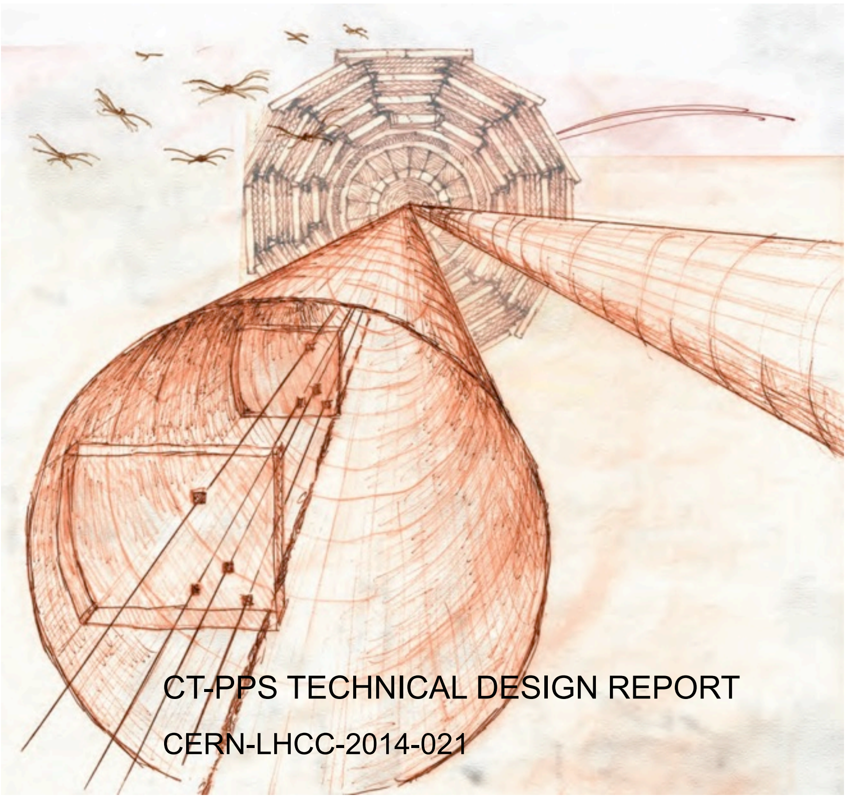
CT-PPS Status

Concept and strategy for 2016

Joao Varela, LIP



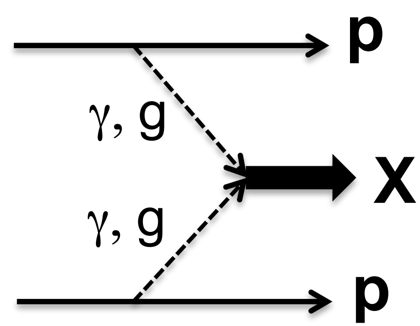
LHC Working Group on Forward Physics and Diffraction

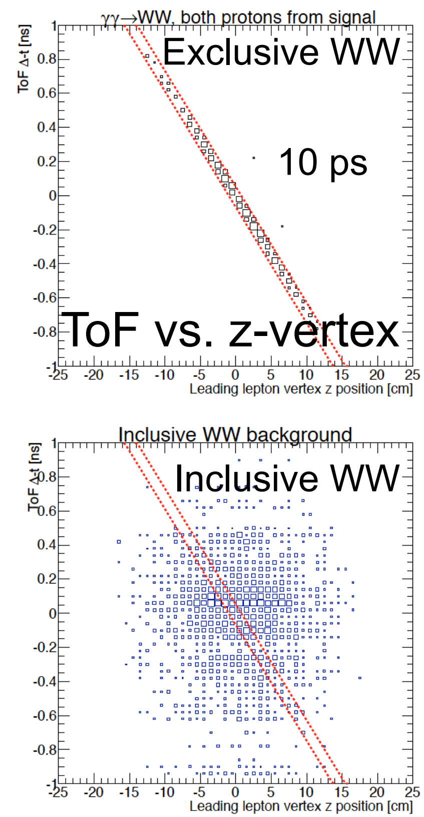
15-16 March 2016

CT-PPS concept

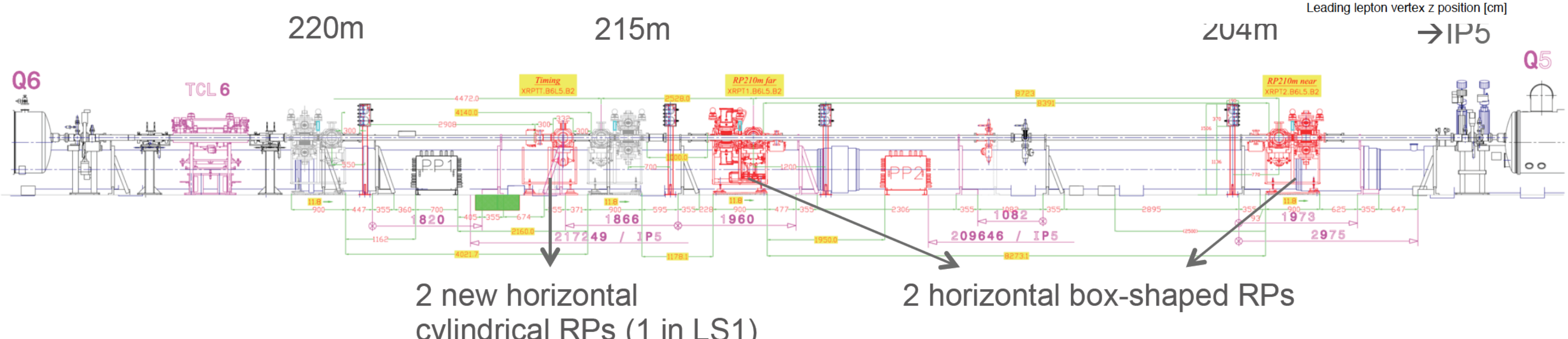
Proton tagging of central exclusive production

– **photon or gluon fusion**





- Proton spectrometer using **LHC magnets**
- Two tracking stations with **3D Pixel detectors**
- One station with **Timing detectors**



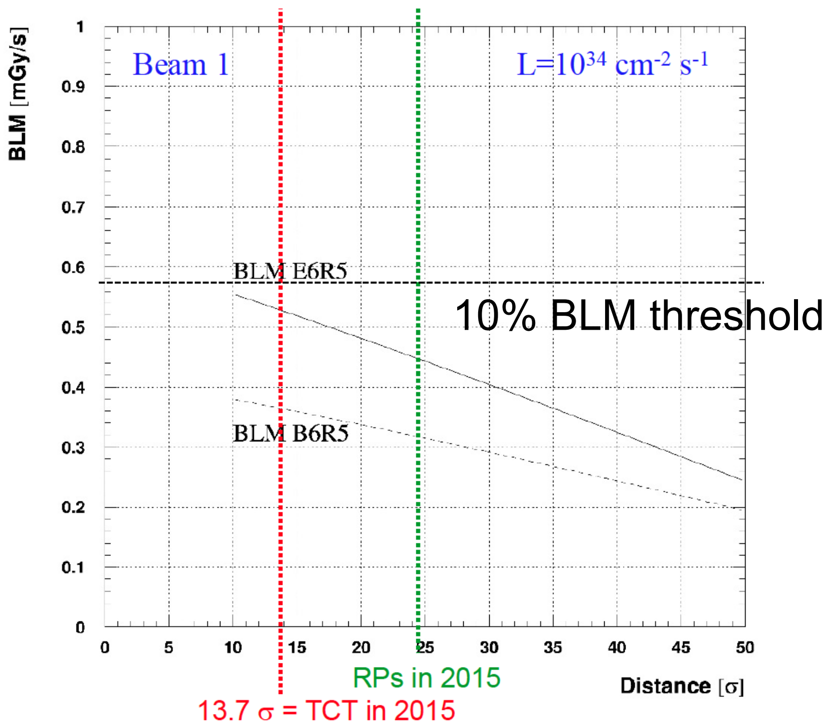
RPs insertion tests

Observations from RP Insertions in 2015:

- Tests up to 4x10^{33} $cm^{-2}s^{-1}$
- No beam instabilities introduced
- BLM response is well below thresholds
- Vacuum pressure: no problem observed
- Temperature in RP increases with luminosity, no problem expected

Extrapolations to 10^{34} and to smaller distances to the beam look promising

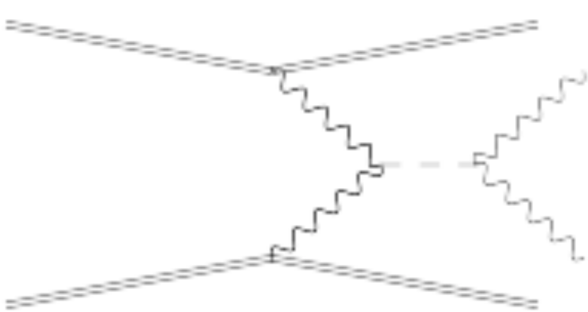
All horizontal pots at N σ



Advancing the CT-PPS planning

- Results presented at the LHC Jamboree on an excess in the diphoton mass spectrum in ATLAS and CMS motivated to advance the actual ‘Physics operation’ (foreseen in the TDR in 2017)
- The CMS-TOTEM common project aims to explore among other things the $\gamma-\gamma$ interactions through ‘elastic’ pp scattering
- We plan to search for $\gamma-\gamma$ resonance production in photon fusion already in 2016

A number of papers consider γγ production of a 750GeV resonance decaying to γγ

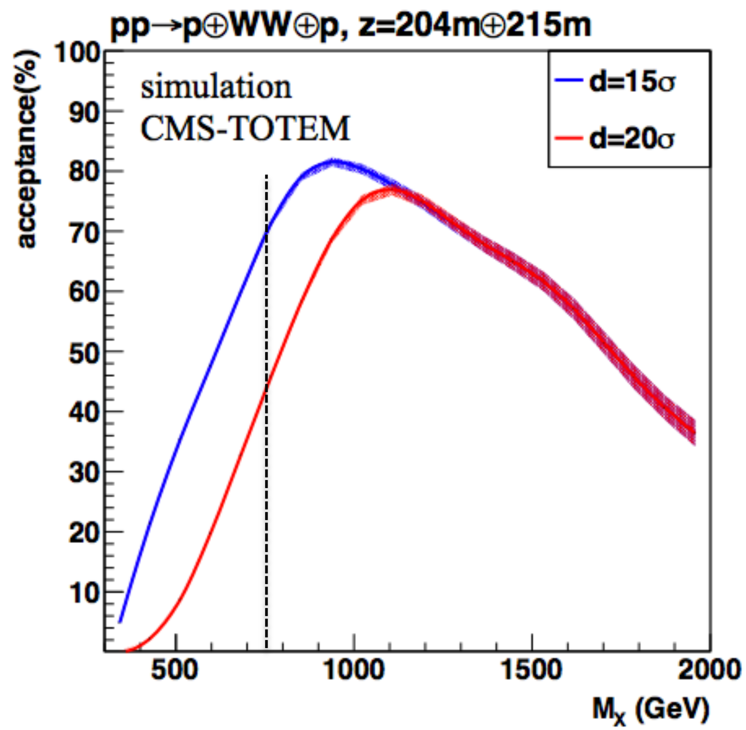


Fichet, von Gersdorff, Royon (arXiv:1601.01712, arXiv:1512.05751)
Csaki, Hubisz, Terning (arXiv:1512.05776, arXiv:1601.00638)
Harland-Lang, Khoze, Ryskin (arXiv:1601.07187)
Anchordoqui, et al (arXiv:1512.08502)
Nomura and Akada (arXiv:1601.00386)
d’Eramo, de Vries, Panci (arXiv:1601.01571)
Danielsson, Enberg, Ingelman, Mandal (arXiv:1601.00624)
Ben-Dayan and Brunstein (arXiv:1601.07564)
Martin and Ryskin (arXiv:1601.07774)
Barrie, et al (arXiv:1602.00475)
Molinaro, Sannino and Vignaroli (arXiv:1602:07574)
Abel and Khoze (arXiv:1601.07167)

CT-PPS potential

- Expected LHC luminosity in 2016 is around 30 fb^{-1}
- Exclusive cross section of the production of a 750 GeV resonance via photon-photon fusion in the diphoton decay channel is estimated ~0.3-0.6 fb
  - under the hypothesis that the resonance is dominantly produced in $\gamma\gamma$ fusion

Acceptance depends on distance of approach to the beam



from CT-PPS TDR
LHC optics β^*=0.6m (2014)

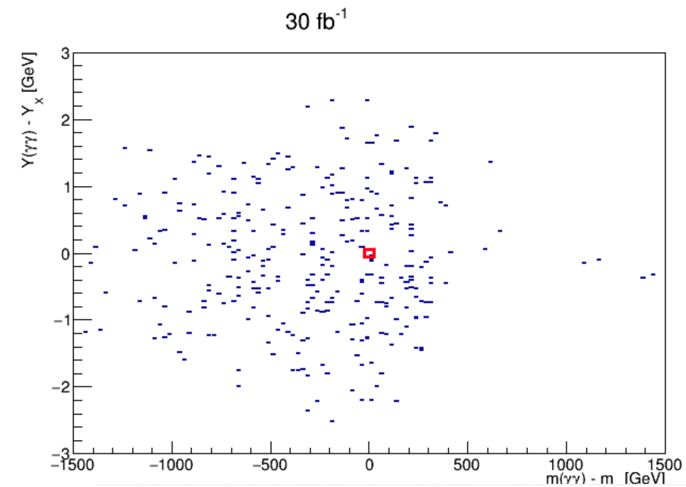
Diphoton simulation study

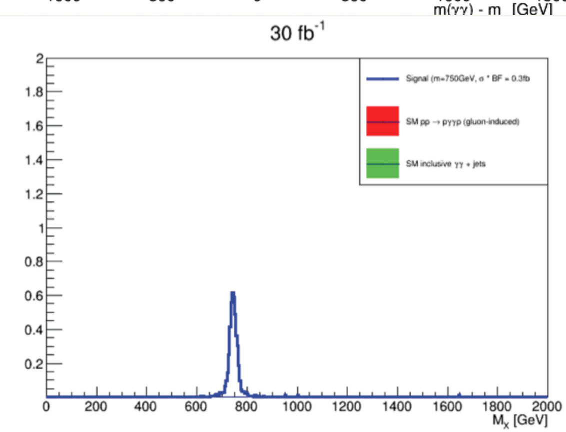
- "Easier" scenario than channels studied for CTPPS TDR: high-mass, low background, very good resolution in central CMS (no jets or missing ET)

- Backgrounds (Inclusive γγ+jets + others)
- Signal (σ*BF=0.3-0.6 fb)

- Diphoton kinematic cuts
- Diphoton-diproton matching cuts
- Acceptance*efficiency for signal: ~29-41%

- With $30 fb^{-1}$:
  - signal 3-7 events
  - background ~0.1 events





$m(X)\ [X = 13TeV - m(pp)]$

See talks by Christophe Royon and Jonathan Hollar

CT-PPS accelerated plan

- Aim to collect physics data in normal CMS runs in 2016
- Proton tracking detectors
  - use TOTEM silicon strip detectors (lifetime ~10 to 20 fb^{-1})
  - replace by 3D Pixel Detectors when ready (fall 2016)
  - DAQ and Offline Rec Software integrated in CMS
  - aiming to be in operation at start-up of LHC collisions
- Proton timing detectors
  - use Diamonds adapted from TOTEM developments
  - development of readout chain is well advanced
  - DAQ and reconstruction software integrated in CMS
  - installation in June TS

This plan was approved by both Collaborations and is being implemented

LHC Optics

Recently proposed LHC optics (beta* 40-50 cm) brings the CT-PPS acceptance at M=750 GeV close to zero.

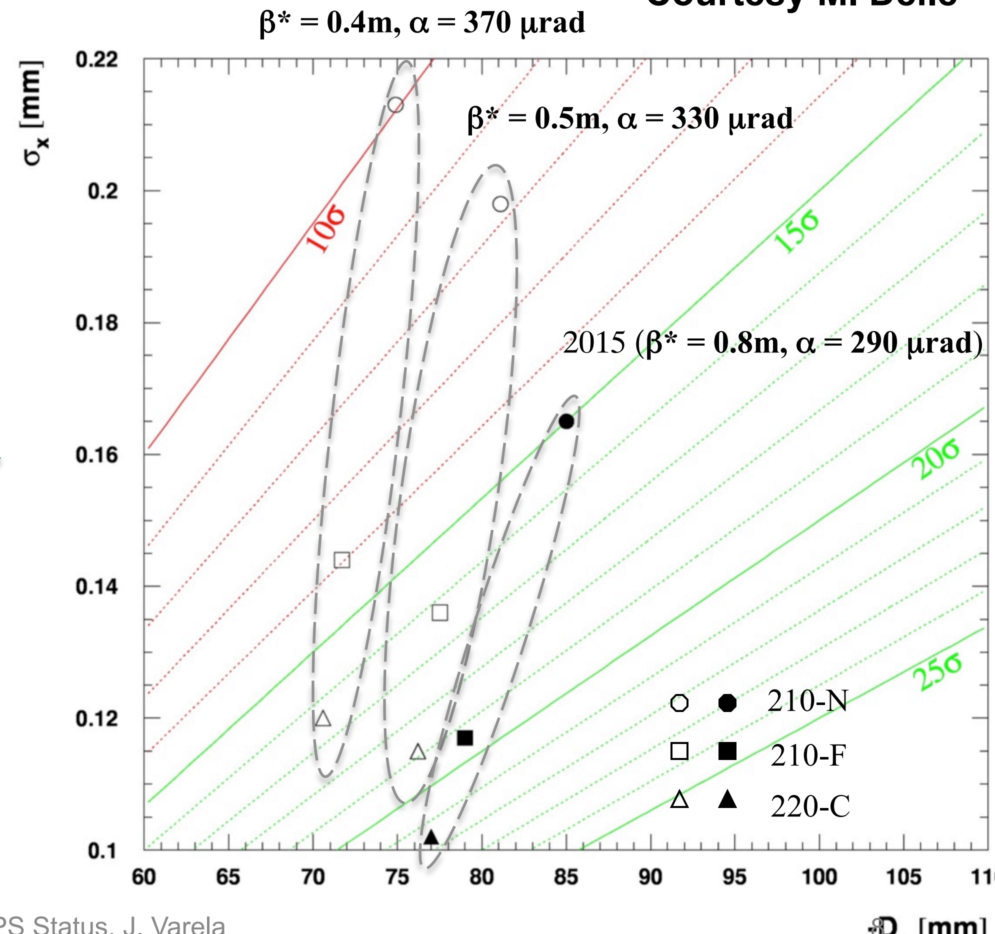
We have asked for a revision of the optics making it compatible with CT-PPS requirements for physics

Horizontal RP approach to N σ_x needed to reach $\xi_{min} = 0.035$ or rapidity $y_{max} = 0.5$

$$y_{max} = \ln \frac{M}{\xi_{min}\sqrt{s}}$$

with M = 750 GeV, √s = 13 TeV

Courtesy M. Deile



Proposal to LMC

- In order to minimise the impact on the CT-PPS performance, it is proposed:
  - To study and develop a new crossing bump aiming at increasing (in absolute value) the single-pass dispersion at the XRPs (gain could be of ~ cm)
  - In parallel, to explore options to insert XRPs closer to the beam (to be ensorsed by collimator group)

  - The study of a new squeeze for improved optical conditions at the XRPs (aiming at reducing the sigmas) is put on hold for the time being, as it would have a strong impact on the preparatory activities for beam.

M. Giovannozzi et al., LMC meeting 9/3/2106

Towards full CT-PPS

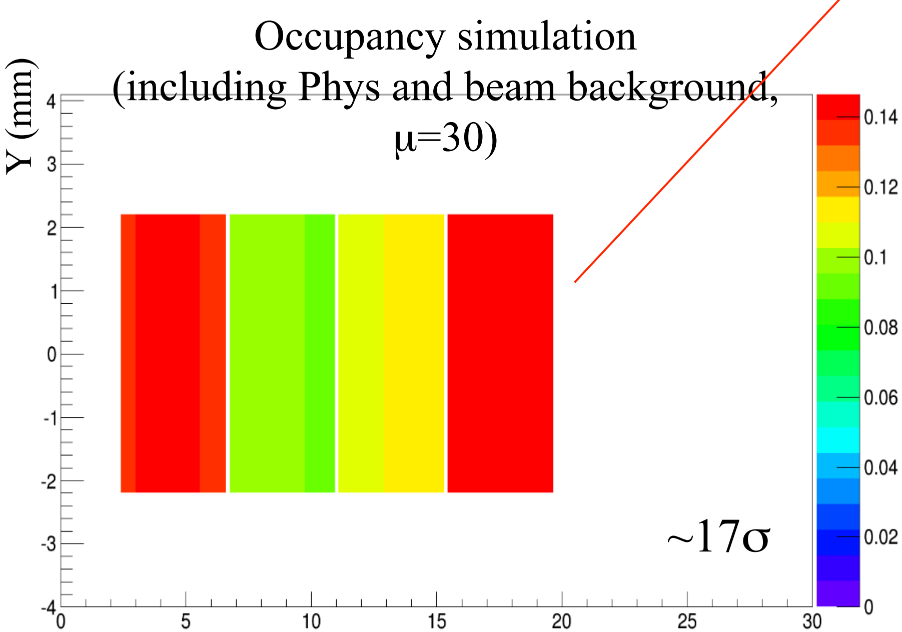
- Pixel Tracking:
  - sensors, electronics and mechanics is on-going
  - aim at replacement of Strips
  - schedule for detector installation: fall 2016

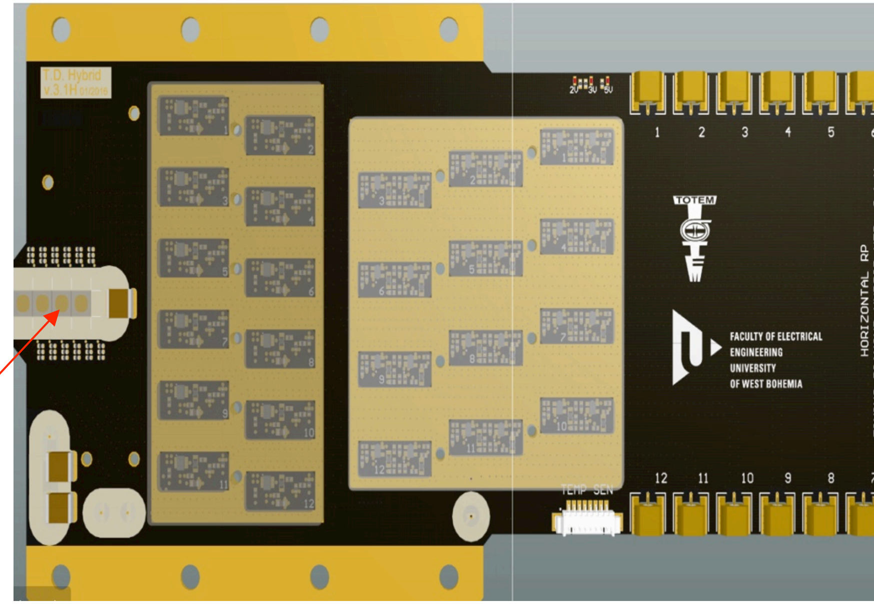
- Timing Detectors:
  - Baseline now are Diamond sensors but full validation in LHC environment is still needed
  - Fast Silicon and Quartic R&D is pursued
  - Readout electronics is compatible with all sensor options
  - Mechanics and cooling are also compatible

- MicroTCA DAQ system
  - based on CMS Pixel Upgrade components
  - firmware and software under development

Diamond board for CT-PPS

- Geometry of the first pixel determined in order to have uniform occupancy per BX (and also for the primary signal)
- Inefficiency due to pile-up ~7% (dependent on the beam background extracted at 8 TeV)



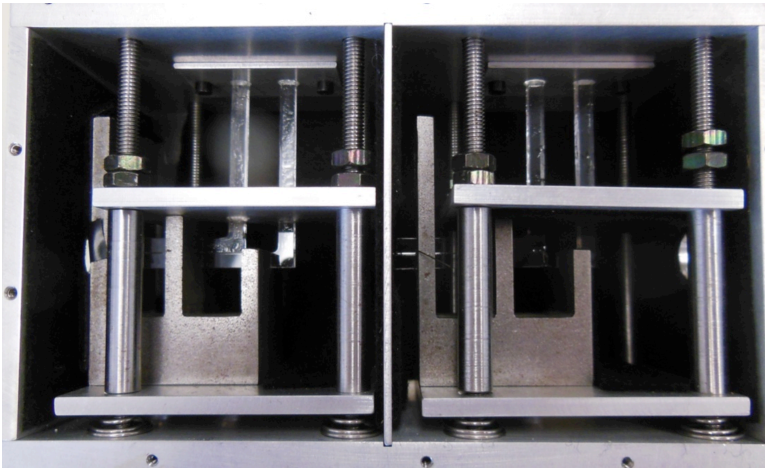


- The CT-PPS diamond boards are already in production.
- Design improved in order to reduce discharge probability.

Quartic detector

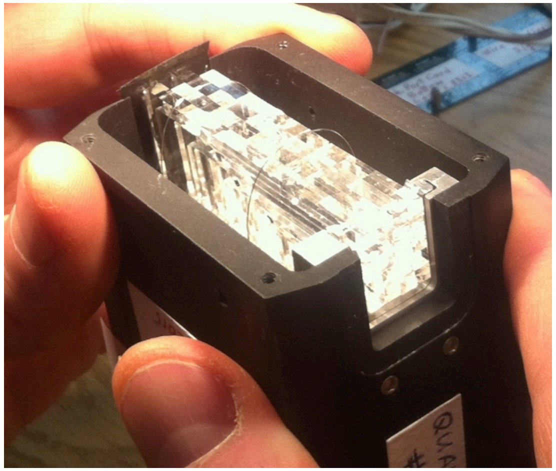
- Cerenkov light in quartz radiator bars
- Quartic module: 20 (4x5) 3x3 mm^2 L-shaped bar elements

Differences between 2012 test module and 2015 prototype



2 bars per module adjacent on one side
3x3 mm bars
R bars 30mm and 40mm
LG bars 40mm and 43.2 mm
Bars from Specialty Glass (US)

$\sigma(t)$ = 30 – 35 ps



20 (4x5) bars adjacent on 2,3, or 4 sides
3x3 mm bars
R bars 18 – 63mm
LG bars 58.8 – 71.2 mm
Bars from IHEP

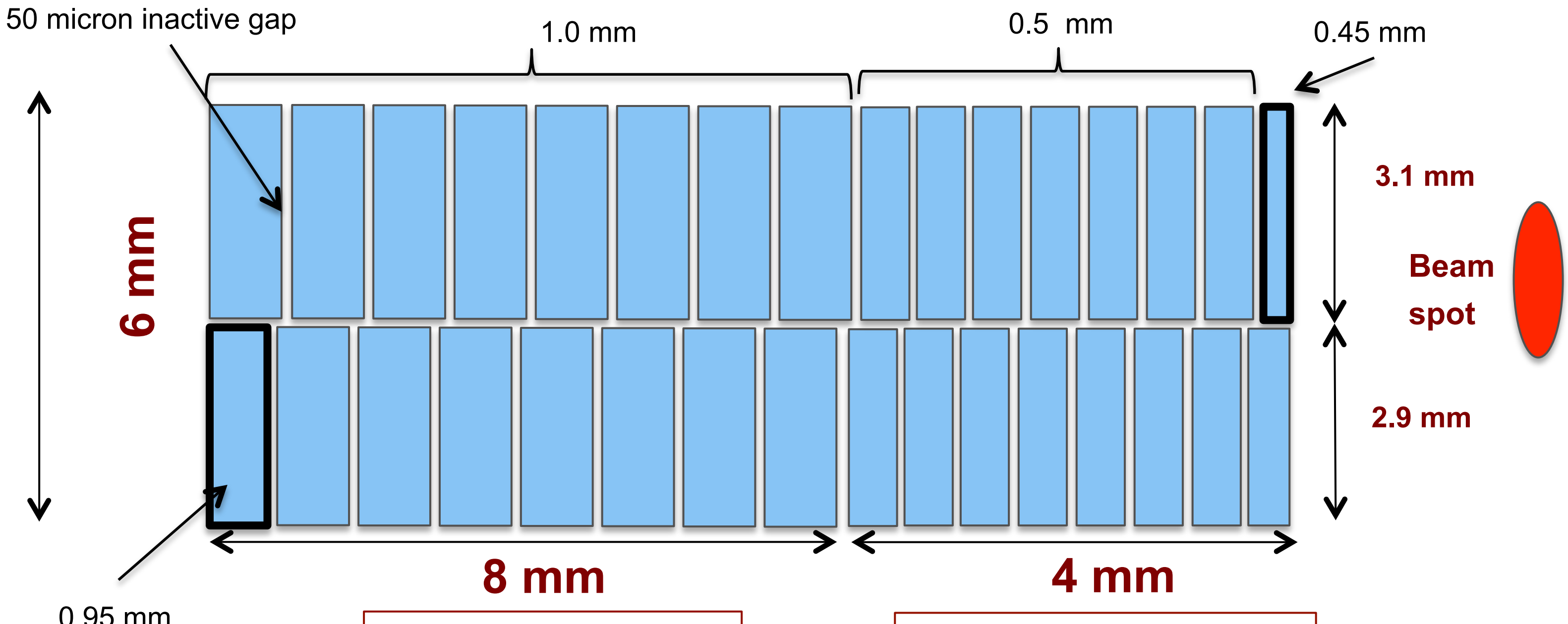
$\sigma(t)$ = 75 – 125 ps

Timing silicon detectors

- A Timing detector for CT-PPS based on UFSD Sensors
- Based on developments made within the RD50 collaboration

Area = 12mm x 6mm;
Thickness = 50 um;
# of pixels = 32
# of planes: 4-6 per side

Use silicon sensors with low internal gain (gain ~ 10) to obtain excellent timing resolution: σ ~ 30 ps



16 Pixel ~ 3 mm^2
Cap. Pixel ~ 6 pF

16 Pixel ~ 2 mm^2
Cap. Pixel ~ 4 pF

Reference timing system

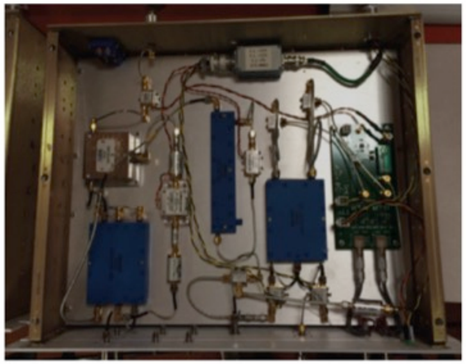
Clock distribution with ~1 ps jitter, 1 ps/C° drift

CMS/SLAC system:

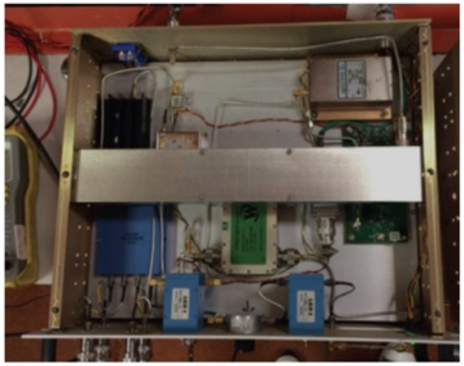
- **Coaxial cable was installed at Year End TS:**
  - cable through the bypass (~470 m total length). Working with CERN EN group on details of master/ slave clock units installation

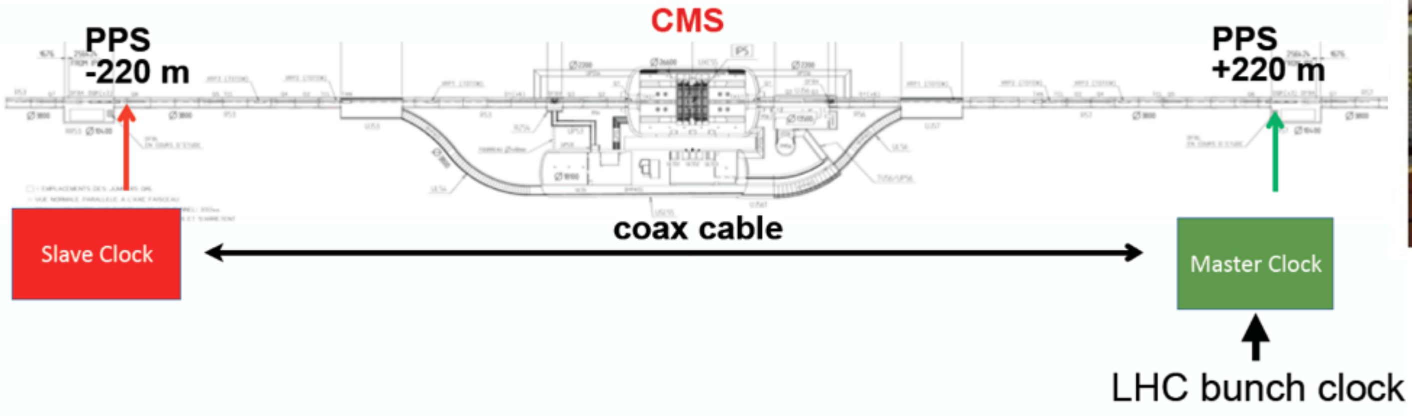
- Procurement of parts for master/slave units is ongoing

Master Clock

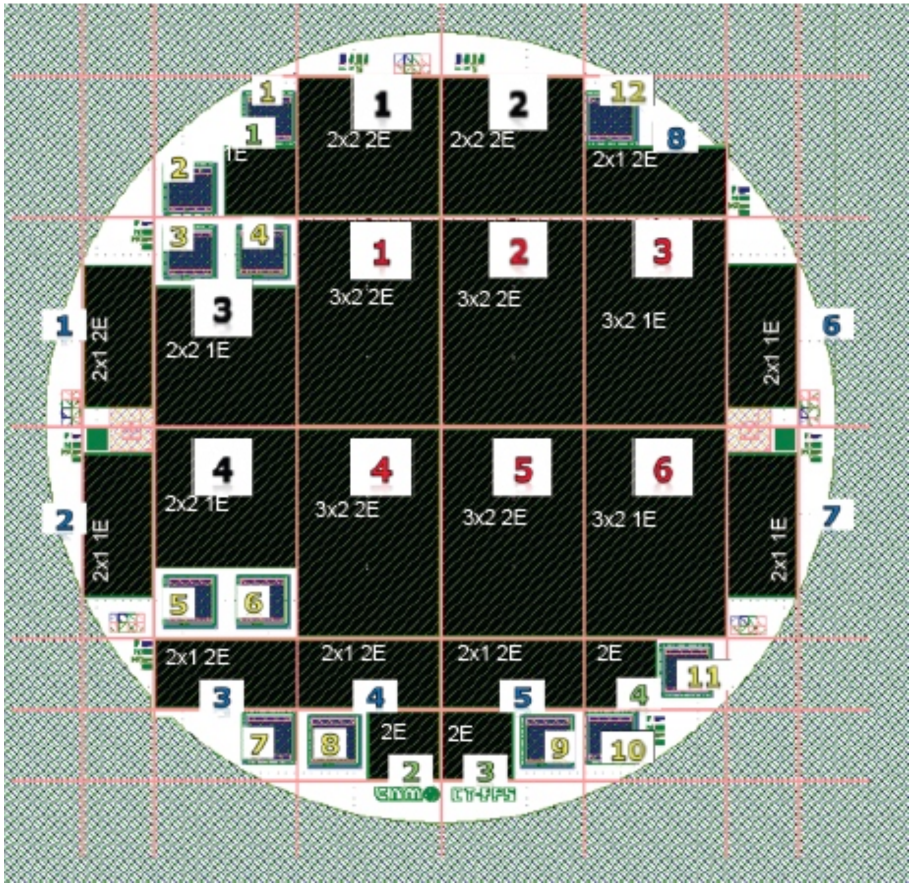


Slave Clock





CNM 3D production for CT-PPS



Wafer thickness 230um
p-type N=10^{12} atm/cm3
p-stop isolation
FZ HR (100) silicon.

- Production of 24 wafers
- Each wafer:

	2E	1E
6 detectors 3x2	4	2
4 detectors 2x2	2	2
8 detectors 2x1	5	3
4 single chip	3	1
Diodes	6	6

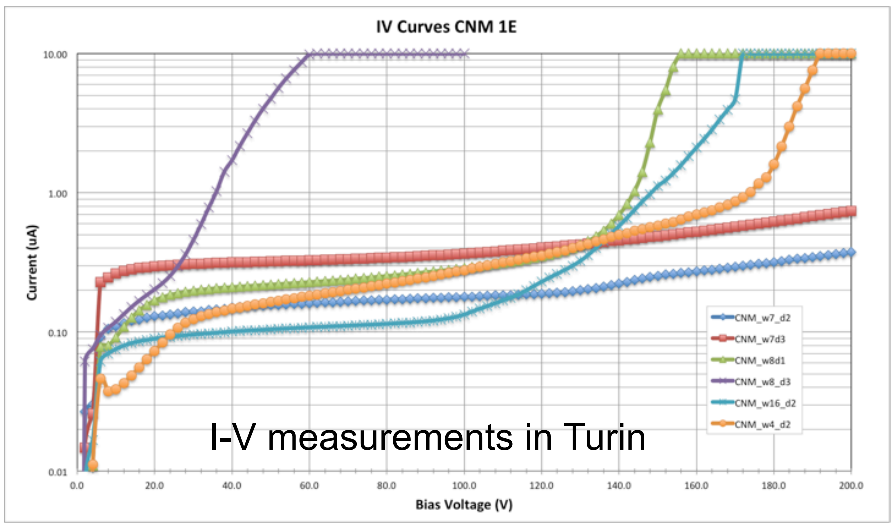
2E – two electrodes
1E – one electrode

- CT-PPS tracking system:
  - 4 tracking stations
  - 6 planes per station
  - one 3x2 detector per plane

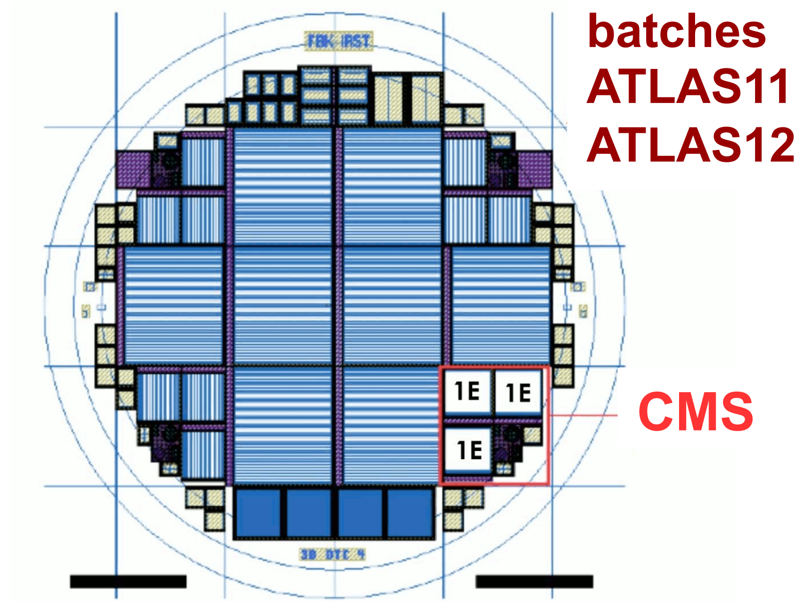
CNM 1E sensor studies

Few CNM 1E sensors (from ATLAS-IBL production) were bump-bonded at X-Ray Imatek in Barcelona to PSI46dig.v2.1 ROCs

Wire bonding and lab tests done in Turin



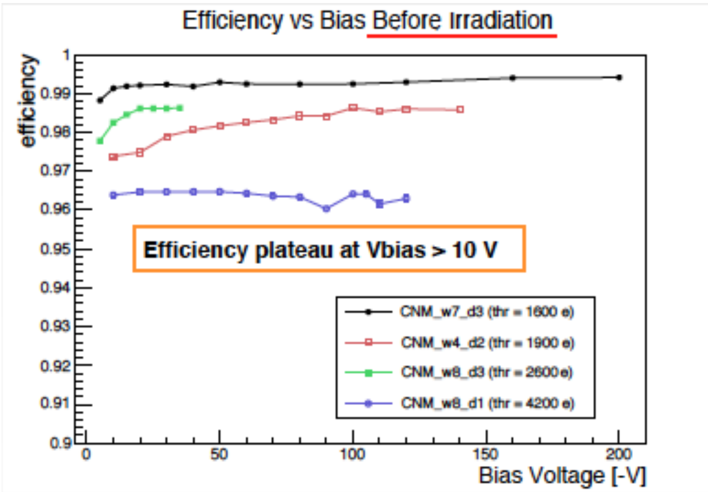
Detectors were **tested in June at Fermilab** with a 120 GeV proton beam

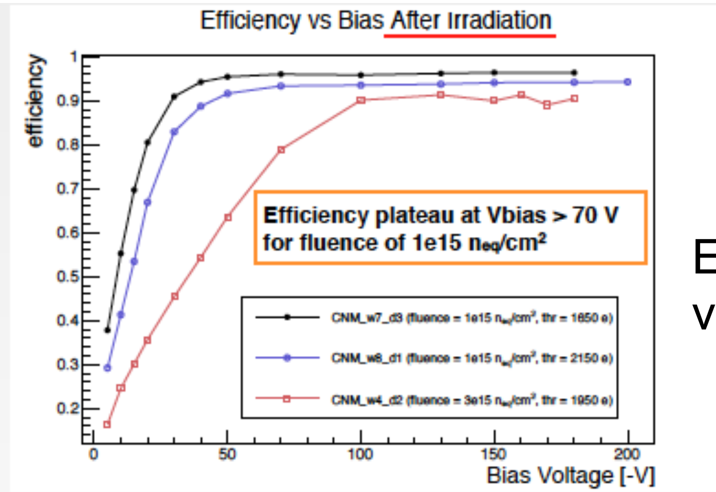


4 detectors were **irradiated at the PS** to **$1x10^{15}$ and $3x10^{15}$ n_{eq}/cm^2** and **tested again at Fermilab at the beginning of November**

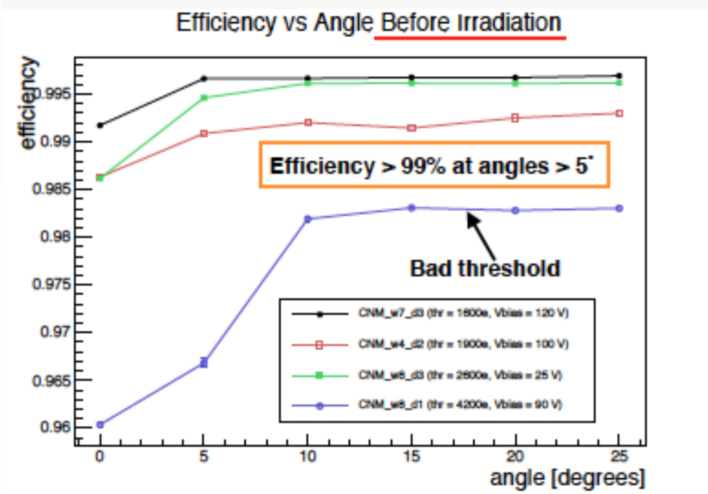
Hit efficiency

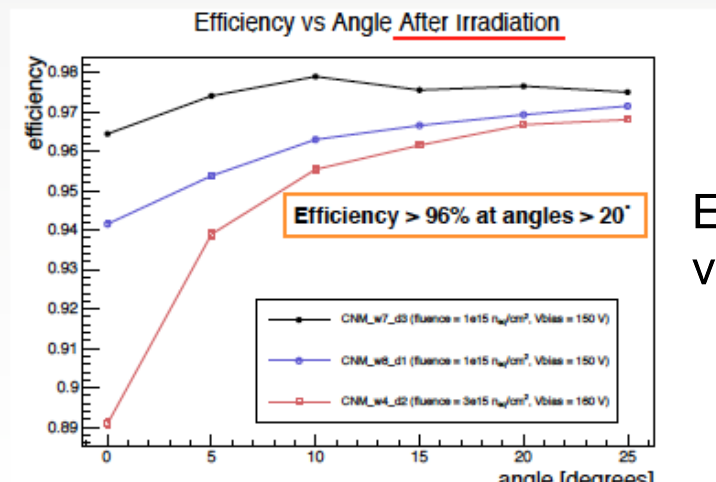
Before irradiation | After irradiation





Efficiency vs Bias



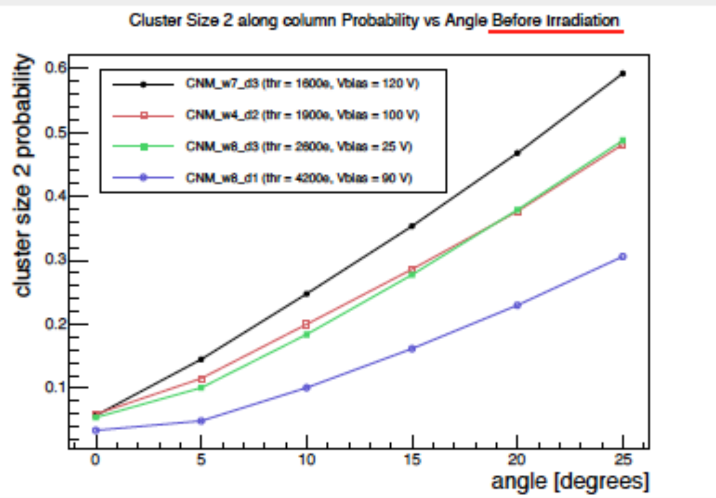


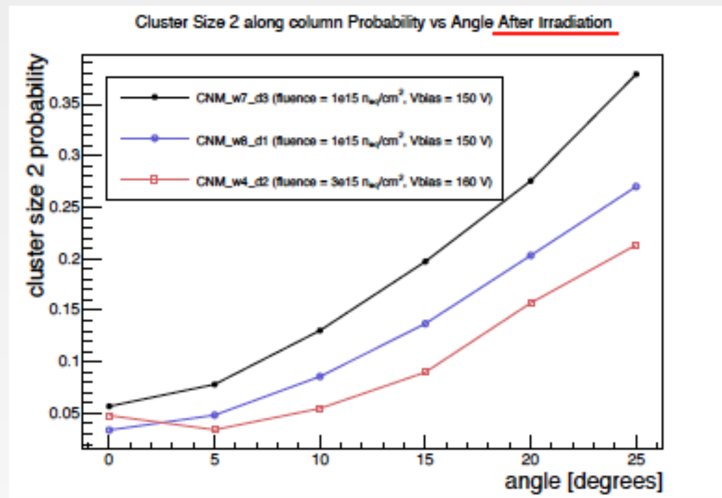
Efficiency vs Angle

X resolution weighted by cluster size

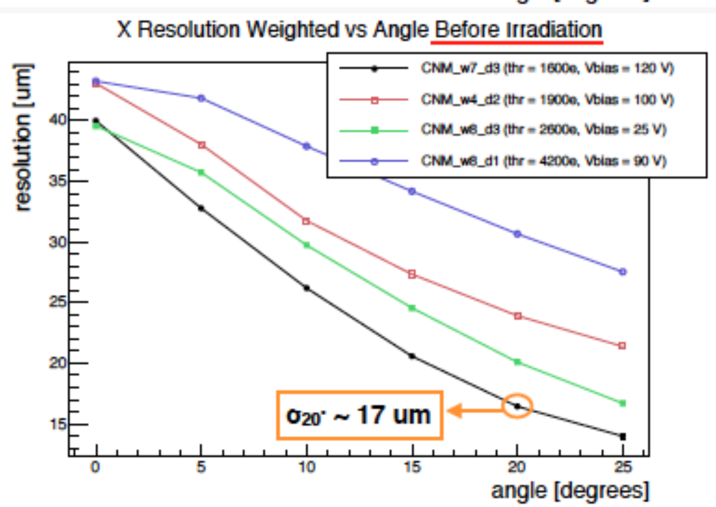
Before irradiation

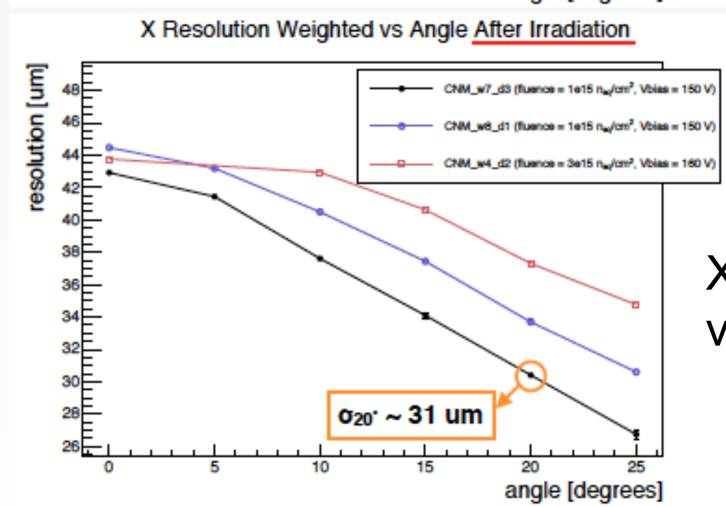
After irradiation





Cluster size 2 vs angle





X resol weighted vs angle

Pixel tracking status

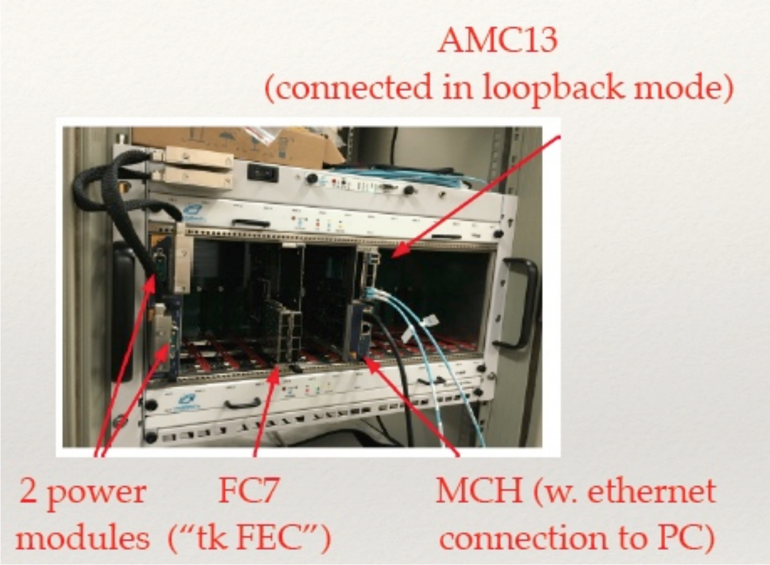
- Production:
  - First batch produced. Second batch completed in March
  - 30 modules bump-bonded to Readout Chips (ROC), expected by the end of March.

- Test-beam results:
  - Test-beam results on irradiated CNM 3D sensors are promising
  - Efficiency greater than 96% after irradiation to fluence of $1x10^{15}$ neq/cm^2
  - Long pitch resolution of ~17 (31) μm before (after) irradiation (angle 20°)

DAQ and Offline

- Integration of detector readout in Central DAQ
  - Integration of TOTEM Strips in CMS Central DAQ
  - Development and integration of CT-PPS uTCA DAQ
- DCS integration
  - based on TOTEM DCS
- Integration of software in CMSSW 8
  - TOTEM strips tracking reconstruction
  - Timing detectors software
- Other areas being developed:
  - DQM, Alignment, Calibration, Databases, Validation, Certification

uTCA Hardware



Conclusions

- We have new motivations for CT-PPS to be ready for physics in 2016

- Using available detectors from TOTEM makes it possible

- Full integration in CMS in a short time scale is challenging but feasible

- Changes to LHC optics are being made to increase CT-PPS acceptance for physics

Backup