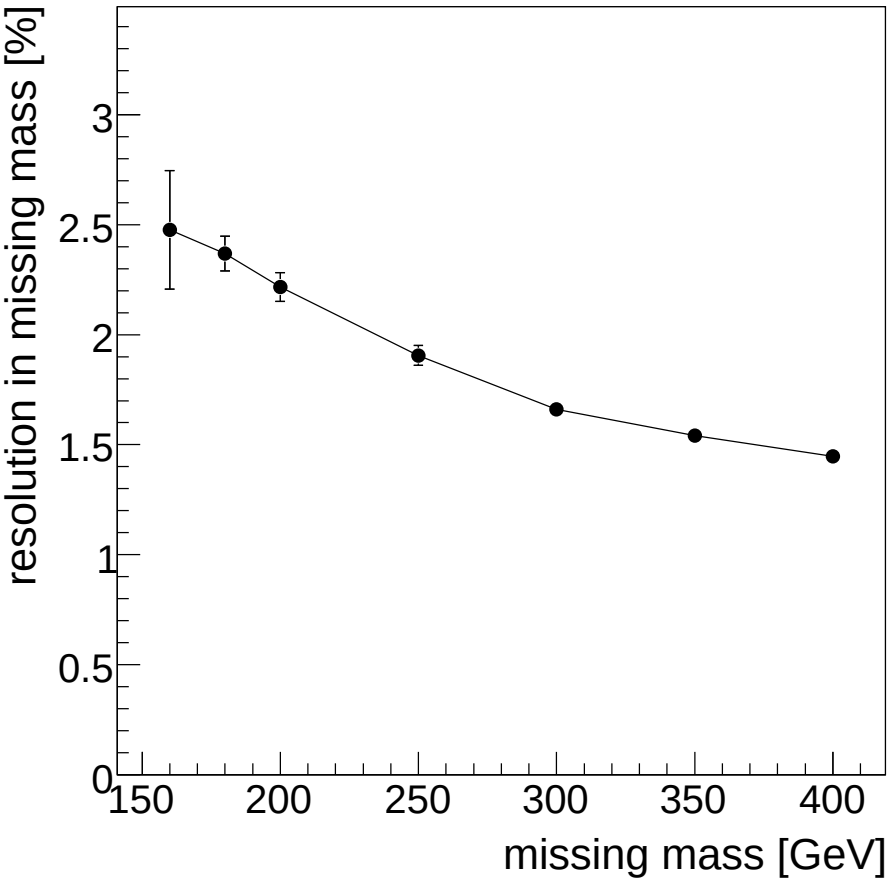
Missing mass resolution



- reconstruction code:
  - precomputed table in ξ,p_T, and ϕ for hits in the two RP stations
  - linear interpolation
  - tracks reconstructed using brute force by minimizing χ^2
  - full detector simulation being developed by Krakow group
- for $\sigma_i = 10\,\mu$m, the expected detector resolution is about 0.6%

- realistically, due to uncertainties in the detector alignment, final precision of about $15 - 20\,\mu$m can be achieved
- 8 meters distance between RP stations gives acceptable resolution of about 1%

Beam influence on M_X resolution



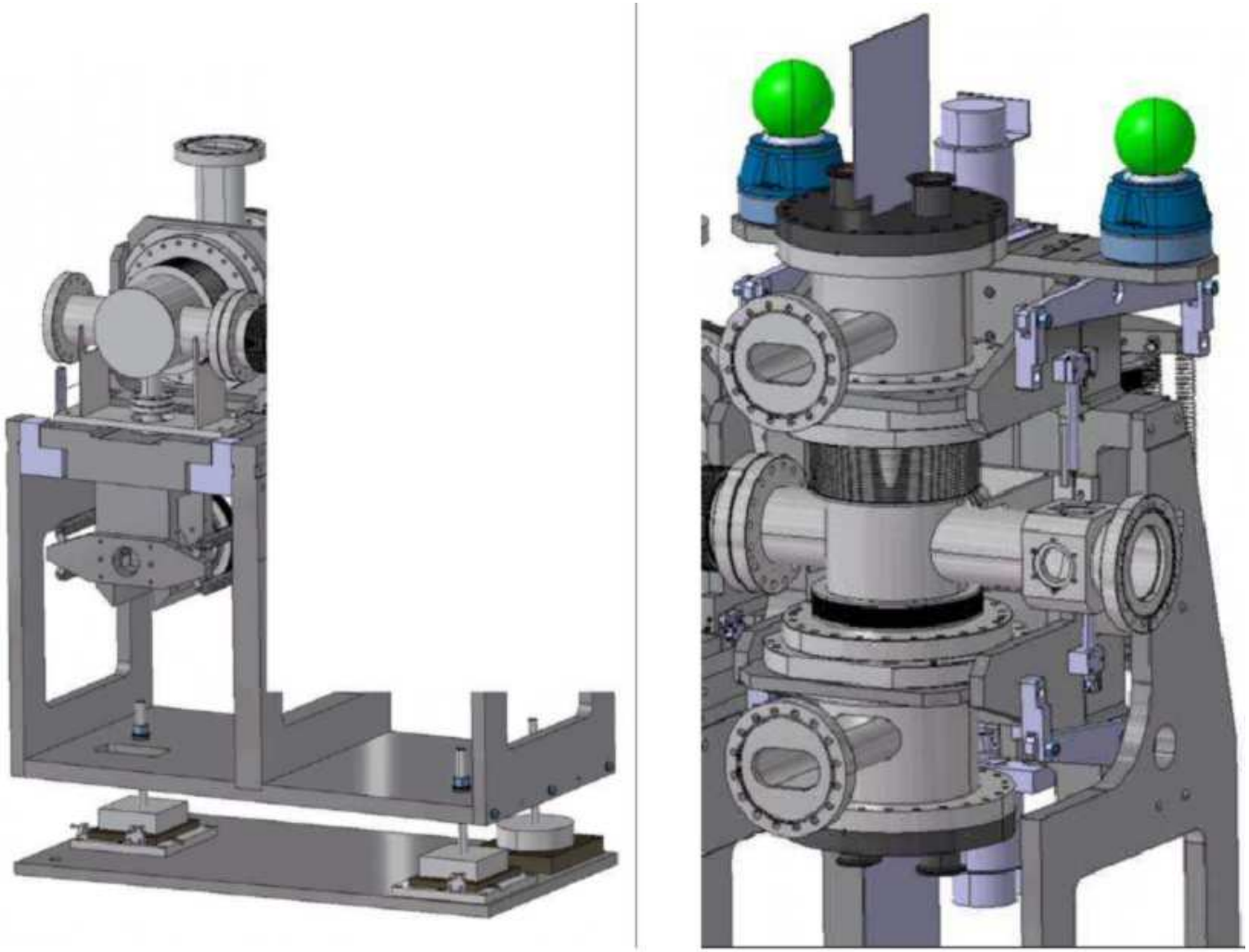
- beam energy ($\sigma_E = 0.77\,\text{GeV}$) and angular spread ($\vartheta_{x,y} = 30.2\,\mu\text{rad}$) have negligible effect on M_X resolution
- this is not true for the beam transversal size ($\sigma_{beam} = 16.6\,\mu\text{m}$)
- interaction region is smaller

$$\sigma_{int} = \sigma_{beam}/\sqrt{2} = 11.7\,\mu\text{m}$$

but it still leads to large resolution degradation

- we would clearly benefit if the ATLAS central tracker can constrain vertex transversal position with accuracy better than 10 microns
- protons reconstructed independently, resolution may improve if one uses the information that both are coming from the same vertex

Roman Pots

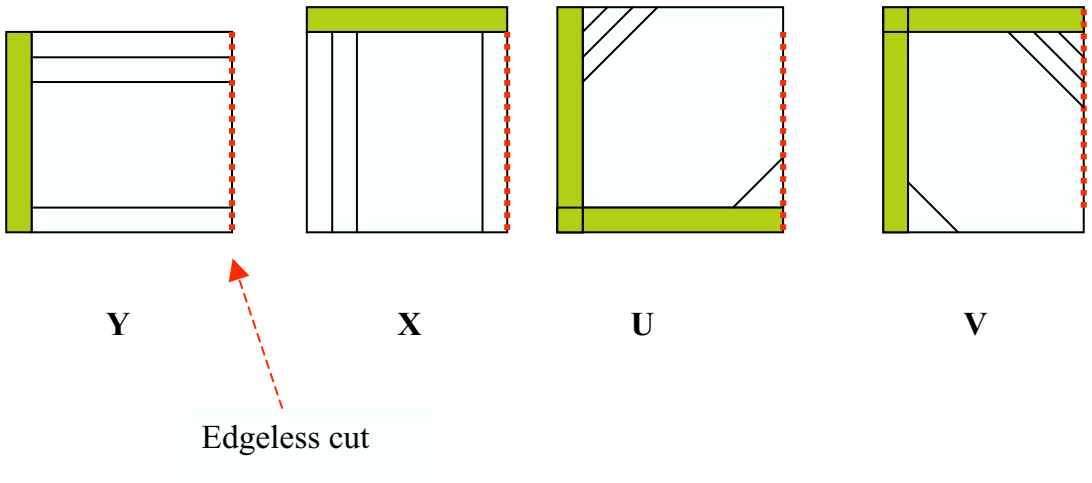


- same approach as used by ATLAS luminosity project
- adopt TOTEM design
  - use horizontal RP only
- RP mechanics build by Vacuum Praha for both experiments
- thin window produced in CERN
- step motors

  (1 step $\equiv 5\,\mu$m)
- position control
  - counting motor steps
  - LVDT (Linear Variable Differential Transformer)

- only minor changes expected for RP220

Detectors and readout



Requirements:

- good precision of about $10 - 15\,\mu$m
- radiative hardness
- $5 - 10$ ns time resolution to identify individual bunch crossings
- edgeless ($30 - 60\,\mu$m)

Solution: silicon strip detectors

- $50\,\mu$m pitch with digital readout

  (resolution of $50\,\mu\text{m}/\sqrt{12} = 14\,\mu$m)

- 1Y, 2X, 1U, and 1V layers (trigger: 2 layers with $100 - 200\,\mu$m pitch)
- ABCDnext chip developed by Krakow group, standard ATLAS readout
- first prototypes from CANBERRA just about to arrive, will be tested in Prague and Saclay in test-stands with laser
- option to switch to 3D detectors which are being developed for FP420

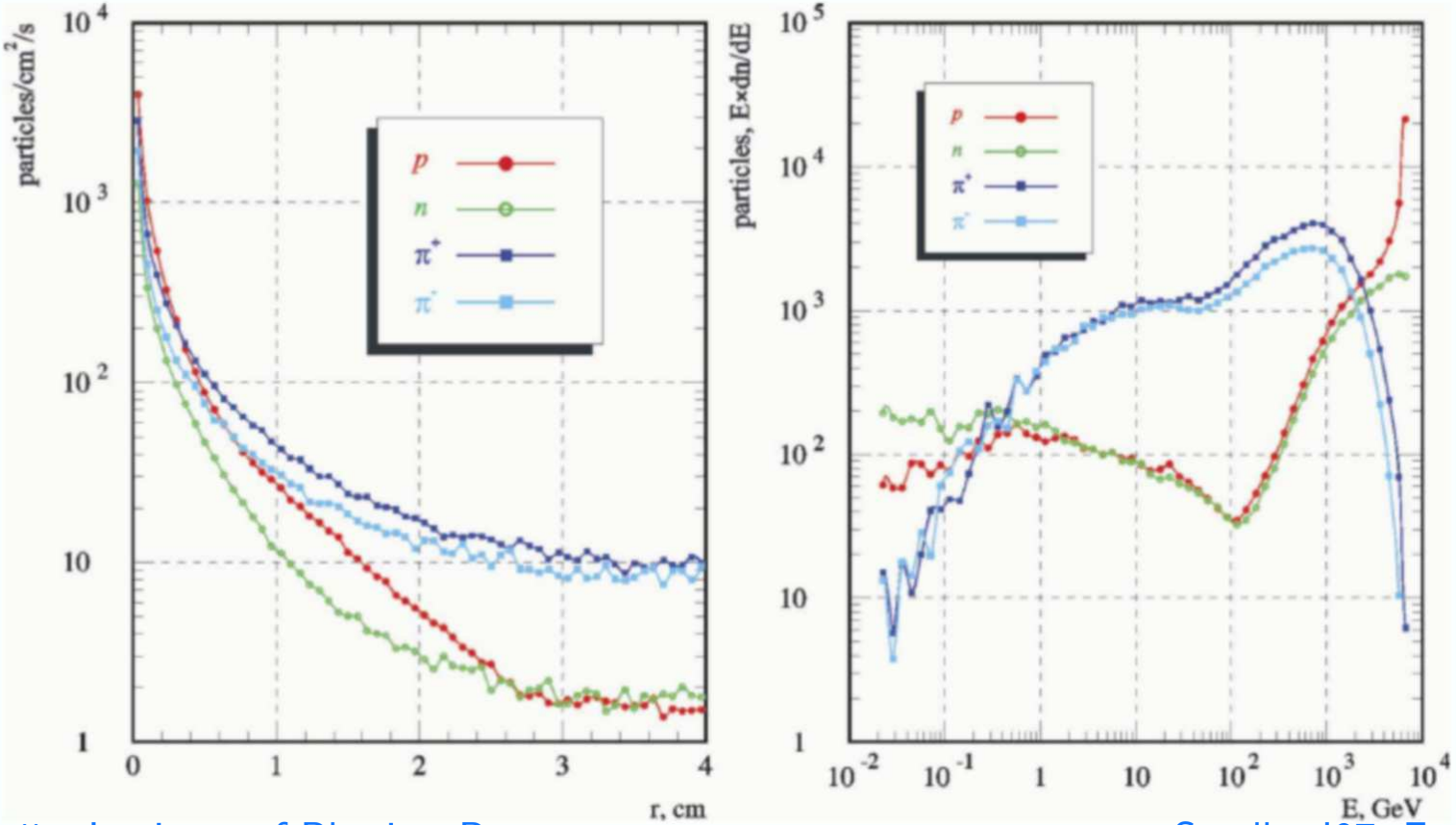
Roman pot fluxes (from Vadim Talanov)

RATE EVOLUTION WITH CUTS [MD2005]

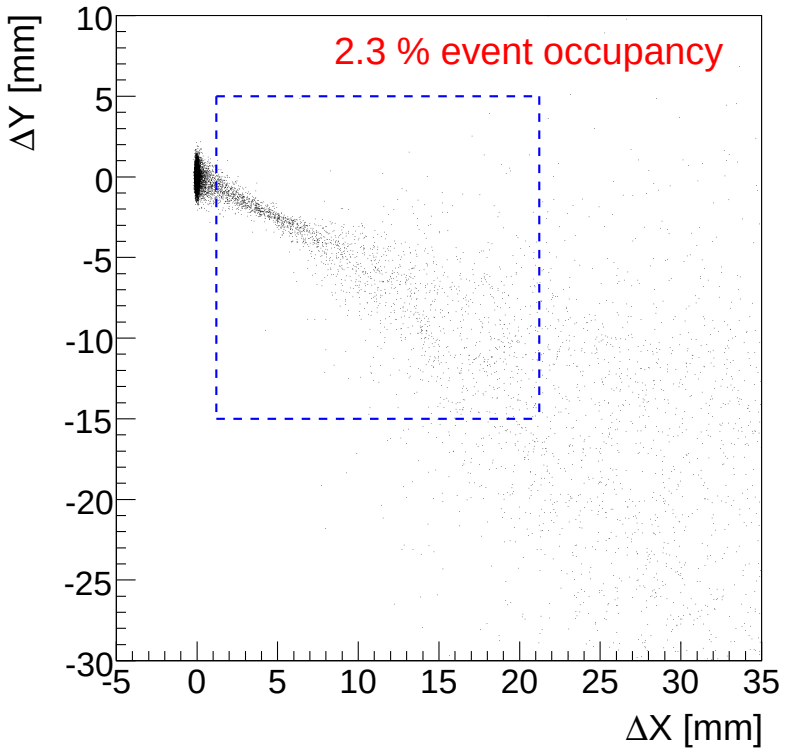
Particle flux in [Hz]

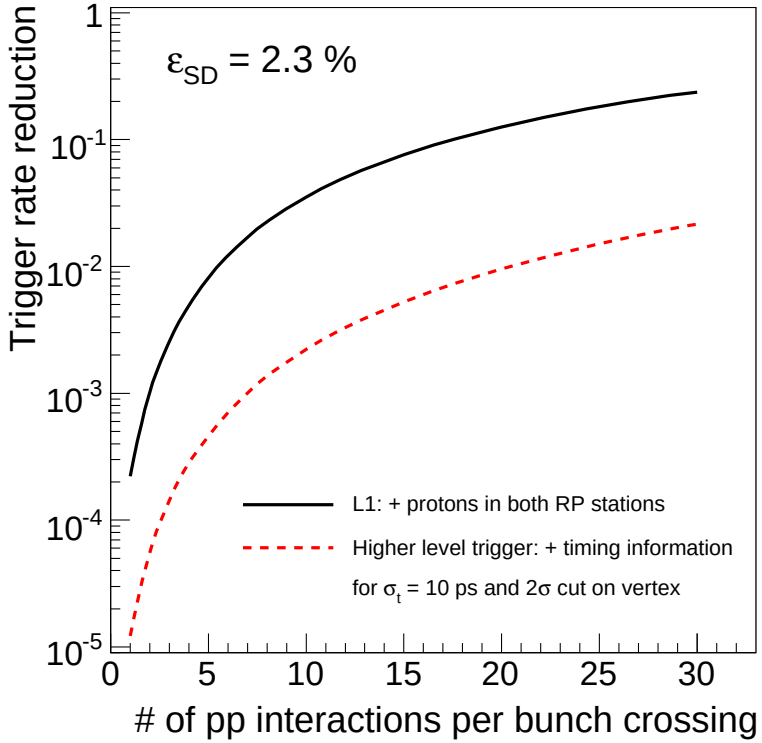
$\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\cdot\mathrm{s}^{-1}$

	p	n	π^+	π^-	e^+	e^-	
Pot at 220m	344	174	616	406	4630	3361	9.4×10^3



Physics background

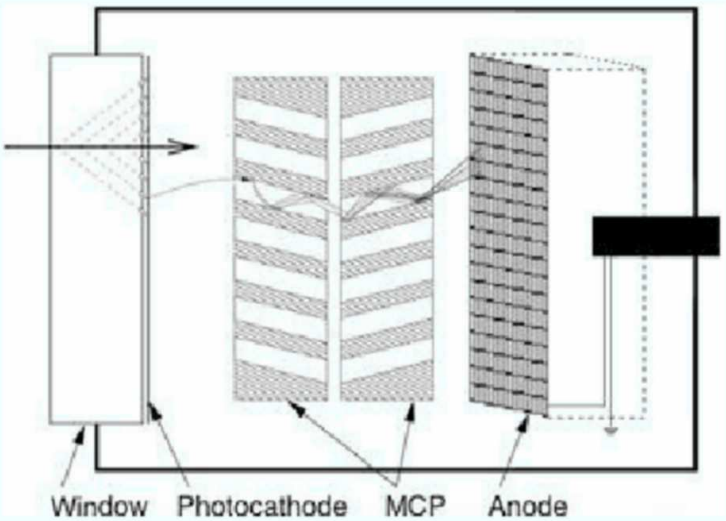




- soft SD dominates over the halo background
- even the probability that DPE event is faked by non-diffractive one with overlapping 2 SD events is huge at $\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2} \cdot \mathrm{s}^{-1}$
- precise time information will help to identify real DPE evens: where vertex position from the time two protons hit RP, $v_z = \Delta t/2$, should agree with the vertex reconstructed from the central tracker

Ultra fast timing detector

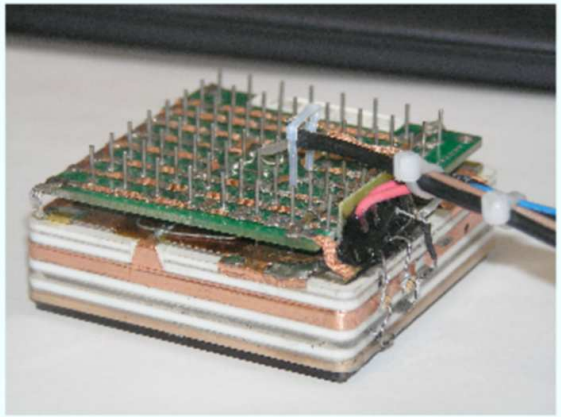
- Use UC Chicago/ANL (Henry Frisch, at el.) generic development



- new MCP 2x2 inches tubes developed by Burtle/Photonis
- Application for ultra fast timing for future detectors (SLHC, ILC, CLIC) and medical imaging
- collaboration of UC, ANL, Stony Brook, and Saclay

will provide the timing detector for RP220 project

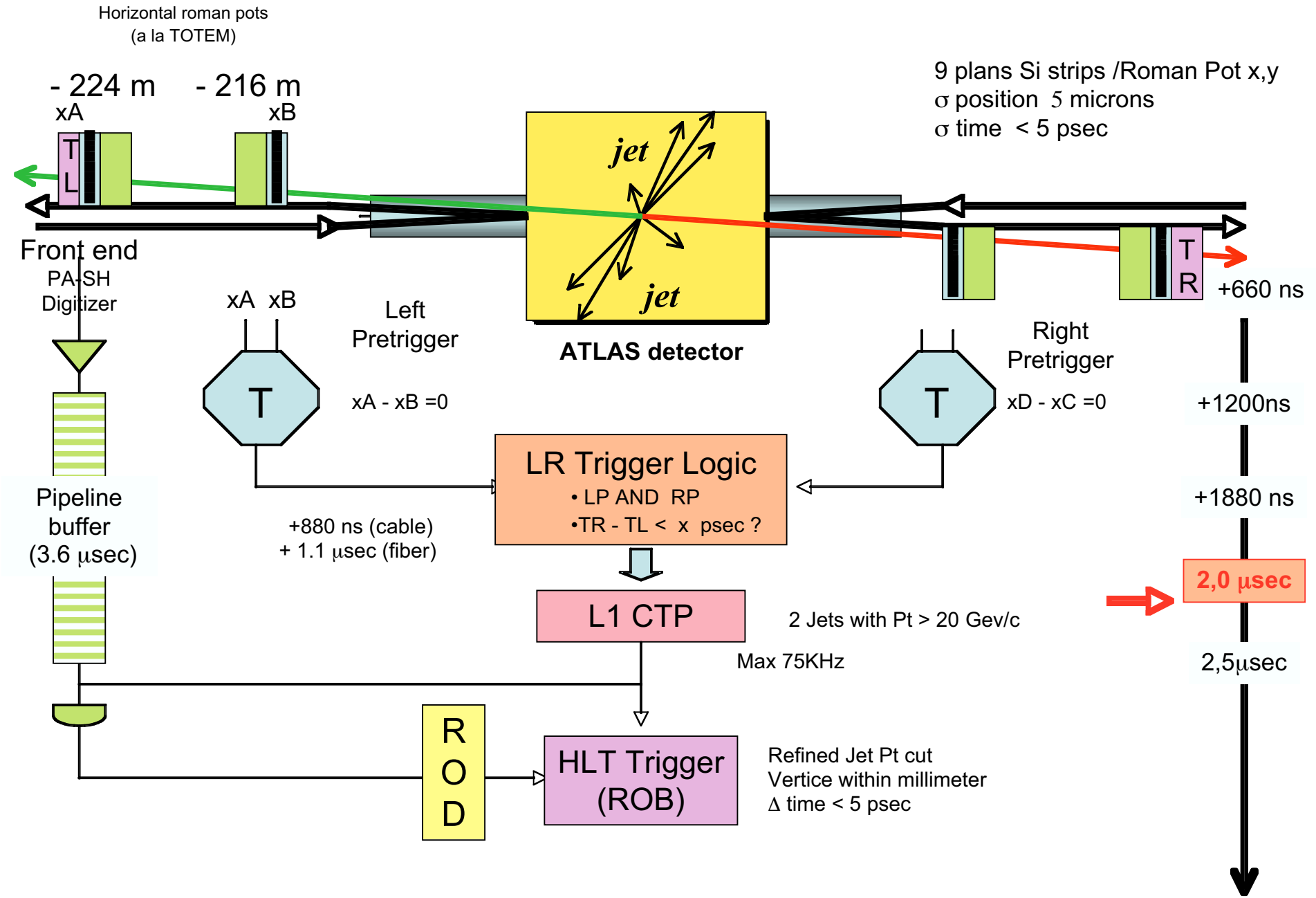
- Requirements:
  - time resolution of about $5 - 10$ ps
  - radiation hardness
  - size of $2 \times 2 \times 2$ cm, edgeless
- Availability: preliminary version by 2008-2009 (~ 40 ps), final 2011-2012



Photonis Prototype

  - more info: http://www-d0.fnal.gov/royon/timing (Timing workshop in Saclay, 2007)

DPE Trigger


Horizontal roman pots
(a la TOTEM)
- 224 m
- 216 m
xA
xB
T
L
9 plans Si strips /Roman Pot x,y
σ position 5 microns
σ time < 5 psec
jet
jet
ATLAS detector
T
R
+660 ns
Front end
PA-SH
Digitizer
xA xB
Left
Pretrigger
xA - xB =0
T
Right
Pretrigger
xD - xC =0
T
+1200ns
LR Trigger Logic
• LP AND RP
•TR - TL < x psec ?
+1880 ns
Pipeline
buffer
(3.6 μsec)
+880 ns (cable)
+ 1.1 μsec (fiber)
2,0 μsec
L1 CTP
2 Jets with Pt > 20 Gev/c
Max 75KHz
2,5μsec
R
O
D
HLT Trigger
(ROB)
Refined Jet Pt cut
Vertice within millimeter
Δ time < 5 psec

Triggering on Exclusive Higgs

$\mathcal{L}$ $[\text{cm}^{-2} \cdot \text{s}^{-1}]$	n_{pp} per bunch X-ing	2-jet rate $E_T > 40\,\text{GeV}$ [kHz]	RP220 rejection factor	$\xi < 0.05$ rejection factor
1×10^{32}	0.35	2.6	120	300
1×10^{33}	3.5	26	8.9	22
2×10^{33}	7	52	4.2	9.8
5×10^{33}	17.5	130	1.9	3.9
1×10^{34}	35	260	1.27	2.2

- assuming, ATLAS L1 2-jet trigger has similar performance as CMS one

  TOTEM NOTE 2006/01, CMS NOTE 2006/054

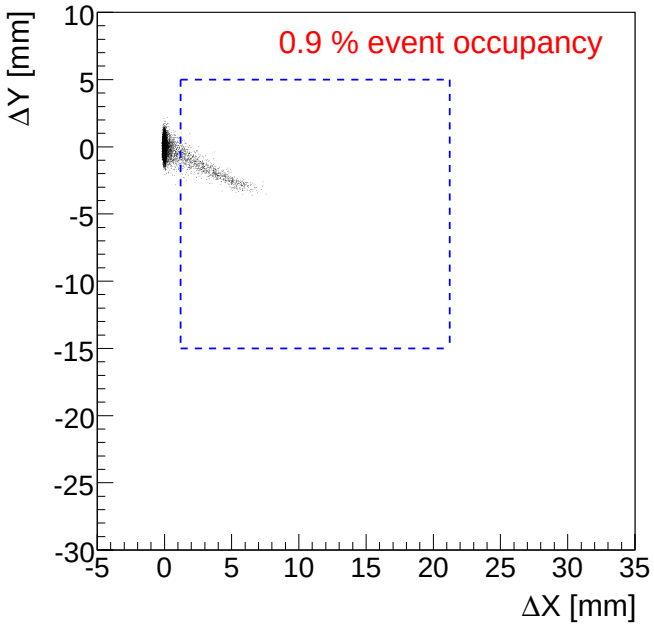
$+$ exclusivity $E_{T1} + E_{T2} > 0.9 H_T$ (factor 2)

$+$ $\eta_p \cdot (\eta_1 + \eta_2) > 0$ (factor 2)

$\Rightarrow$ keep the trigger unprescaled up to

$$\mathcal{L} \sim 2 \times 10^{33}\,\text{cm}^{-2} \cdot \text{s}^{-1}$$

- the only way how to trigger on $H \to b\bar{b}$ is to ask one proton at RP220
- the other proton must be in RP420
- since $\xi_{420} > 0.002 \Rightarrow \xi_{220} < 0.05$ for $M_H = 140\,\text{GeV}$



Plans

Sept, 2007: feasibility study of the project; tests of the first silicon strip detector prototypes (basic performance and edgeless)

2008-2009: fabrication of the silicon strip detectors, first prototypes of Roman Pot and timing detectors, test-beams

2009-2010: installation of roman pots in ATLAS (still with prototypes of timing detectors)

2012: (highest LHC lumi): final timing detectors

Summary

- Instrumenting the beam line around ATLAS opens a whole range of physics, traditionally studied at HERA, LEP, or TEVATRON, and not accessible without forward proton detection (proton structure functions, photo-production, luminosity measurements, $W\gamma$ anomalous couplings)
- Precise, event-by-event estimate of central mass brings new experimental techniques of mass measurements namely in case of exclusive DPE production
- Proposed project of RP at 220m significantly extends the potential of existing LHC forward proton projects for this physics
- RP220 project well started, and the proposal is being finalized
- Together with FP420, there will be a common diffraction project for ATLAS and we aim to collaborate on silicon and timing detectors.
- New collaborators to work on diffractive physics are very much welcome