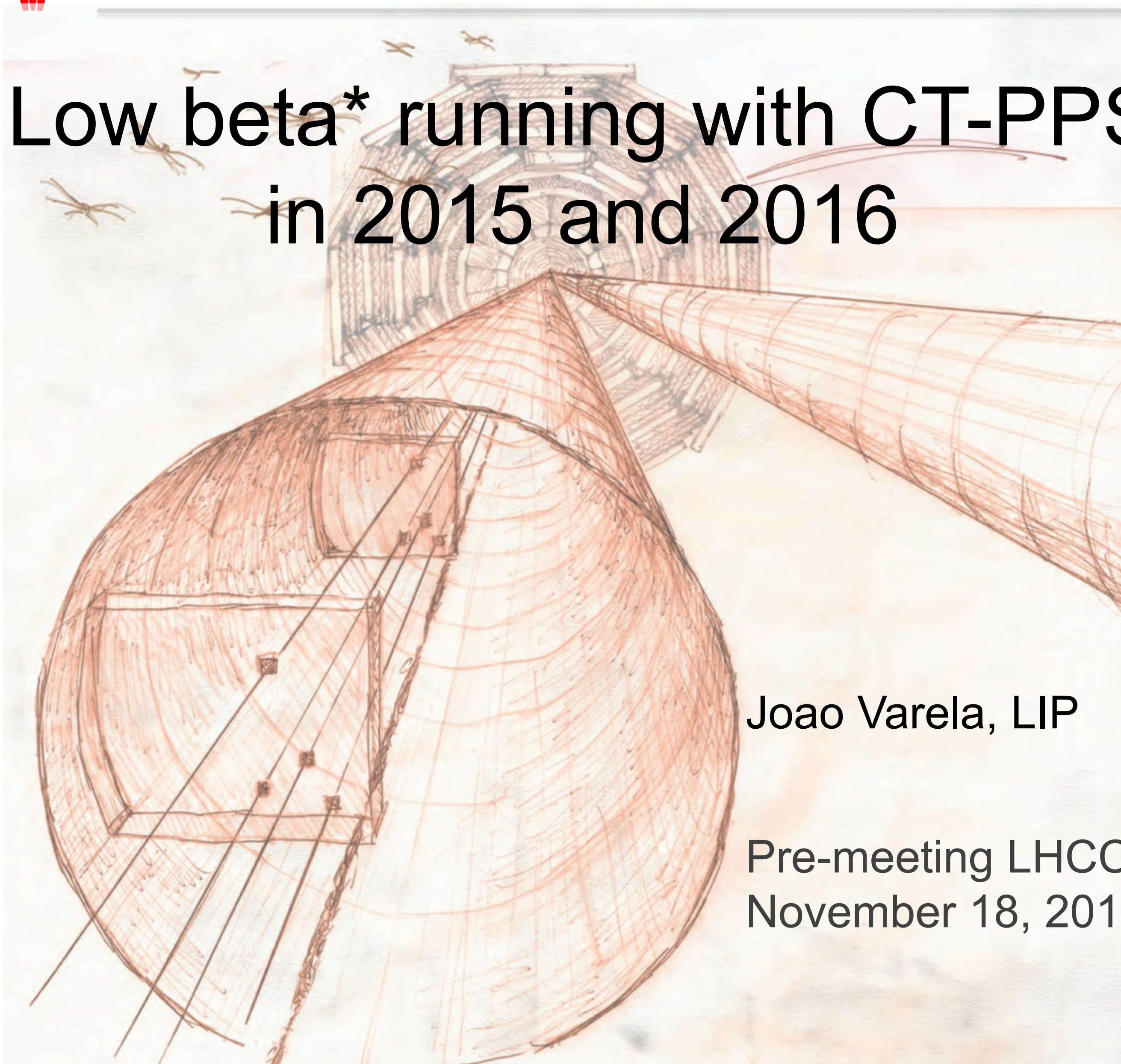
Low beta* running with CT-PPS in 2015 and 2016



Joao Varela, LIP

Pre-meeting LHCC
November 18, 2014

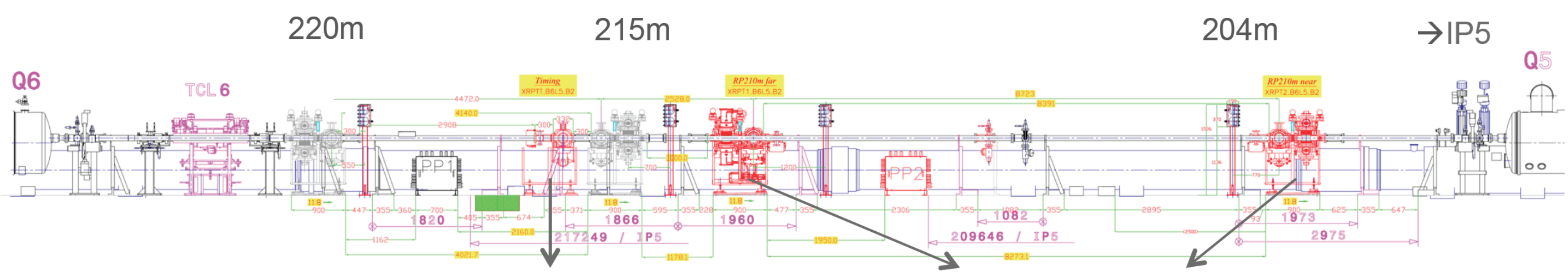
Detector concept

CT-PPS concept:

1) Proton spectrometer making use of **machine magnets**
2) Two tracking stations with **pixel detectors**
2) One stations with **timing detectors**

Project scale:

- Detector cross section ~ 4 cm^2
- 144 pixel ROCs
- 200 timing channels
- Total cost ~ 1 MCHF



2 new horizontal cylindrical RPs (1 in LS1)

2 horizontal box-shaped RPs

Equipped with timing detectors, for PU rejection

Equipped with tracking detectors to measure the displacement of the scattered protons w.r.t. the beam

Main issues

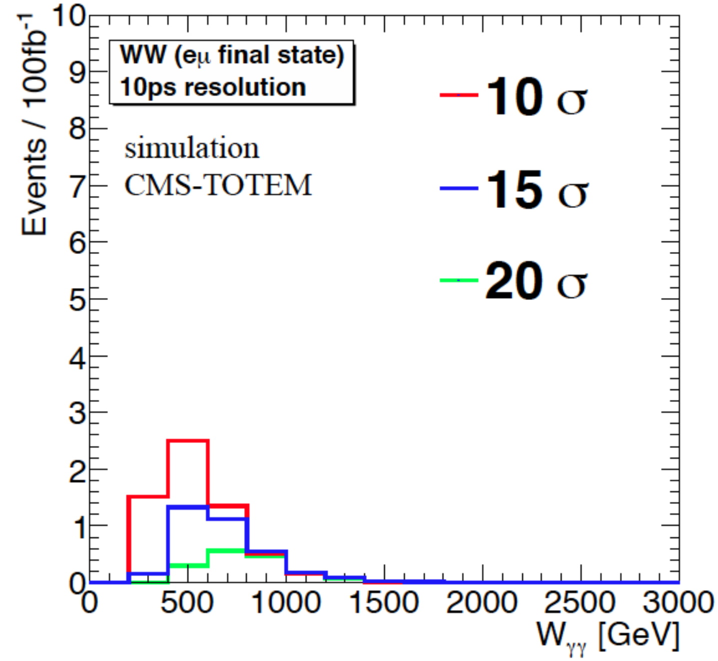
- Physics performance at high luminosity (2.10^{34} cm^{-2} s^{-1})
  - pileup background, beam background
- Detector operation close to the beam
  - RP and MBP expected performance
  - RF impedance, showers originated in the detectors
- Radiation levels
  - in detectors and front-end electronics
- Timing detectors
  - 10 ps
- Tracking detectors
  - 5.10^{15} $protons.cm^{-2}$

Luminosity requirements

Benchmark:

Observation of WW events in e-mu channel requires 100 fb-1

selection 15 σ	
WW yields per 1/fb	exclusive WW
generated $\sigma \times \mathcal{B}(WW \rightarrow e\mu\, \nu\bar{\nu})$	0.86±0.01
$\geq$ 2 leptons ($p_T > 20$ GeV, $\eta < 2.4$)	0.47±0.01
opposite sign leptons, "tight" ID	0.33±0.01
dilepton pair $p_T > 30$ GeV	0.25±0.01
protons in both PPS arms (ToF and TRK)	0.055 (0.054)±0.002
no overlapping hits in ToF + vertex matching	0.033 (0.030)±0.002
ToF difference, $\Delta t = (t_1 - t_2)$	0.033 (0.029)±0.002
$N_{tracks} < 10$	0.028 (0.025)±0.002



Yields of dijet events per 1/fb

Pileup=25 :

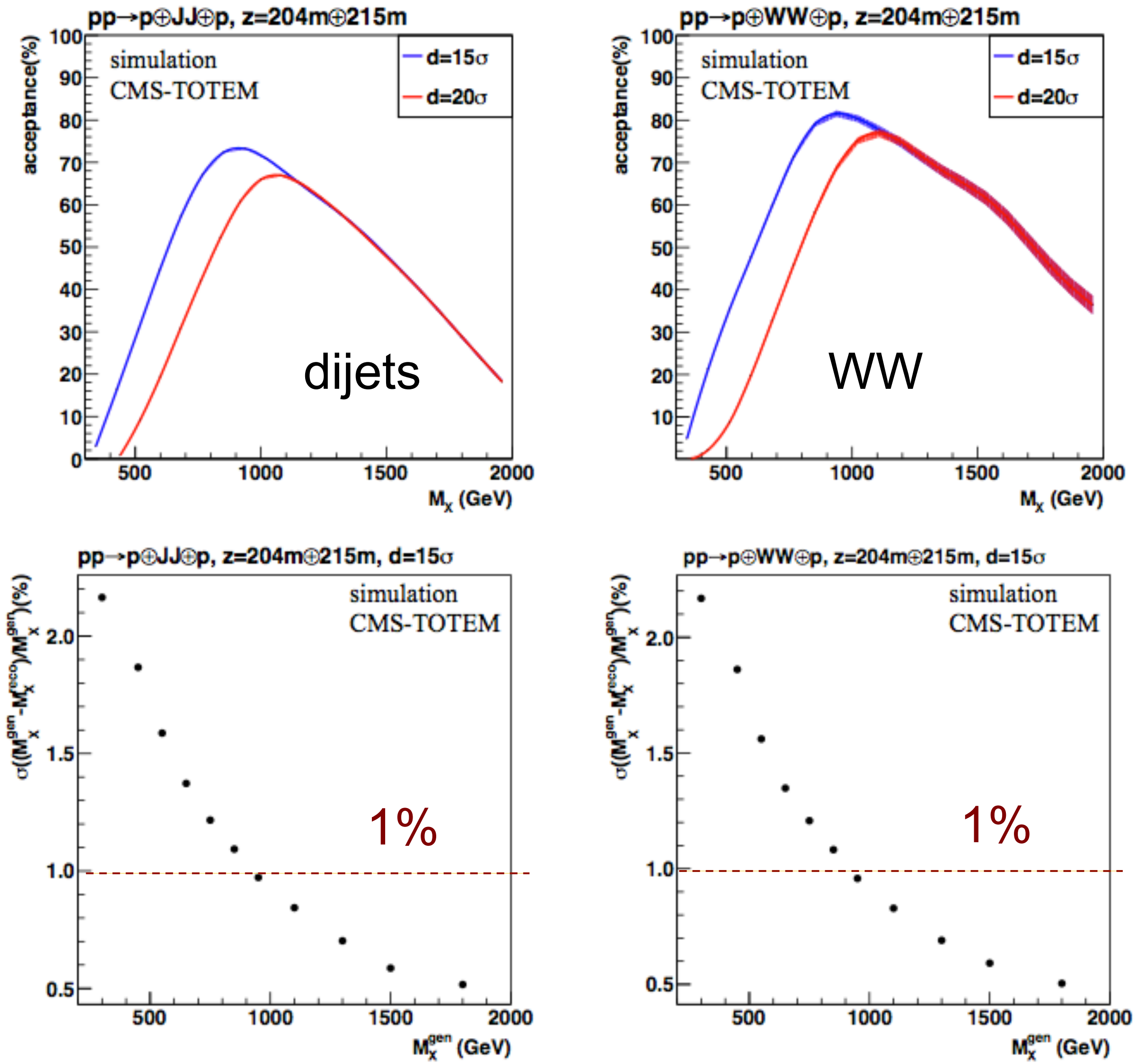
Selection	Exclusive dijets		DPE		SD		Inclusive dijets	
	events	ϵ (%)	events	ϵ (%)	events	ϵ (%)	events	ϵ (%)
total number of events	652±5	100	290×10^3	100	2.6×10^6	100	2.4×10^{10}	100
≥ 2 jets (p_T >100 GeV, $\|\eta\| < 2.0$)	250±4	38	25×10^3	8.7	190×10^3	7.6	3.4×10^8	1.4
PPS tagging (fiducial)	50±2	8	15×10^3	5.1	12×10^3	0.5	0.1×10^8	0.05
no overlap hits in ToF detectors	43±2	7	14×10^3	4.8	$10 (18) \times 10^3$	0.4	0.1×10^8	0.04
ToF difference, Δt	30 (23)±2	4.6	$11 (9) \times 10^3$	3.8	3×10^3	0.1	$0.3 (0.6) \times 10^6$	1×10^{-3}
$0.70 < [R_{jj} = (M_{jj}/M_X)] < 1.15$	20 (15)±1	3.1	15 (14)±3	0.01	85 (110)±15	-	$16 (30) \times 10^3$	1×10^{-4}
$\Delta(y_{jj} - y_X) < 0.1$	15 (12)±1	2.4	6 (4)±2	-	3 (11)±3	-	$1.8 (3.4) \times 10^3$	-
N_{tracks}	7.4 (5.8)±0.4	1.1	0.8 (0.6)±0.3	-	1±1	-	19 (35) ± 1	-
≥ 2 jets (p_T > 150 GeV, $\|\eta\| < 2.0$)	3.5 (2.6)±0.2	0.5	0.2 (0.1)±0.1	-	1±1	-	9 (17) ± 1	-

⇒ S/B ~ 1/3 (μ=25)

S/B ~ 1/8 (μ=50)

Mass acceptance and resolution

- PPS selects exclusive systems in 300-1700 GeV range (ε>5%)
- At 15σ acceptance larger by a factor of two (wrt 20σ) for lower masses



Project phases

- The CT-PPS plan includes an **exploratory phase** in 2015-16 followed by a **production phase**.
- Exploratory phase (2015-16)

  Show that CT-PPS does not prevent the stable operation of the LHC beams.
  - In 2015:
    - Evaluate RPs
    - Demonstrate the timing performance of the Quartic baseline
    - Use TOTEM silicon strip detectors at sustainable radiation
    - Integrate the CT-PPS detectors into the CMS trigger/DAQ system.
  - In 2016:
    - Evaluate the MBP option
    - Upgrade the tracking to 3D pixel detectors
    - Upgrade the timing detectors if required/possible

2015

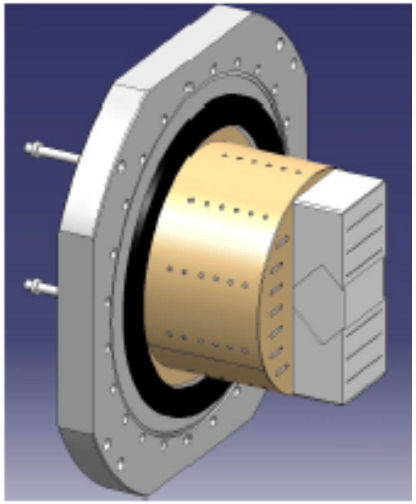
Approaching the beam

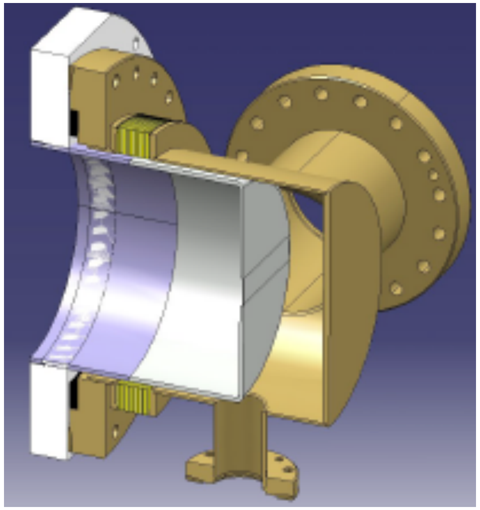
- Options considered:
  - Roman Pots (RP) developed by TOTEM
  - Movable Beam Pipe (MBP) pursued by CMS and ATLAS
- RP will be tested in the exploratory phase in 2015.
- The MBP solution is pursued in parallel
  - low RF impedance option
  - aiming at joint project of LHC collaborations and machine
  - possible installation of a prototype for tests in 2016

Roman Pots

- Tests of TOTEM RPs at high luminosity revealed important issues (vacuum, beam dumps, heating).
- Several improvements have been carried by TOTEM (and CMS) in collaboration with BE-ABP.
  - New RF shielding in standard box-shaped RPs
  - New cylindrical RP for timing detectors
  - 10 um thick copper coating
  - New ferrites

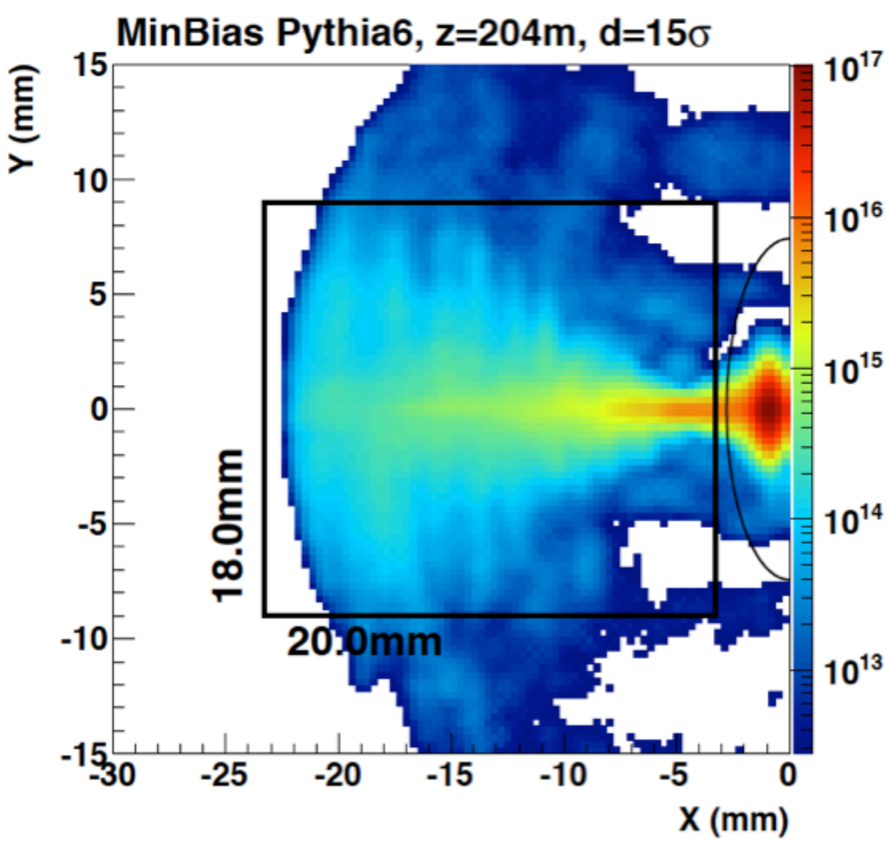
To be tested in 2015





Radiation levels

Radiation levels in the detector volume were studied using TOTEM data and simulations



Per 100 fb^{-1}:

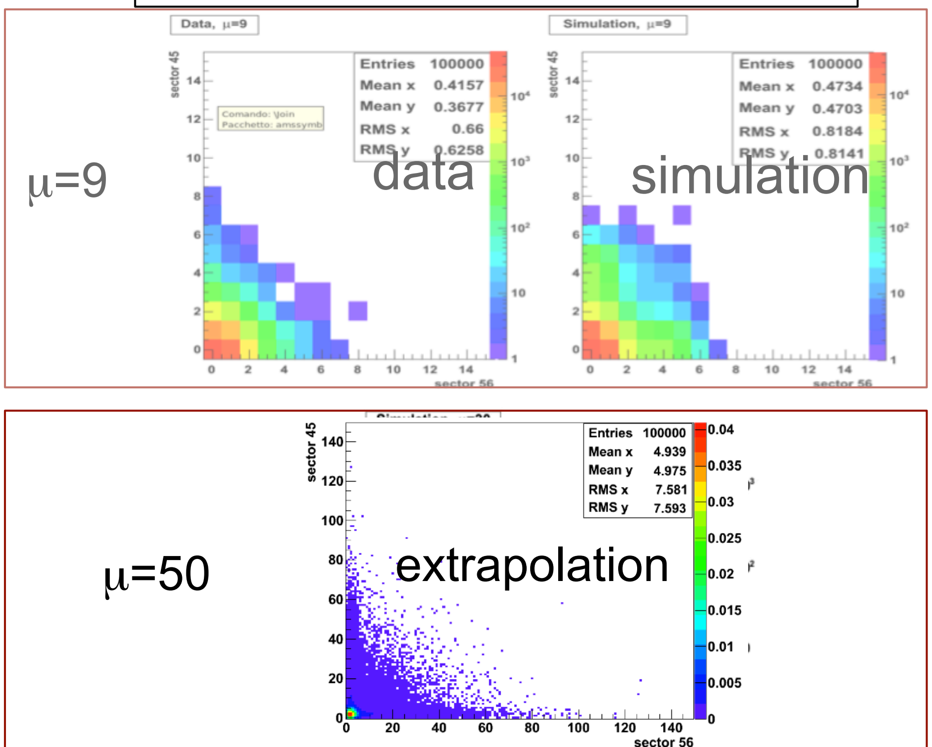
- Proton flux up to 5.10^{15} cm^{-2} in the pixel detectors
- 10^{12} neq/cm^2 and 100 Gy in photosensors and readout electronics

To be confirmed with measurements in 2015

Machine induced backgrounds

- Used TOTEM data at $\mu=9$
- Extrapolate to $\mu=25$ and 50

track multiplicity in the two arms

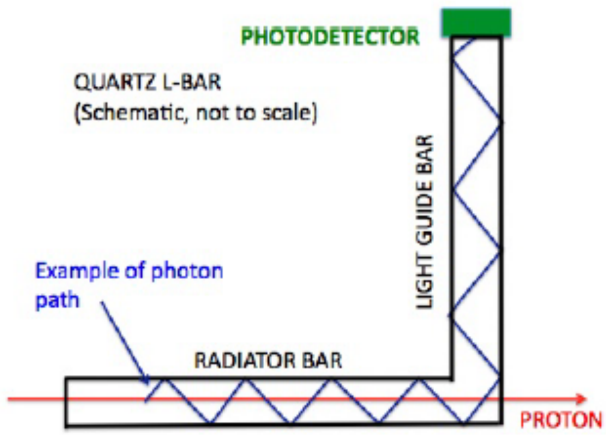


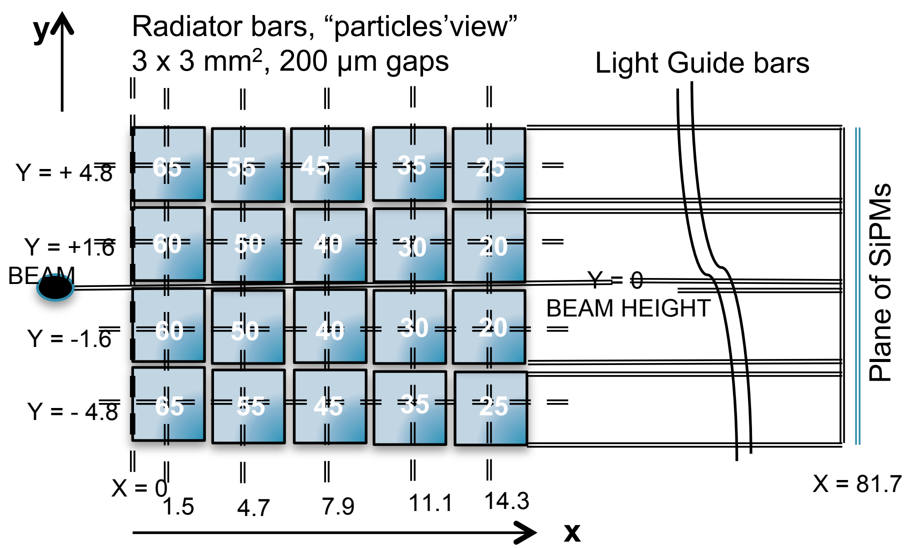
To be confirmed with measurements in 2015

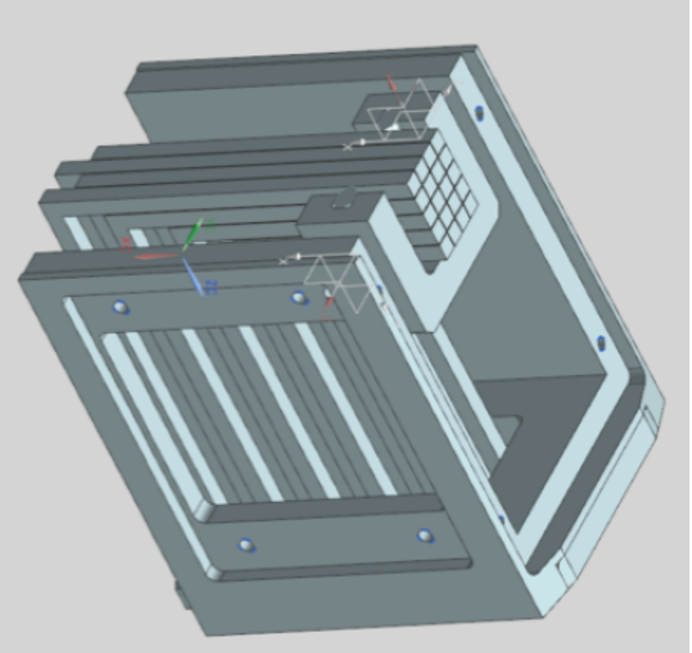
Timing detector baseline

To be installed in October 2015

- Quartic module:
  - 4x5=20 3x3 mm^2 bar elements
  - 200 μm wire grid separating the bars
  - active area is 12.6 mm x 15.8 mm



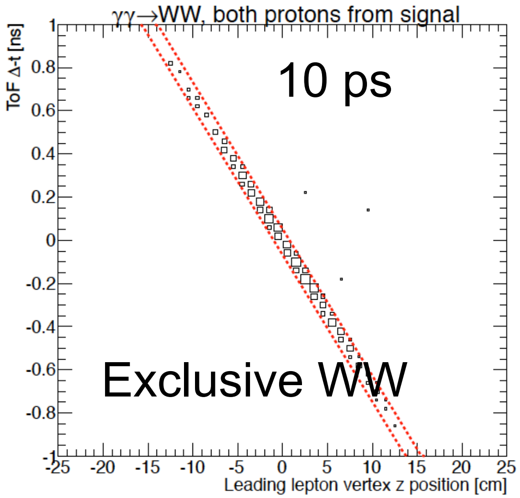


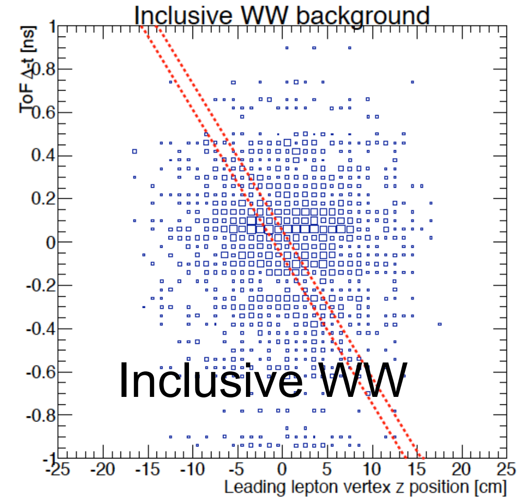


CT-PPS timing vs. z-vertex

- Use timing to reject pileup background
- Two scenarios were studied:
  - 10ps and 30ps time resolution

To be validated with measurements in 2015



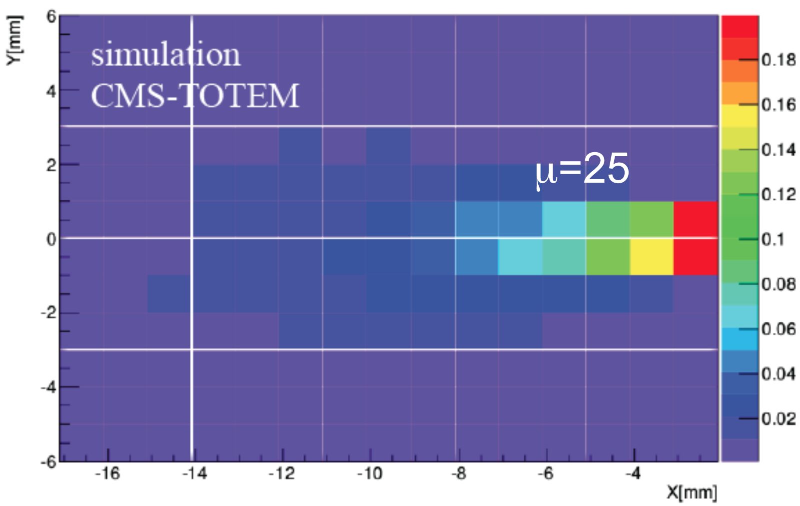


Detector occupancy

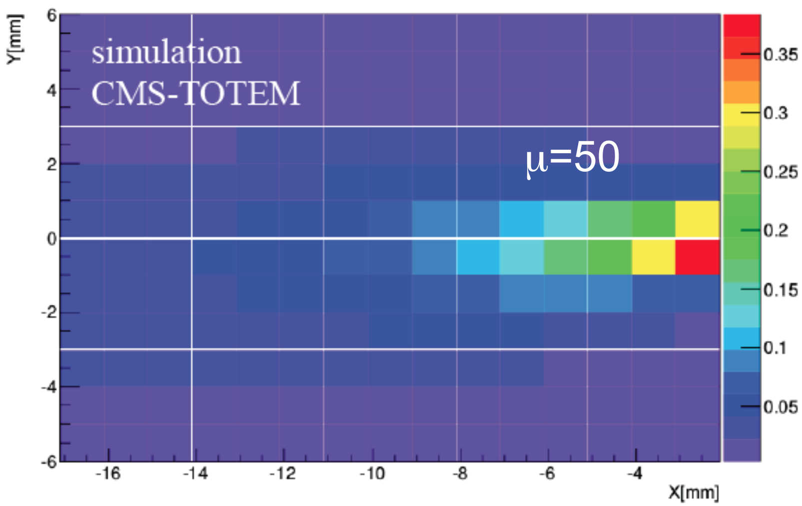
- Occupancy of the time-of-flight detectors at 15 σ from the beam

To be confirmed with measurements in 2015

occupancy /mm^2



occupancy /mm^2



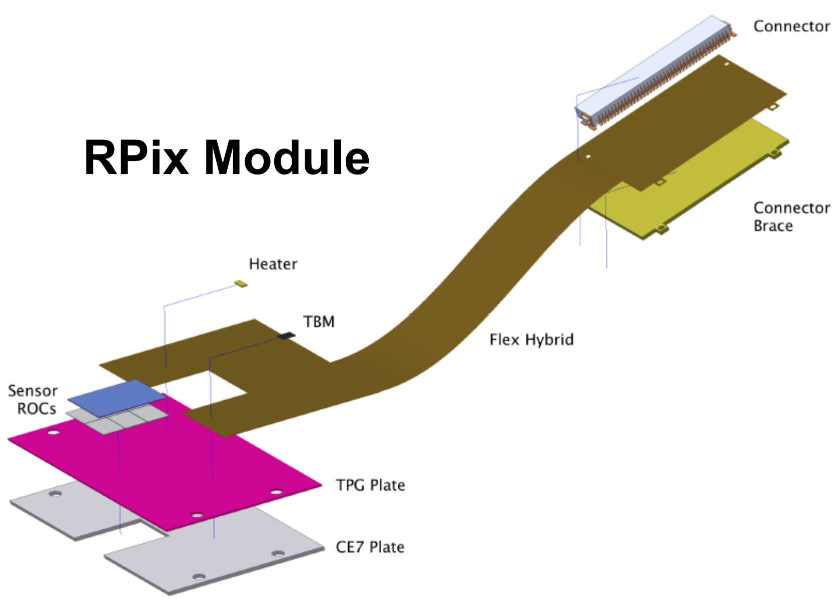
2016

Tracking baseline

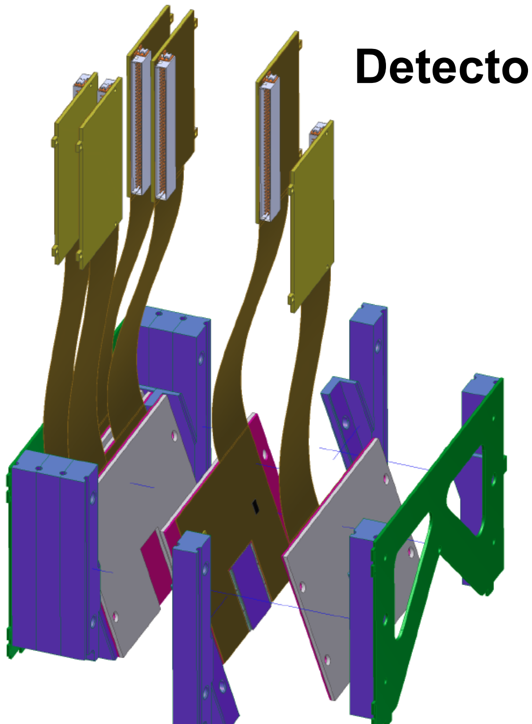
To be installed in March 2016

- 3D silicon sensors
- PSI46dig ROC, with same readout scheme as for Phase I Upgrade of the CMS pixel system
- 6 detector planes per station

RPix Module



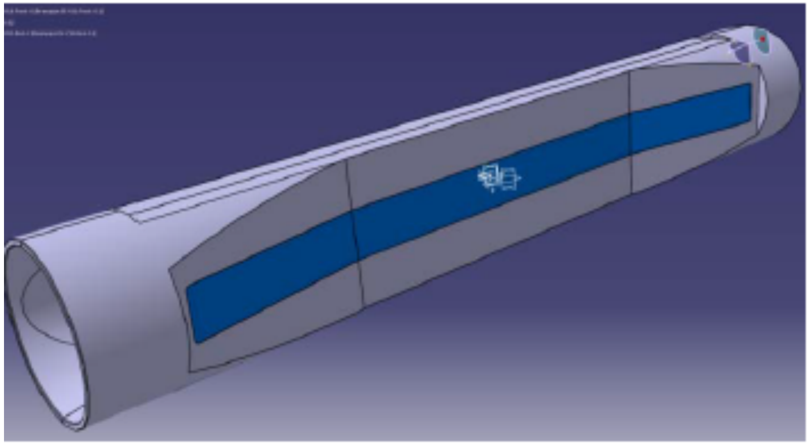
Detector support

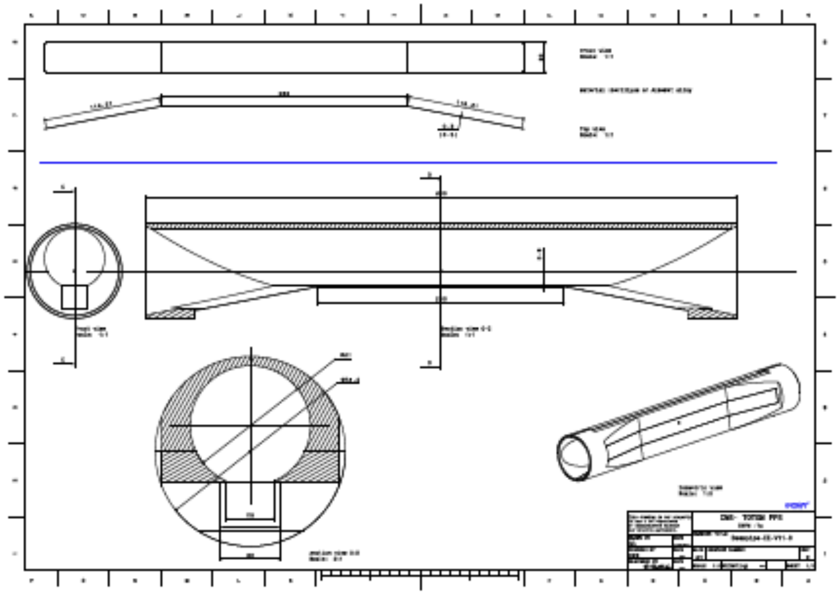


Moving Beam Pipe

Interior surface tapered into a conical shape creating a smooth transition to reduce the RF impedance effects.

At 1 mm, **RF impedance** is estimated at **0.05% (trans) and 0.5% (long).**





R&D on solid state detectors

- Motivations:
  - solid state detectors may have fine segmentation reducing the channel occupancy
  - detectors are thin and light, reducing nuclear interactions and allowing a large number of layers N
- Diamond detectors
  - Very fast signals
  - Requires R&D on frontend electronics
  - Requires R&D on radiation and rate effects
- Timing silicon detectors
  - Based on Low-Gain Avalanche Diodes (LGAD)
  - Requires R&D on frontend electronics
  - Requires R&D to improve radiation resistance

Running scenarios in 2015-2016

- **Roman Pot Insertion Commissioning 2015**
  - RP insertion tests are carried out in end-of-fill studies
  - Start with beams separated by 5- 6 sigma in IP5 ($L=10^{30-31}$)
  - Find an optimal set of positions of RPs and collimators.
- **Timing Detector Commissioning 2015-16**
  - Commissioning of the timing detector as a function of luminosity
  - End-of-fill studies with separated beams
- **Data Production Phase >2016**
  - RP insertion movements will executed by the LHC operator immediately after declaration of stable beams.
  - Aim at accumulating up to 100 fb^{-1} of data before LS2

BACKUP

AQGC yields (in fb)

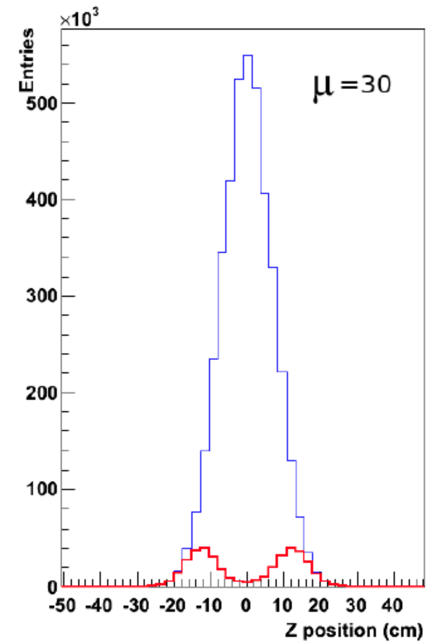
Table 4: Cross section (in fb) for the expected exclusive WW events due to anomalous quartic gauge couplings, for different values of anomalous coupling parameters (a_0^W and a_C^W) after each selection cut (for a timing resolution of 10 ps). In case of different values, numbers in parentheses are for a timing resolution of 30 ps. Only the $e\mu$ final state is considered. Statistical uncertainties are shown.

selection	cross section (fb)	
	$a_0^W/\Lambda^2 = 5 \cdot 10^{-6}\text{GeV}^{-2}$ ($a_C^W = 0$)	$a_C^W/\Lambda^2 = 5 \times 10^{-6}\text{GeV}^{-2}$ ($a_0^W = 0$)
generated $\sigma \times \mathcal{B}(WW \to e\mu\, \nu\bar{\nu})$	3.10±0.14	1.53±0.07
≥ 2 leptons ($p_T > 20$ GeV, $\eta < 2.4$)	2.33±0.08	1.00±0.04
opposite sign leptons, "tight" ID	1.82±0.08	0.78±0.03
dilepton pair $p_T > 30$ GeV	1.69±0.07	0.68±0.03
protons in both PPS arms (ToF and TRK)	0.52 (0.50)±0.04	0.18 (0.17)±0.02
no overlapping hits in ToF detectors	0.35 (0.32)±0.03	0.12 (0.11)±0.01
ToF difference, $\Delta t = (t_1 - t_2)$	0.35 (0.32)±0.03	0.12 (0.11)±0.01
$N_{\text{tracks}} < 10$	0.27 (0.24)±0.03	0.11 (0.10)±0.01

Trigger strategy

- Two-photon physics:
  - the leptonic final states are captured by the CMS lepton triggers
    - The trigger efficiency is expected to be very high given that the lepton thresholds are 30 GeV or below.
  - Final states with hadronic decays of one W or one tau will be accessible using the lepton+jet triggers.

- Hadronic physics
  - Large inclusive QCD jet background
  - L1 timing trigger selecting events in the tails of the distribution of the collision z-vertex



In red distributions of the vertexes separated by at least 1 cm

RPs installed