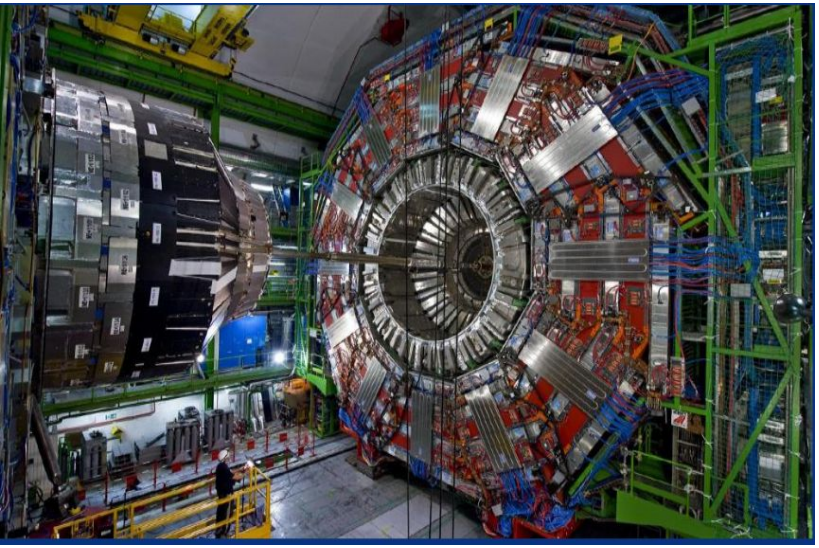
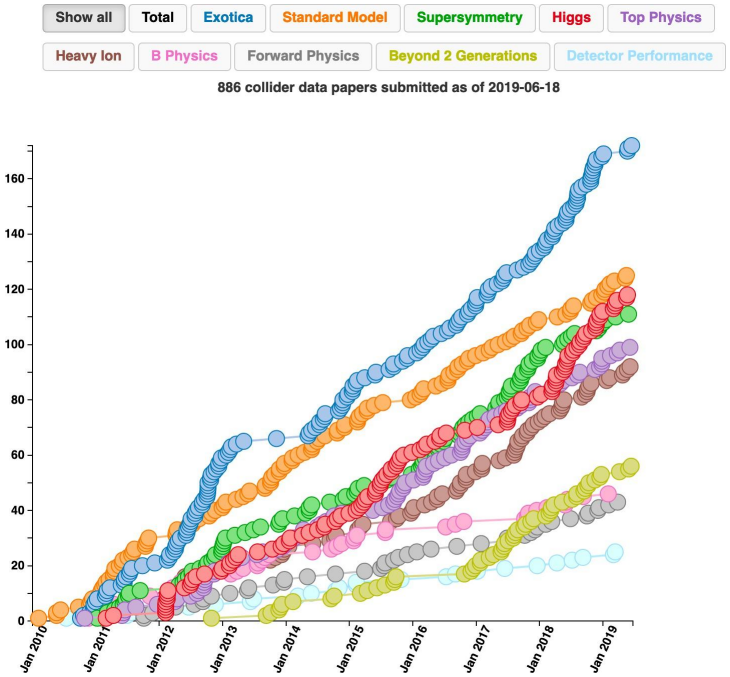
Preventivi 2020: CMS

G. Bagliesi
04/07/2019



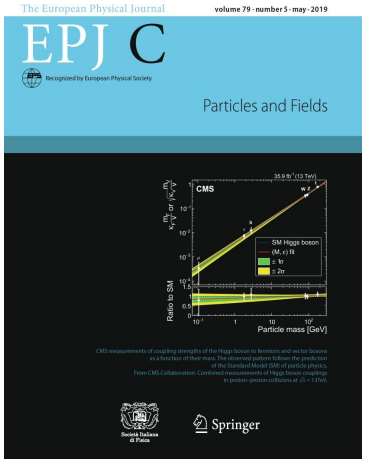
- Situazione CMS
- Fisica
  - attività a Pisa (flash)
- Upgrade tracker (fase II)
  - Inner pixel
  - Outer Tracker
- Tier2: stato e richieste
- Responsabilità 2019-20
- Anagrafica 2020
- Sommario richieste

Publication and Analysis Status



One of our recent papers on the title page of EPJC

Combined measurements of Higgs boson couplings in proton-proton collisions at √s = 13 TeV , *EPJC 79 (2019) 421*



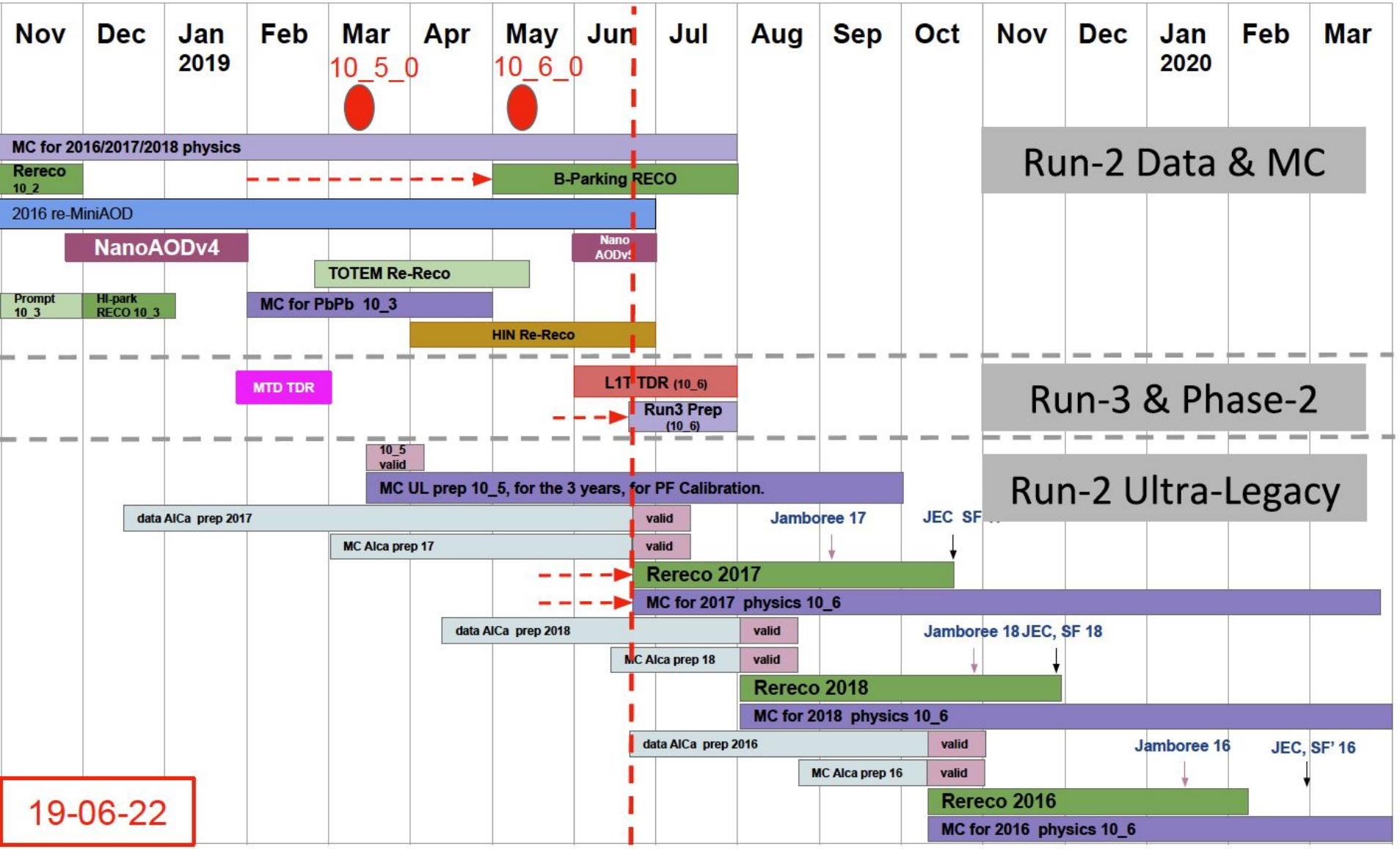
Submitted 900th paper on May 17th !

Analysis approval status

- 57 pre-approved - approved
- 37 in ready-for-CWR - FR
- 36 in journal review
- 9 accepted

Submissions	CMS	ATLAS	LHCb	ALICE
2019	39	43	28	21
2018	141	103	42	39
2017	132	105	60	31

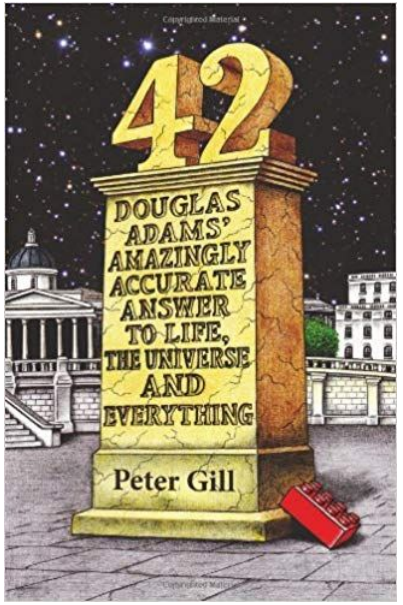
2019 production timelines



Conditions in 2021

WLCG requested a statement on the maximum luminosity deliverable in 2021, to plan computing resources

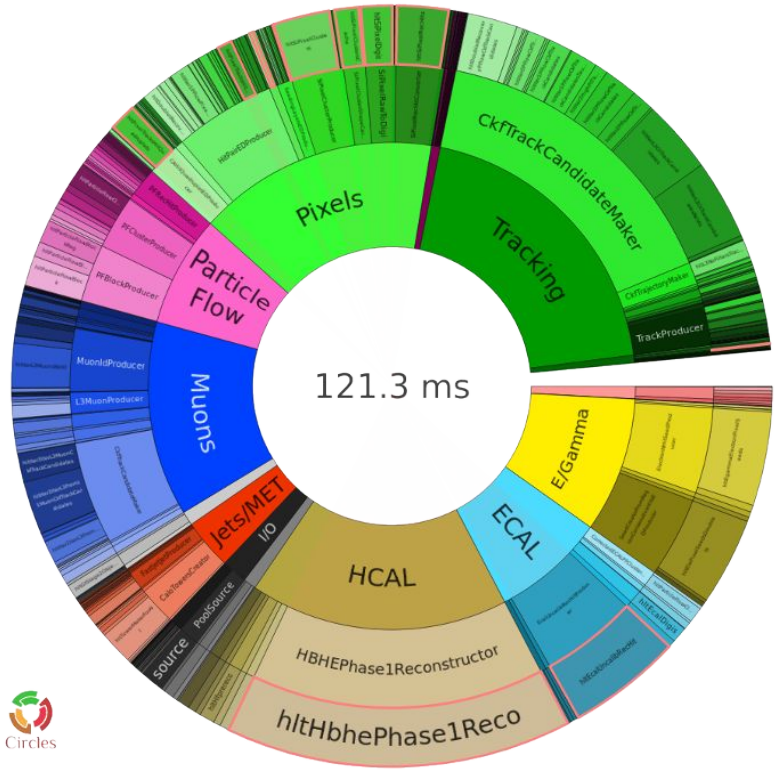
- The answer is 42 (!)
- Indeed, these numbers are strongly opinion dependent, depending on commissioning time of the whole LHC and injector chain and also on the choice on the energy
  - some mentioned 7fb^{-1} as a limit
- But 42 fb^{-1} with an availability of 50% can be used for contingency planning (not as a promise in any way)



Various options (nothing new):

- Plan A 2×7 = 14 TeV in 2021, up to several months more training while starting up injectors
- Plan B 2×6.5 = 13 TeV in 2021, then 14 TeV

fraction of HLT runtime ported to GPUs



Element	Time	Fraction
hltEcalUncalibRecHit	20.7 ms	4.8 %
hltHbhePhase1Reco	62.7 ms	14.7 %
hltPixelLayerQuadruplets	0.1 ms	0.0 %
hltPixelLayerTriplets	0.1 ms	0.0 %
hltPixelTracks	0.7 ms	0.2 %
hltPixelTracksHitDoublets	2.6 ms	0.6 %
hltPixelTracksHitQuadruplets	4.8 ms	1.1 %
hltPixelVertices	0.1 ms	0.0 %
hltSiPixelClusters	10.2 ms	2.4 %
hltSiPixelClustersCache	4.3 ms	1.0 %
hltSiPixelDigis	5.7 ms	1.3 %
hltSiPixelRecHits	9.3 ms	2.2 %
selected	*121.3 ms*	*28.5 %*

Showing 1 to 12 of 12 entries

- Almost 30% of the HLT could run on GPUs **today**
- Porting to GPUs 40% of the HLT by Run 3 is a realistic goal

Tracker: Project **Patatrack** demonstrated that GPU can do ‘pixel tracking’ : very promising solution for HLT reconstruction at run 3 allowing better Physics performance and shorter reconstruction time.

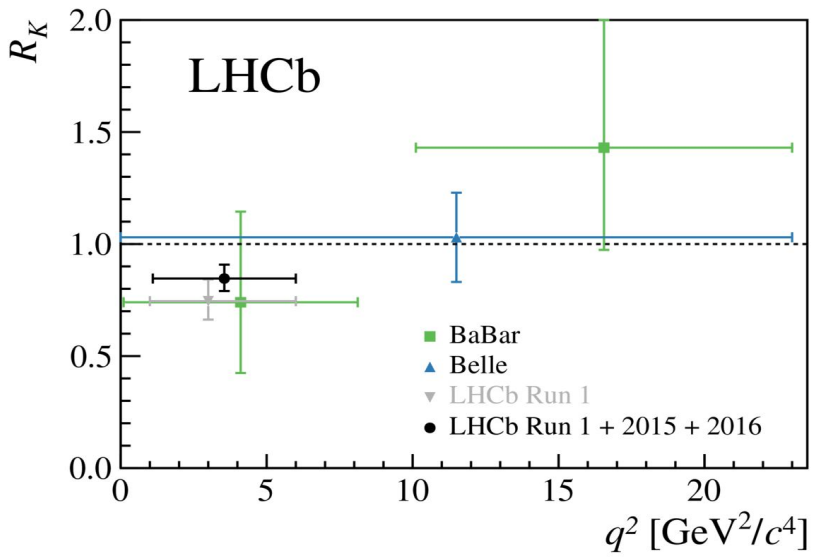
Processing of special datasets

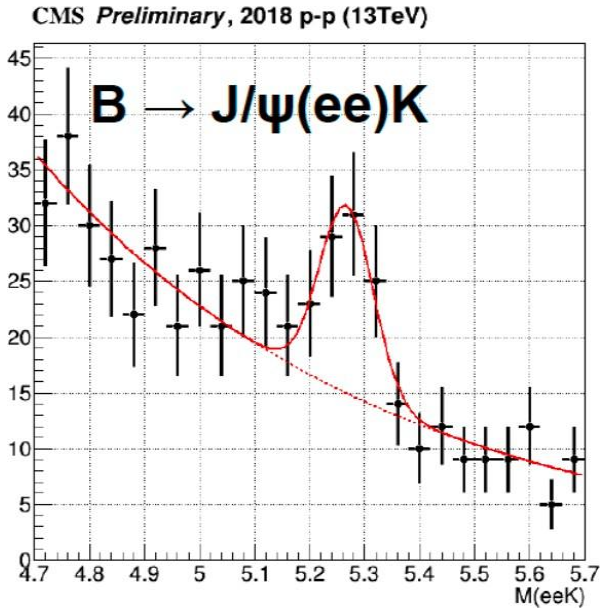
Important efforts for this year involving the DPGs, POGs and PAGs

- Big thanks to PPD and Offline & Computing!
- Processing of the BPH parked data in progress
  - First checks of the processed data match expectations

The large collection of unbiased B decays opens many other possibilities such as rare B_s decays, R(D*), FV decays to leptons, CPV, …

- Processing of the heavy ion data collected in 2018 is ongoing
  - Next major HIN conference: Quark Matter (November)





Situazione tracker

Tracciatore di CMS durante shutdown

- **Preparazione per Run 3:**
  - Prevista luminosità di picco ~2-2.2*10^{34}cm^{-2}s^{-1}
    - Fino a ~60-70 interazioni simultanee
  - Luminosità integrata ~250-300 fb^{-1} (+ 190 fb^{-1} Run 1+2)
- **Manutenzione e miglioramenti rivelatore a pixel**
  - Sostituzione strato più interno (layer 1)
    - Sensori non irraggiati, nuovi chip di lettura
      - Nuovi chip già disponibili
  - Sostituzione convertitori DCDC: eliminate causa rotture
    - Nuovo chip già disponibile
  - Alimentatori (CAEN) modificati per raggiungere 800V
- **Tracciatore a strisce: mantenuto freddo (circa 0 C) per evitare effetti negativi radiazione accumulate**

Estrazione rivelatore a pixel
barriere contro umidità
tracciatore a strip nello sfondo

Sequenza lavori su rivelatore a pixel

Costruzione moduli e integrazione sulla meccanica: Agosto 2019 – Marzo 2020

Assemblaggio convertitori DCDC e installazione: Settembre 2019 – Maggio 2020

Modifica alimentatori e reinstallazione in caverna: Agosto 2019 – Febbraio 2020

Integrazione delle nuove componenti test e re-installazione in CMS: Marzo 2020- Ottobre 2020

Piani per LS2

- Sostituzione layer piu' interno rivelatore a pixel
  - Nuovi chip di lettura: minor rumore, minore inefficienza dinamica, eliminata sorgente di SEU che necessitano spegnimento/accendimento
- Sostituzione convertitori DCDC del rivelatore a pixel
- Potenziamento alimentatori rivelatori a pixel (CAEN) per raggiungere 800V
  - Per evitare la necessita' di sostituire il layer piu' interno per una terza volta prima della fine di Run 3
- Preparazione per ridurre ulteriormente la temperatura del rivelatore a Strip a -25C durante Run 3
  - Mantenimento della temperatura dei sensori del rivelatore a Strip sotto a 0 C durante l'upgrade di HCAL per evitare reverse annealing

Altre attività legate al tracciatore

- **Aggiornamento sistema di protezione del tracciatore (DSS)**
  - Intervento coordinato da P.G. Verdini
- **Ri-organizzazione architettura e software sistema di controllo e monitoraggio del tracciatore (DCS)**
  - Intervento coordinato da P.G. Verdini
- **Aggiornamento calibrazioni e allineamento del tracciatore per nuova campagna di ricostruzione e simulazione dati Run 2**
  - Effetti radiazione costringono ad aggiornare decine di volte per anno le calibrazioni e l'allineamento

Analisi a Pisa e laureandi+dottorandi

Informazione minimale:
altre attività non citate qui sono in corso di completamento o in fase iniziale di sviluppo

- VBF H->mumu (**Azzurri, Mandorli, Negin, Rizzi**)

- B-tagging con tecniche di deep learning (**Giannini, Rizzi**)
- tau -tagging con tecniche di deep learning (K. Androsov)

- X->HH->bbbb (**Rizzi** + FNAL)

- X->HH->bbtautau (**Androsov, Bagliesi, Ciocci, Di Domenico, Grippo,** + LLR)
  - Notevole miglioramento di S/B grazie al lavoro del gruppo di Pisa

- VBF H->bb, VH->bb (**Azzurri, Rizzi, Giannini** + varie istituzioni esterne)
  - observation a 5 sigma (contributo fondamentale pisano)

- EW (VBF) Z+jj, W+jj (**Azzurri** + varie istituzioni esterne)

- Misura massa del W (**Bertacchi**, **Bianchini**, **Manca**, **Rolandi** + CERN)
  - Ruolo leader nell'analisi del gruppo pisano

- CP Violating phase phi_s con Bs->Jpsi Phi **(G. Fedi, F. Ligabue, F. Palla + Padova + Rochester + Madras)**

- Fase2 activities, test beam analysis (**S. Parolia**)

Perfezionandi/dottorandi: **L. Giannini, , V. Bertacchi, E. Manca, G. Mandorli, S. Negin, M.R. Di Domenico, S. Parolia**

Dettaglio attivita' post-doc CMS

- K. Androsov
  - Borsa INFN calcolo scientifico CMS: ML per tau-tag, analisi hh→ bbtautau, tau Trigger
- G. Fedi
  - Ass. Ric. UniPI: Conv. BPH Spectr.&Prop. (L3), analisi CP-viol nel B_s , Track trigger
- M.T. Grippo
  - Ass. Ric. UniPI: analisi hh→ bbtautau, pixel R&D, HLT tau trigger
- S. Chowdhury
  - Assegno SNS: Massa del W, tracker POG

CMS Tesi I

Sito WEB: http://cms.pi.infn.it

Elenco tesi: https://goo.gl/0nf0T8

- **Fisica del bosone di Higgs (contatti: Paolo Azzurri, Giuseppe Bagliesi, Agnese Ciocci, Andrea Rizzi)**
  - Studio del bosone di Higgs in stati finali b-bbar ad LHC con l'esperimento CMS
  - Studio del bosone di Higgs in stati finali tau+tau- ad LHC con l'esperimento CMS
  - Studio della produzione di coppie di bosoni di Higgs in stati finali con b e/o tau ad LHC con l'esperimento CMS
  - Studio della produzione di coppie di bosoni di Higgs in stati finali con W e tau ad LHC con l'esperimento CMS
  - Ricerca del bosone di Higgs in stati finali mu+mu- ad LHC con l'esperimento CMS
  - Studio della fisica dell'Higgs negli scenari di upgrade dell'esperimento CMS ad LHC

- **Fisica Elettrodebole (contatti: Paolo Azzurri, Gigi Rolandi)**
  - Fusione elettrodebole di bosoni Z o W ad LHC con l'esperimento CMS
  - Misura di precisione della massa del bosone W con l'esperimento CMS

- **Fisica delle interazioni forti (QCD) (contatti: Paolo Azzurri, Andrea Rizzi)**
  - Identificazione di quark e gluoni con l'esperimento CMS
  - Identificazione di quark b con l'esperimento CMS

- **Fisica del quark-b (contatto: Fabrizio Palla, Franco Ligabue)**
  - Misura della violazione di CP nel canale Bs->Jpsi Phi con il nuovo rivelatore di vertice di CMS
  - Misura della vita media del Bs con l'esperimento CMS
  - Misura della sezione d'urto del Bs con l'esperimento CMS

CMS tesi II

- **Fisica del quark-top (contatto: Roberto Tenchini)**
  - Misura della produzione di quark top e loro decadimento in tau con l'esperimento CMS: test di universalita' leptonica.
  - Misura di produzione di top singolo in canale s con l'esperimento CMS
  - Misura di produzione associata di top singolo e bosone di Higgs con l'esperimento CMS

- **Fisica oltre il Modello Standard (contatto: Fabrizio Palla)**
  - Violazione dell'universalita' leptonica con R(Jpsi)

- **Rivelatori, Elettronica e Computing (contatti: Giuseppe Bagliesi, Tommaso Boccali, Agnese Ciocci, Roberto Dell'Orso, Alberto Messineo, Fabrizio Palla, Andrea Rizzi)**
  - Sviluppo di sensori innovativi per l'upgrade del rivelatore a Pixel dell'esperimento CMS ad LHC
  - Sviluppo di un trigger di traccia di primo livello per CMS a HL-LHC
  - Tecniche di deep-machine learning nelle analisi dati dell'esperimento CMS ad LHC
  - Test del chip di readout per l'upgrade del rivelatore a pixel di CMS a HL-LHC
  - Simulazione di dispositivi opto-elettronici radiation-hard per HL-LHC e collisori futuri

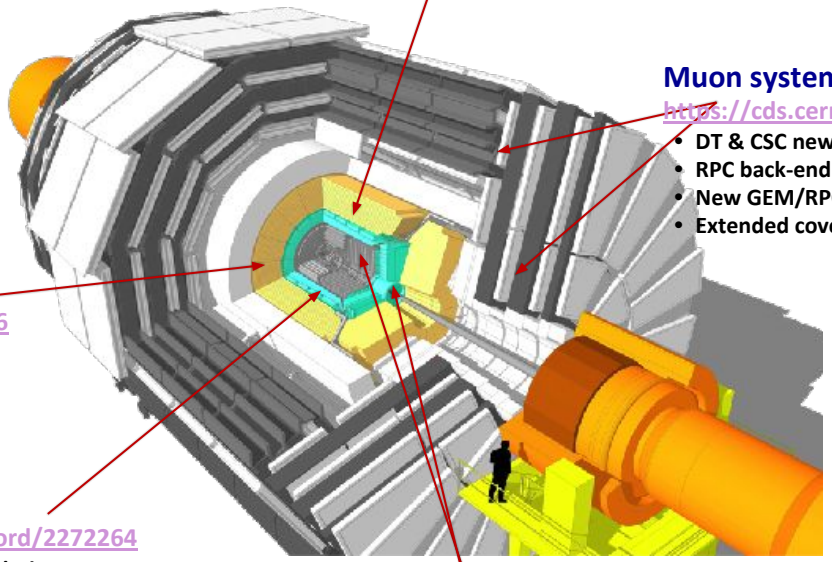
Upgrade fase II

FASE 2 upgrade overview

Technical proposal CERN-LHCC-2015-010 https://cds.cern.ch/record/2020886
Scope Document CERN-LHCC-2015-019 https://cds.cern.ch/record/2055167/files/LHCC-G-165.pdf

L1-Trigger/HLT/DAQ
https://cds.cern.ch/record/2283192
https://cds.cern.ch/record/2283193
- Tracks in L1-Trigger at 40 MHz
- PFlow-like selection 750 kHz output
- HLT output 7.5 kHz

Barrel Calorimeters
https://cds.cern.ch/record/2283187
- ECAL crystal granularity readout at 40 MHz with precise timing for e/γ at 30 GeV
- ECAL and HCAL new Back-End boards



Muon systems
https://cds.cern.ch/record/2283189
- DT & CSC new FE/BE readout
- RPC back-end electronics
- New GEM/RPC $1.6 < \eta < 2.4$
- Extended coverage to $\eta \simeq 3$

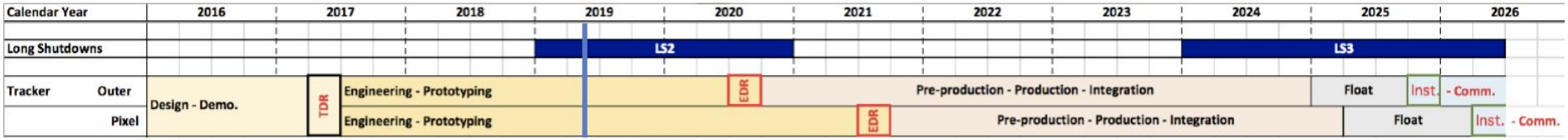
Calorimeter Endcap
https://cds.cern.ch/record/2293646
- 3D showers and precise timing
- Si, Scint+SiPM in Pb/W-SS

Beam Radiation Instr. and Luminosity, and Common Systems and Infrastructure
https://cds.cern.ch/record/2020886

Tracker https://cds.cern.ch/record/2272264
- Si-Strip and Pixels increased granularity
- Design for tracking in L1-Trigger
- Extended coverage to $\eta \simeq 3.8$

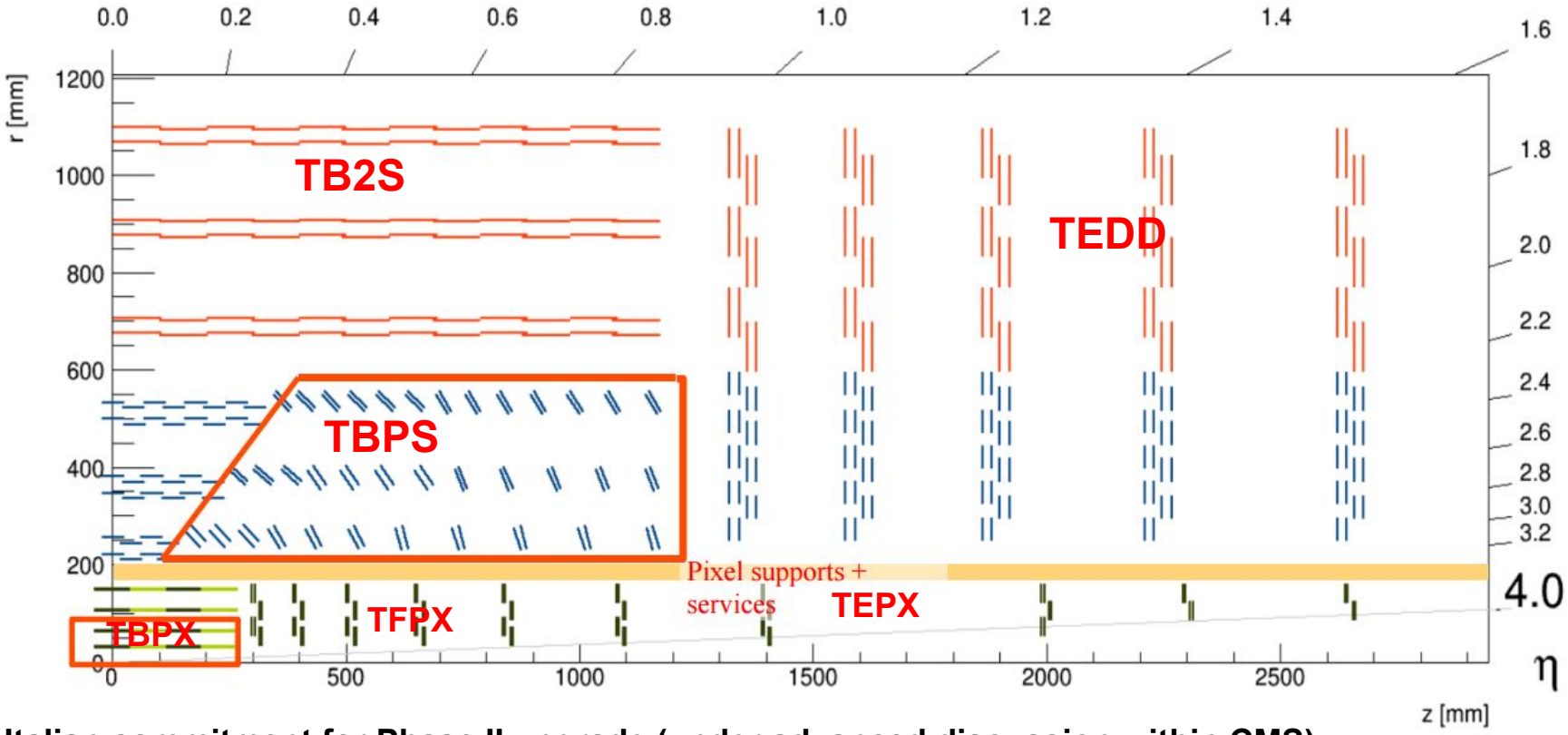
MIP Timing Detector
https://cds.cern.ch/record/2296612
Precision timing with:
- Barrel layer: Crystals + SiPMs
- Endcap layer: Low Gain Avalanche Diodes

Tracker upgrade timescale



N.B: Coinvolgimento italiano in Outer e Inner Tracker

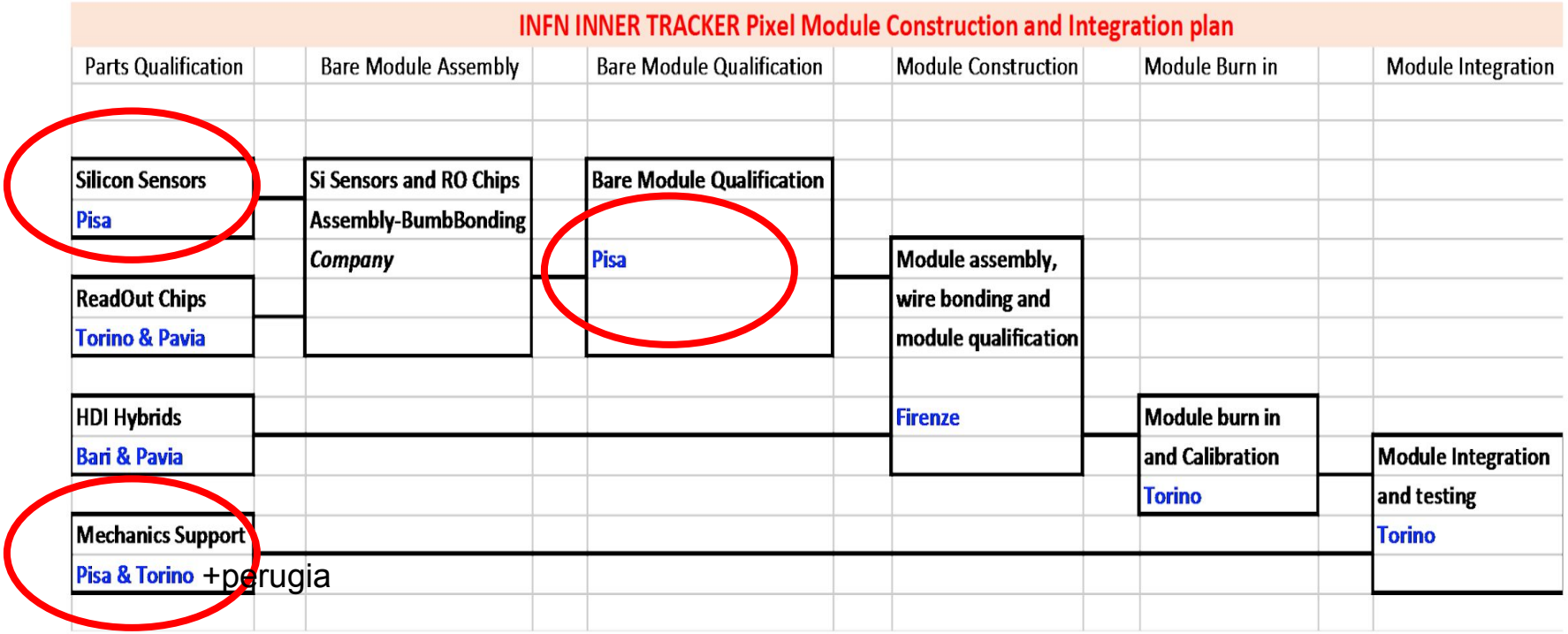
Italy and Tracker Upgrade



Italian commitment for Phase II upgrade (under advanced discussion within CMS):

- First two layers of modules TBPX + fraction of TEPX
- Tilted TBPS
- Pixel barrel support and mechanics
- Tracker safety system
- L1 Track Trigger
- RD53 CHIP development

INFN Inner Tracker Pixel construction plan



- **108 mod 1x2 ROC L1 BPIX (3D possibly)**
- **1020 mod 1x2 ROC L2 Bpix (252) + R1&R2 EPIX (768)**
- **Struttura meccanica completa Pixel Barrel**

In discussione

Financial Contribution ≅5 MCHF
20% of Total Pixel Cost

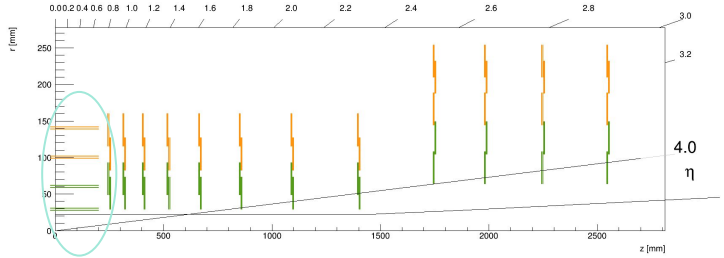
INFN
Istituto Nazionale
di Fisica Nucleare

Pixel Upgrade Projects

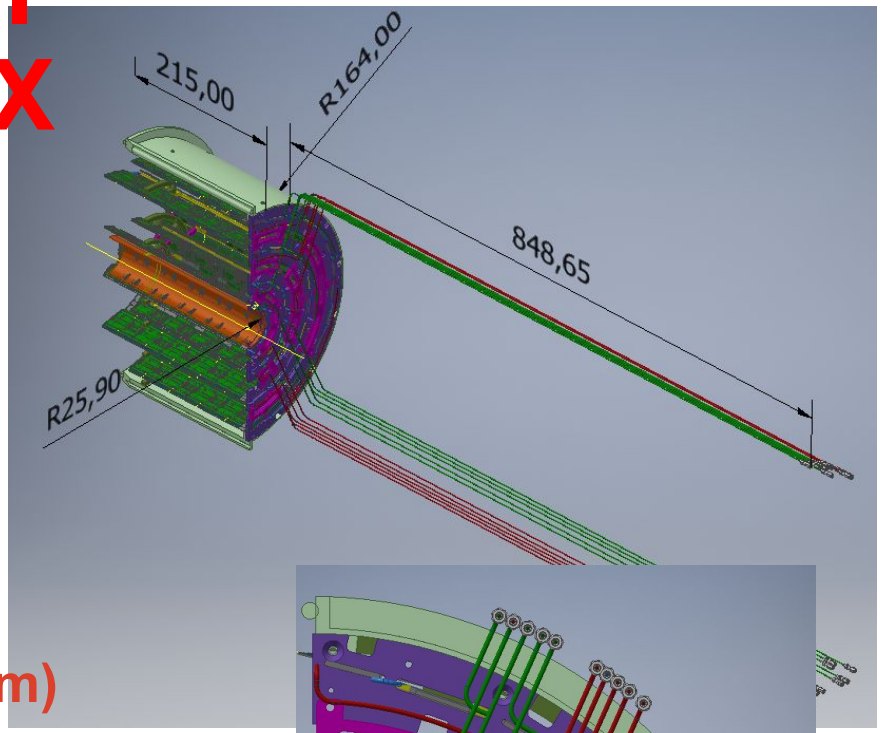
Phase-II activities

CMS upgrade phase II meccanica Pixel TBPX

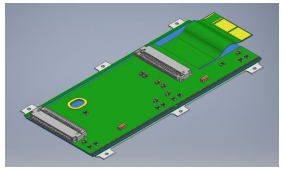
Impegno ufficiale italiano e <u>in particolare di Pisa</u>

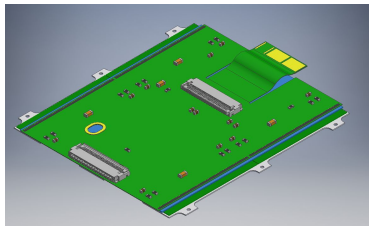


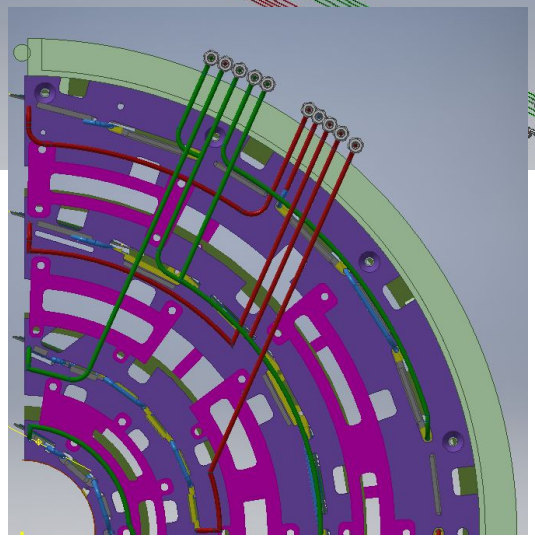
Upgrade - Inner Tracker Barrel Pixel Detector



- 4 layers (r = 30.0-61.5-104.5-146.5 mm)
- lungh. tot. = +-200.7 mm
- 2 tipi di moduli:
  - 324 moduli (1x2 chips)
    - ✔ layer 1 e 2 (36 rods)
  - 432 moduli (2x2 chips)
    - ✔ layer 3 e 4 (48 rods)





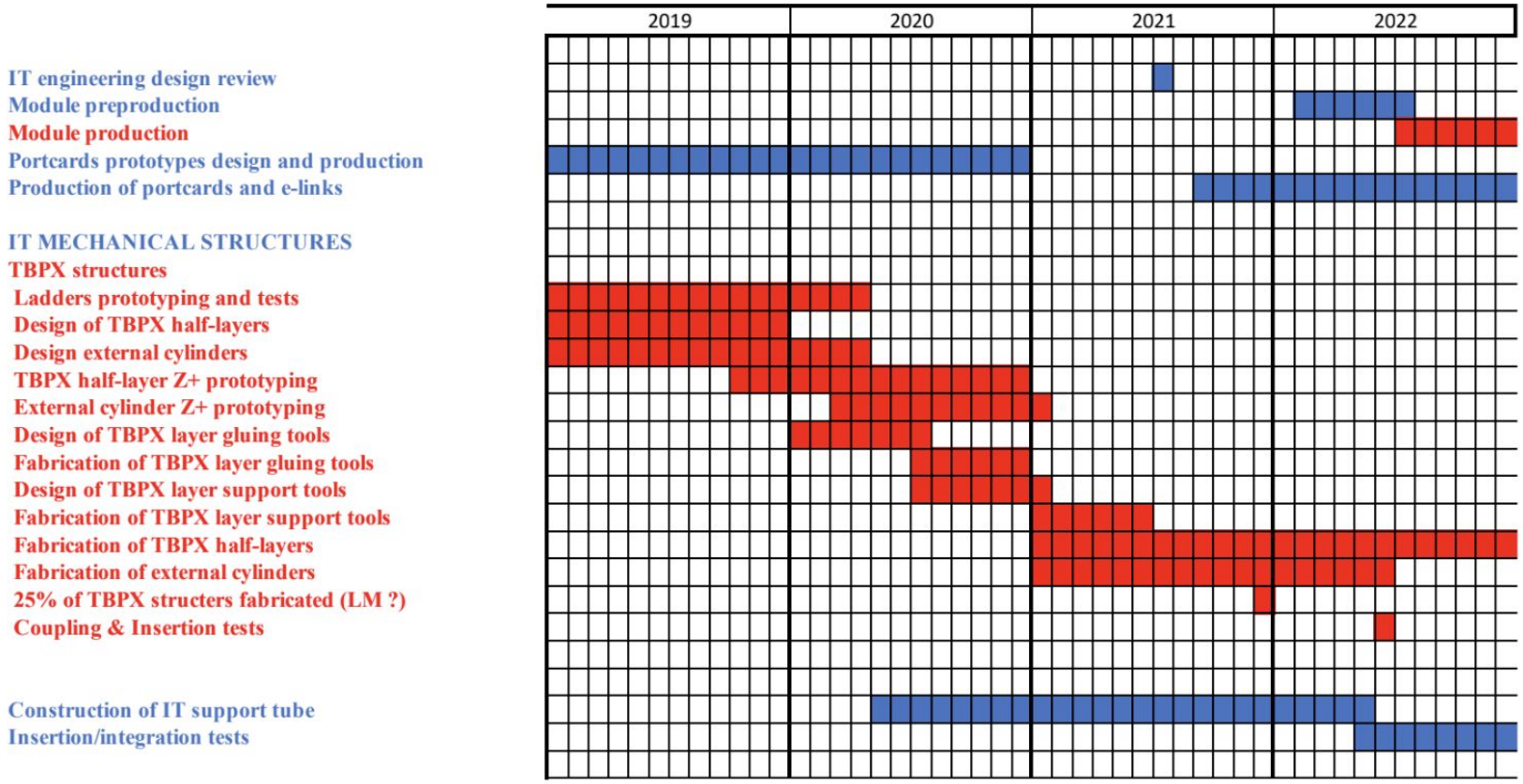


Struttura divisa in 4 settori: forward/backward - left/right

Coinvolgimento: A. Basti, F. Bosi, F. Raffaelli, A. Moggi, M. Massa, R. Dell'Orso

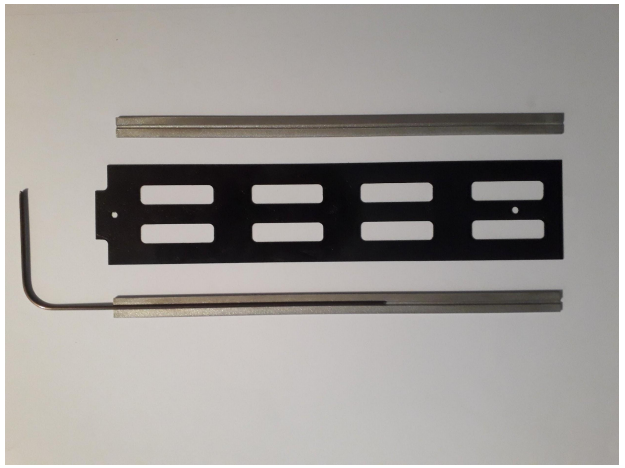
Schedule: strutture meccaniche TBPX

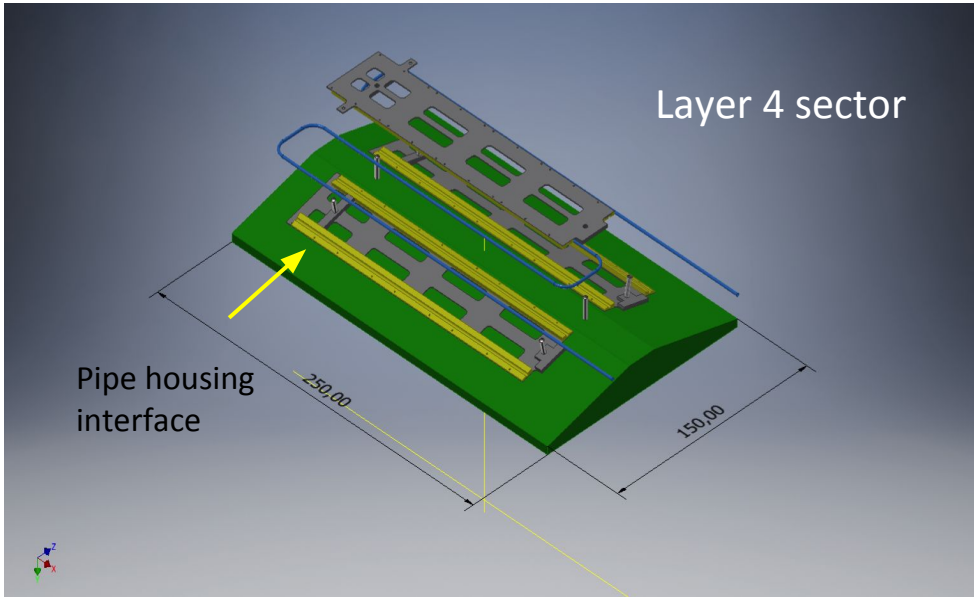
- 3° Technical review - dicembre 2018 al CERN
- 4° Technical review - aprile 2019 al CERN
- **CMS Inner Tracker Workshop – 11-13 novembre 2019 a Pisa**

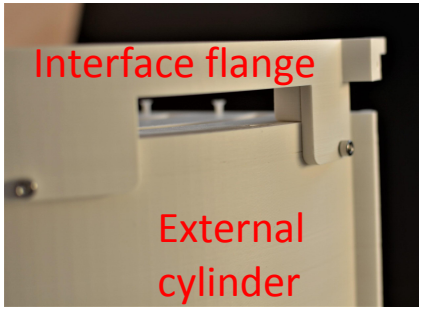


Realizzazione prototipi

1. **Prototipo ladder layer 4**
2. **Prototipo settore layer 4**
   CO2 , Tfluido -35°C, 3 ladders, 1 cooling loop
3. **Prototipo External cylinder**
   Giá realizzato mockup 3D printer
4. **Prototipo half layer 4 Z+**
   Diametro 147 mm,
   lunghezza 210 mm, 14 ladders,
   4 cooling loops
5. **Prototipo ladder layer 1**
6. **Prototipo half layer 1 Z+**







Pixel Phase II: 2019 ongoing activities and results

All sensors were bump-bonded to RD53A and mounted on RICE cards

Pixel prototypes: 50 μm X 50 μm cell size, with different bias technology Planar and 3D

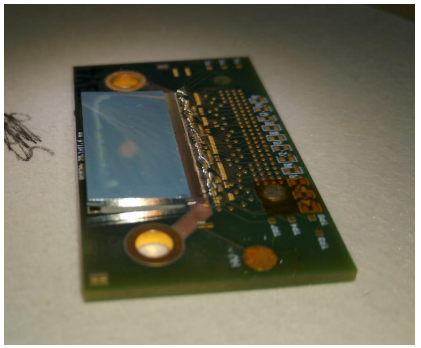
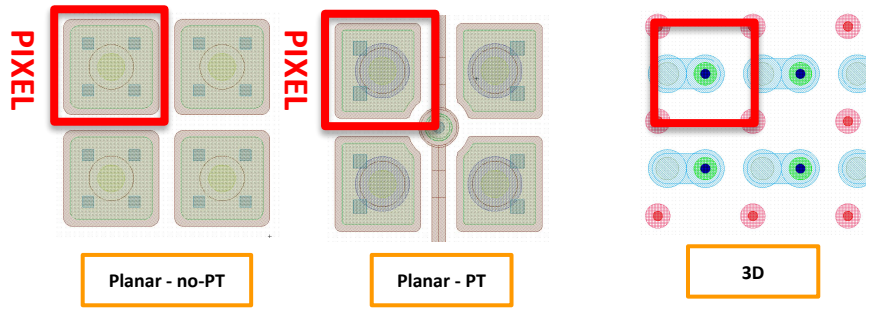


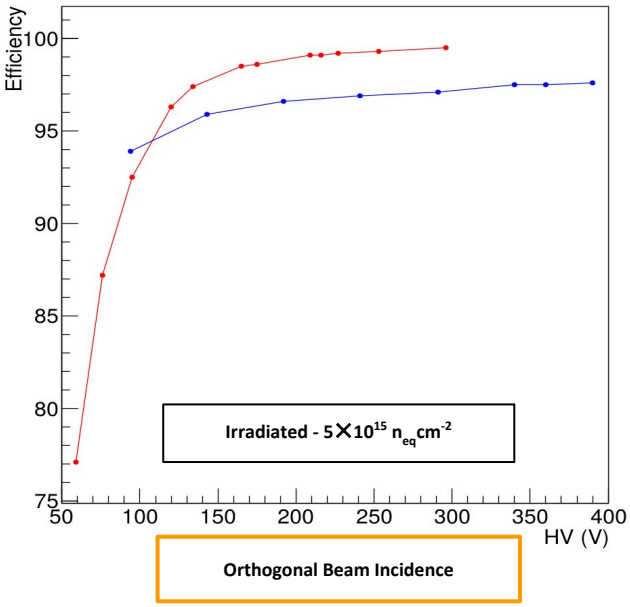
Image of a 3D prototype



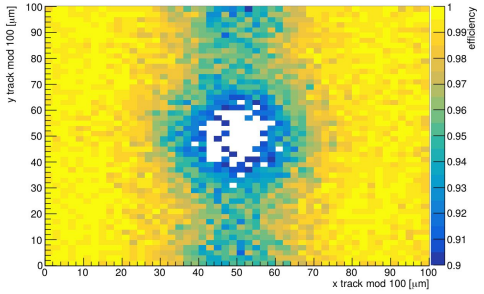
- Results on laboratory qualification and dedicated beam test (Desy and FNAL) on virgin and irradiated detectors
  - target levels for pixel phase II layers: 5×10^{15} $n_{eq}cm^{-2}$ planar, and 1×10^{16} $n_{eq}cm^{-2}$ 3D columnar
  - Pisa started to actively collaborate to both items: laboratory test stand set-up and running + beam test analysis, PhD student involved

Beam test results on Planar and 3D

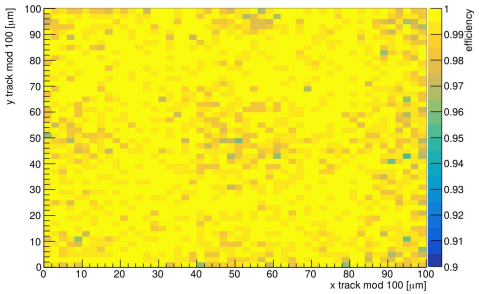
Start to focus on design rules: planar bias tecnology



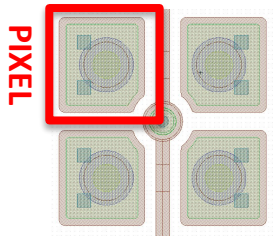
Orthogonal Beam Incidence



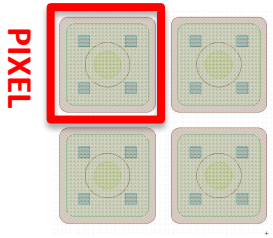
V_{bias} = 390 V



V_{bias} = 295 V



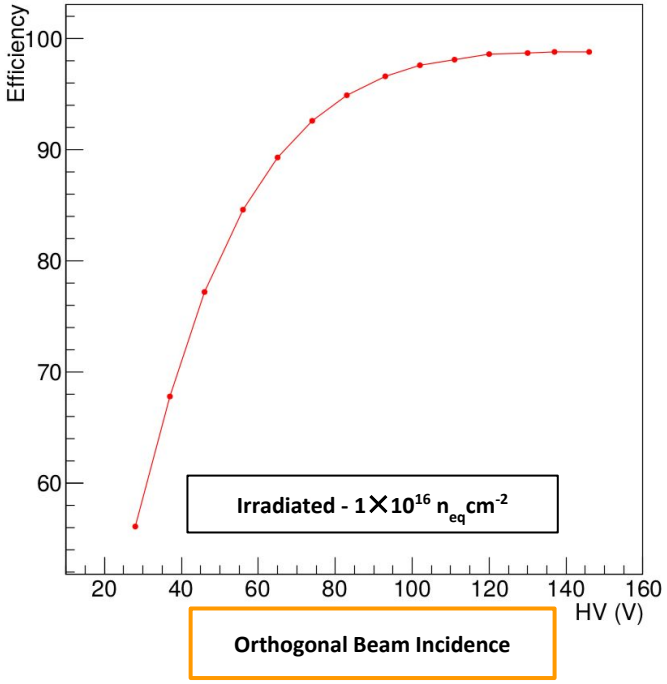
Planar - PT

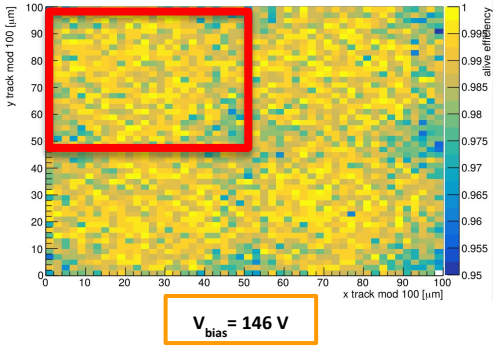


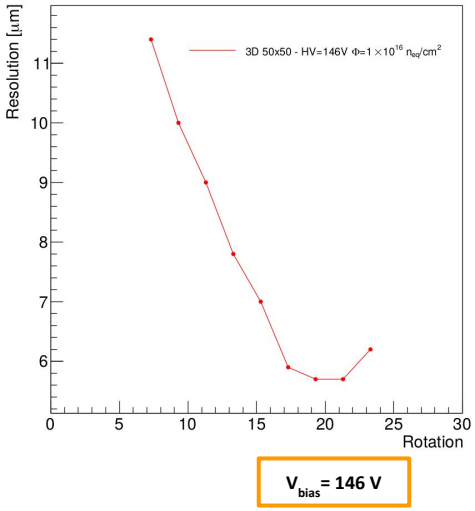
Planar - no-PT

Beam test results on Planar and 3D

Start to focus on design rules: 3D detectors







Pixel devices production: multi-chip modules

First prototype assembly of Pseudo-Quad: Layer 4 with RD53a ROC

Design made by Pisa-Firenze and FBK

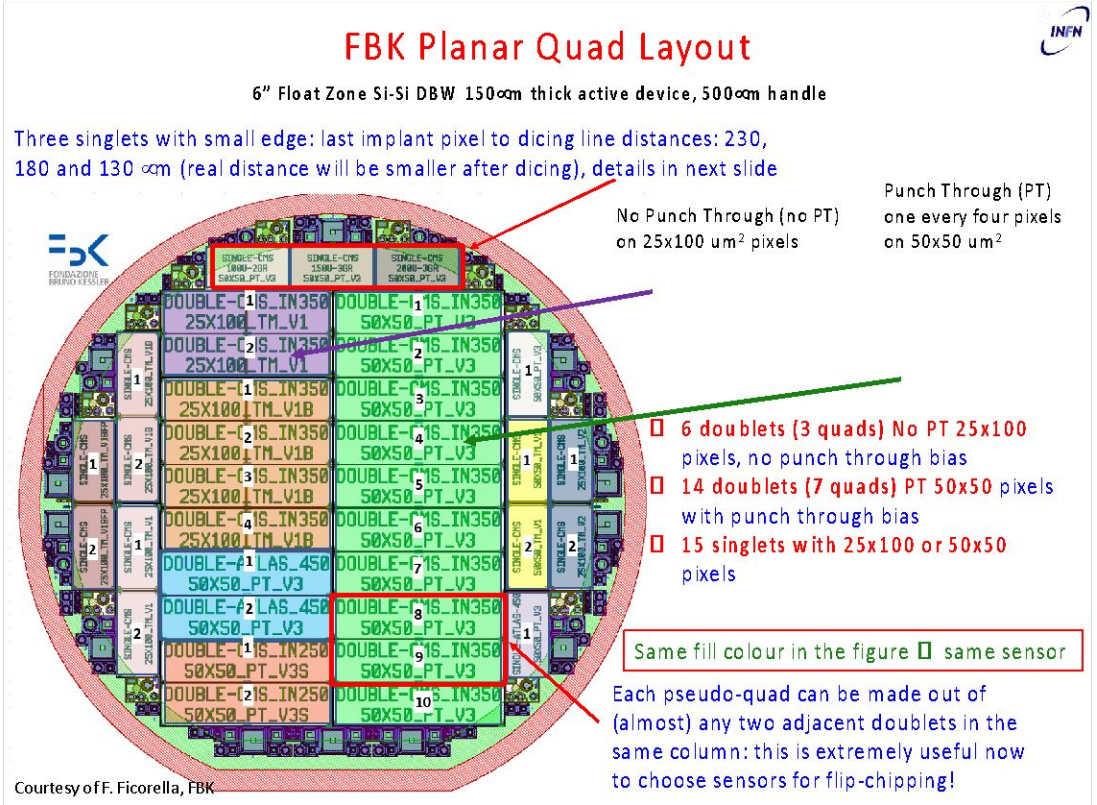
Production Over , good quality even being first design attempt

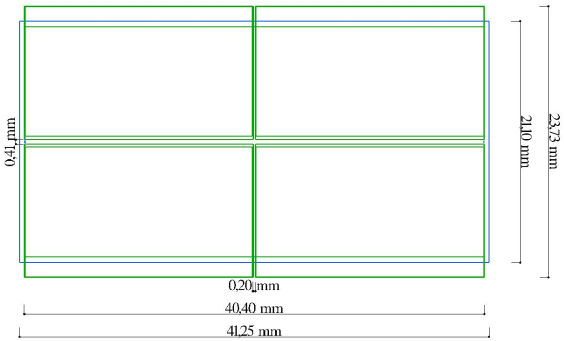
First prototype of 3D RD53a detectors processed by FBK with Stepper lithography

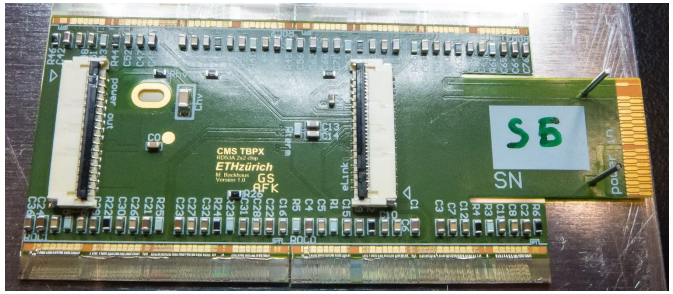
Design made by Pisa-Firenze-TIFPA

Process: running now in FBK

2019-2020 activity: assembly and testing of prototypes







Pixel Phase II: activity in Clean-room (2019-2020)

Qualification test stand

- Refurbishing of probe station, budget 2019 activities already started (PA200)
  - can extend to first part of 2020 (PA 150 project)
- Setting-up of x-ray qualification facility, order/budget this year
  - should be delivered within first half of 2020
- CO_2 cooling system (MARTA), available now, ready for procurement
  - should be delivered in second half 2020

Prototypes design

- Ladder equipped by Pseudo-quad detectors, mechanics structure designed and cooling pipes
  - TFD simulation and comparative tests on prototypes (using existing CO_2 system)
  - Jigs for assembly procedure (challenging and "new")

Prototypes qualification

- Test of prototypes at different assembly stage: wafers, Bare modules, single prototype and chain-on ladder of Pseudo-quads
  - Jigs for single prototype qualification

Setting-up of Pixel production chain

- Clean room equipment should be ready in 2021 for pre-production
  - setting-up of production chain and procedures starts in 2020.

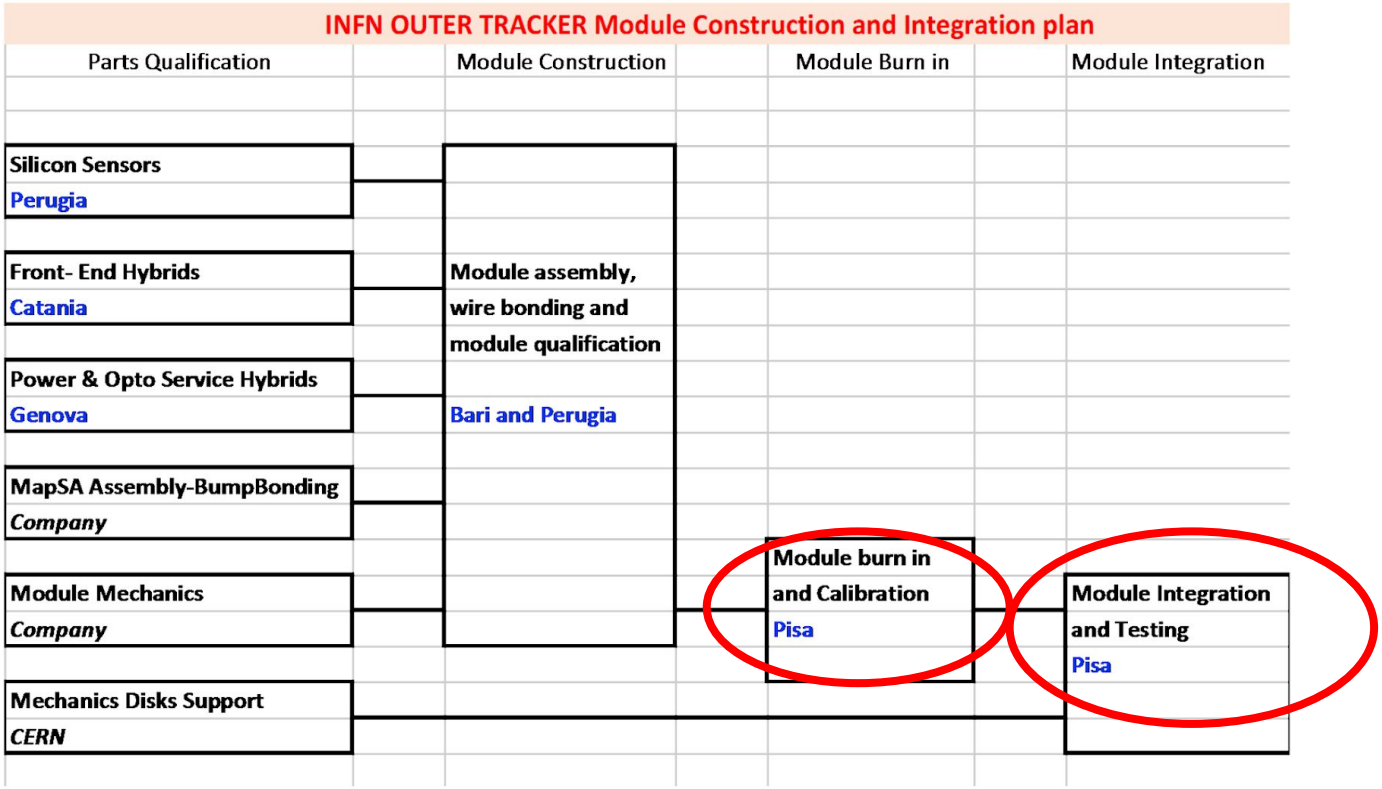
Fisici con specifiche responsabilita gia definite : Androsov, Bagliesi, Ciocci, Dell'Orso, Messineo, Venturi,……

Ingegneri: Basti, Bosi, Massa, Moggi, Raffaelli

Personale tecnico: Balestri,Ceccanti, Mammini, Petragnagni, Profeti, Ragonesi, Soldani

Stima personale tecnico necessario per le varie attivita': 3 FTE

INFN Outer Tracker construction plan



- **Module burn-in and calibration (1956 PS modules)**
- **Module integration on rings and testing (72 rings)**

Financial Contribution ≅10 MCHF
10% of Total Tracker Cost

Preparatione burn-in per moduli TBPS

- Chiller: already procured (Julabo A80)
  - Slightly better specs than the one proposed in FNAL (Julabo FP51)
    - Min temperature -80
    - Power at -40: 1KW (vs 260W of the FP51)
  - Could safely handle more than 10 modules

- Passive box:
  - FNAL design suggest to use a commercial freezer to just exploit the passive components (i.e. insulation) and suggest a model to buy
  - Need to find a similar model on the local market
    - Main constrain is the internal width (> 45cm for the FNAL/Princeton mechanics to fit)

Outer Tracker: To-do 2019

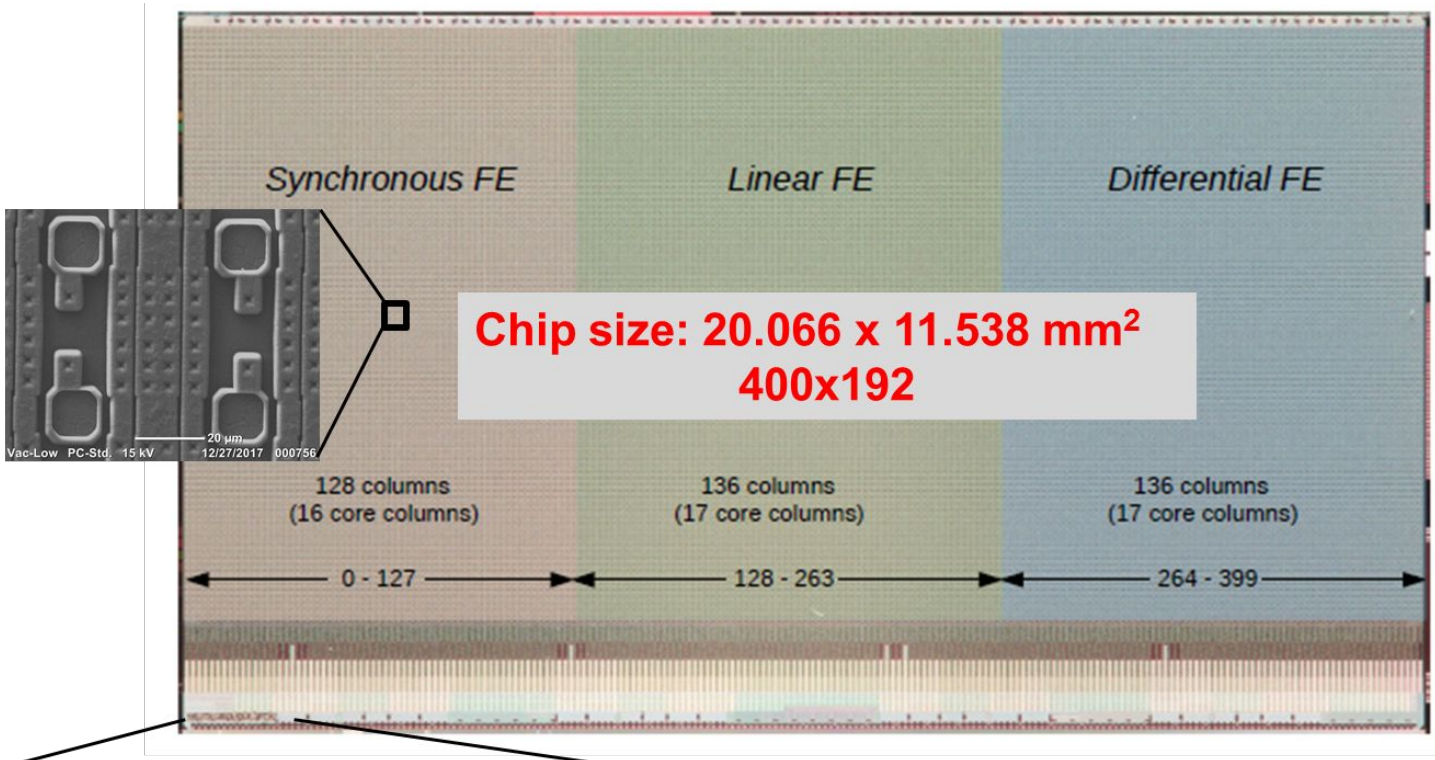
- Test the Julabo
  - Can we control it from ethernet?
  - Test thermal cycles on bypass?
    - Specs are different than FP51 so we may need to gain some local experience with it
- Find and procure a suitable freezer enclosure
  - Locate optimal position for feed-through holes
- Update the mechanic design to our freezer size and possibly increase to 8x2 modules
- Build the mechanical structure

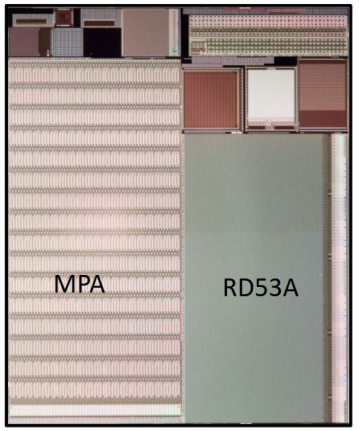
Spese previste 2019-20

- Julabo A80 -> 27kEUR (gia' comprato)
- Spese (assorbibili nei consumi di CMS)
  - Freezer : ~500-1000EUR
  - FNAL board: 1000 EUR
  - Other electronic parts : <500 EUR ??
  - Materiali per lavorazioni officina / struttura meccanica:
    - 4 piastre scambiatore alluminio con tubo di rame affogato ~ 100-200 EUR l'una
    - Lastre alluminio
    - ... altre voci da definire...
    - Si spera che la somma sia meno dei 10k proposti da Princeton

RD 53

RD53A demonstrator





MPW together with CMS tracker chips

- **Aug. 31, 2017: Submission**
- **Dec. 6, 2017: First chip test**
- **Mar. 15, 2018: 25 wafers ordered**
- **Apr. 13, 2018: First bump-bonded chip test**

Chip doc on CDS: http://cds.cern.ch/record/2287593

R. Beccherle, F. Morsani, G. Magazzù, K. Androsov, S. Poulios, F. Palla

Nuovo chip
RD53B

- Dedicated meeting LHCC, experiments, RD53
  - Convergence on how to make final chips: Same design/architecture (RD53B) mapped into two differently sized chips.
- Different pixel geometries for ATLAS and CMS requires different size of the chip.
- One common design team : Two submissions of the RD53B design framework with different matrix sizes
- All common and specific requirements implemented in a unique architecture
  - no difference in the chip bottom or in the core design

RD53B common design team (as RD53A)

Collaboration board chair:
Lino Demaria, Torino

Interface to experiments: Co-spokespersons
Jorgen Christiansen, CERN (CMS) , **Maurice Garcia-Sciveres, LBNL** (ATLAS)
- General organization, Funding, Specifications,

Experiment observers
Duccio Abbaneo, CERN (CMS) ,
Kevin Einsweiler, LBNL (ATLAS)

RD53 design framework for final pixel chips: Flavio Loddo, Bari; Tomas Hemperek, Bonn ~13 FTE

Floorplan/integration: 1 FTE
Flavio Loddo, Bari
- Pixel array, Bump pad, EOC, Power distribution, Bias distribution, Analog/digital isolation, Integration, Verification

Analog FEs with biasing: 2 FTE
Luigi Gaioni, Bari; Ennio Monteil, Torino; Amanda Krieger, LBNL
- Specification/performance, Interface, Analog isolation, simulation model, Abstract, Integration, Verification

Monitoring: 1 FTE
Mohsine Menouni, CPPM;
Francesco De Canio, Bergamo,
IP designers
- Specification/performance, Interface, Analog isolation, simulation model, Abstract, Integration, Verification

PAD frame: 1 FTE
Hans Krueger, Bonn
CDR/PLL: Piotr Rymaszewski, Bonn
High speed drv: Konstantinos Moustakas, Tianyang Wang, Bonn
Diff. IO: Gianluca Traversi, Bergamo

Digital: 6 FTE
Tomasz Hemperek, Bonn; Luca Pacher, Torino
- **Simulation Framework:**
  Sara Marconi, CERN; Herve Grabas, Santa Cruz
  – Framework, Hit generation/ import MC, Reference model / score board, Monitoring/verification tools, Readout rate estimations, Behavioural pixel chip, SEU injection.
- **Pixel array logic:**
  Sara Marconi, CERN; Andrea Paterno, Torino
  – FE interface, Latency buffer, Core/column bus
- **Digital chip bottom:**
  Roberto Beccherle, Pisa; Francesco Crescioli, LPNHE; Andrea di Salvo, Torino
  – Configuration, Control interface, Readout data format/protocol, Compression
- **Verification:**
  Sara Marconi, CERN; Herve Grabas, Santa Cruz;
  Attiq Rehman, Bergen
  SEU: Rafael Girona, Seville
  SET: Fernando Munoz Chavero, Seville
  Mixed signal: Luca Pacher, Torino;
  Aikaterini Papadopoulou, LBNL, Oliver Lemaire, LAL
  – Functional, SEU, Interfaces, specifications
- **Library cells:**
  DICE: Denis Fougeron, Mohsine Menouni, CPPM
  Compact latch: Dario Gnani, LBNL
  Timing characterization : Sandeep Miryala, FNL

Serial Power: 1.5 FTE
SLDO: Michael Karagounis, Andreas Stiller, Dortmund.
Bandgap: Gianluca Traversi, Francesco De Canio, Bergamo
Verification: Alvaro Luengo, Aragon; Stella Orfanelli, CERN
- Shunt-LDO integration, On-chip power distribution, Optimization for serial powering, System level power aspects, Power Verification

Design for testability: 0.5 FTE
Giusieppe De Robertis, Bari
- Scan path, BIST, production test patterns, Fault simulation, bump bonding testing

IPs:
Current DAC: Bari
Voltage DAC: Prague
ADC, mux, temp: CPMM
Power on reset: Seville
Ring osc: LAL
Analog buffer: RAL

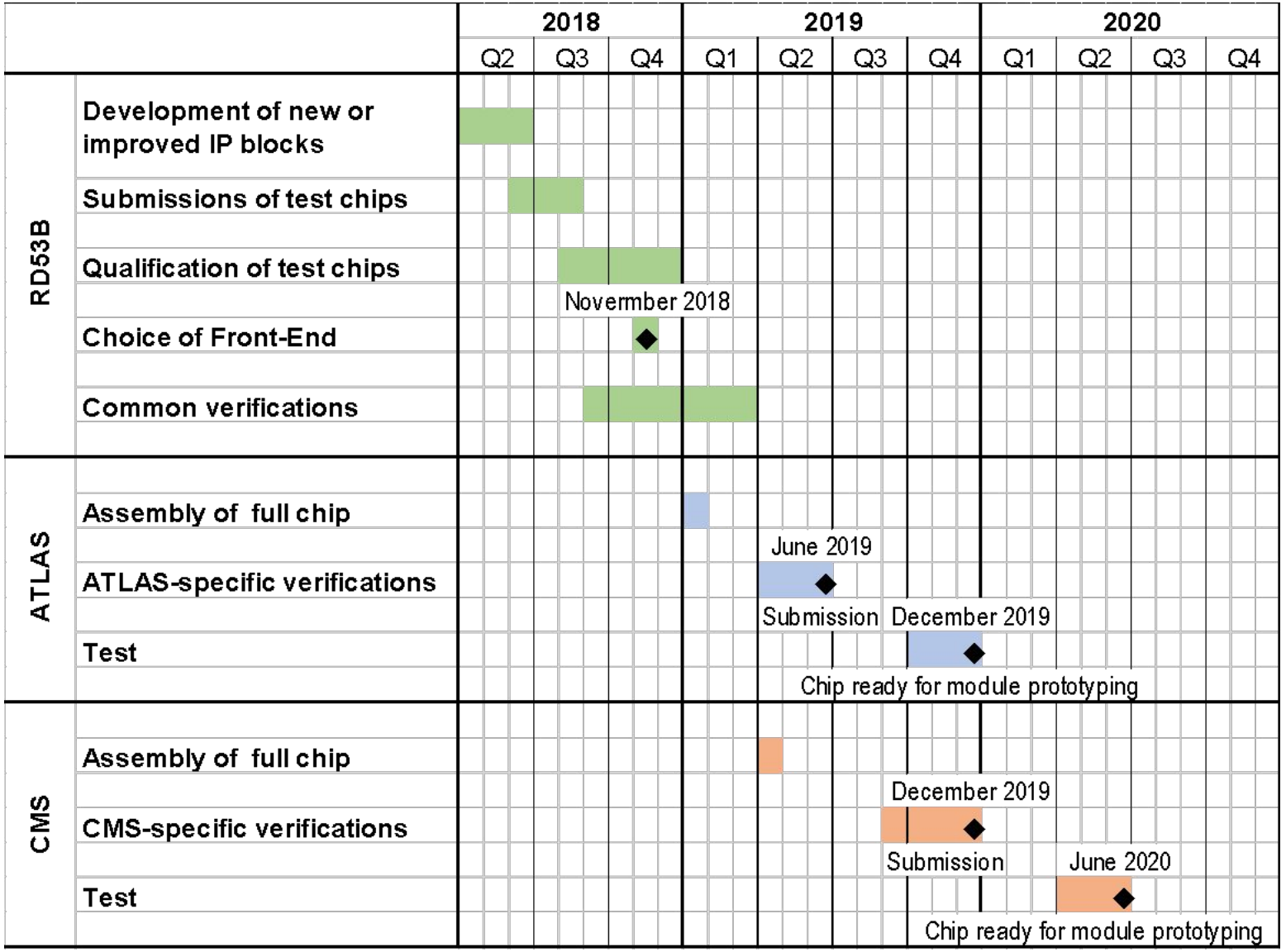
Support and services:
Tools, design kit: Wojciech Bialas, CERN
Repositories: Flavio Loddo, Bari;
Tomasz Hemperek, Bonn
Radiation model: Mohsine Menouni, CPPM

Testing: Timon Heim, LBNL 3 FTE in RD53 + ATLAS/CMS group
YARR system: Timon Heim, LBNL
BDAQ53 system: Marco Vogt, Michael Daas, Hans Krueger, Tomasz Hemperek, Bonn
Radiation test: Luis Miguel Jara Casas, CERN
Plus many ATLAS/CMS groups not formally part of RD53

Pixel sensor and bump-bonding:
Fabian Huegging, Bonn (ATLAS),
Georg Steinbrueck, Hamburg (CMS)

Names in bold: Member of RD53 management board

RD53B - Time schedule



Track Trigger

Introduction

Tracker Data Processing Systems interface the Phase-2 Tracker with CMS

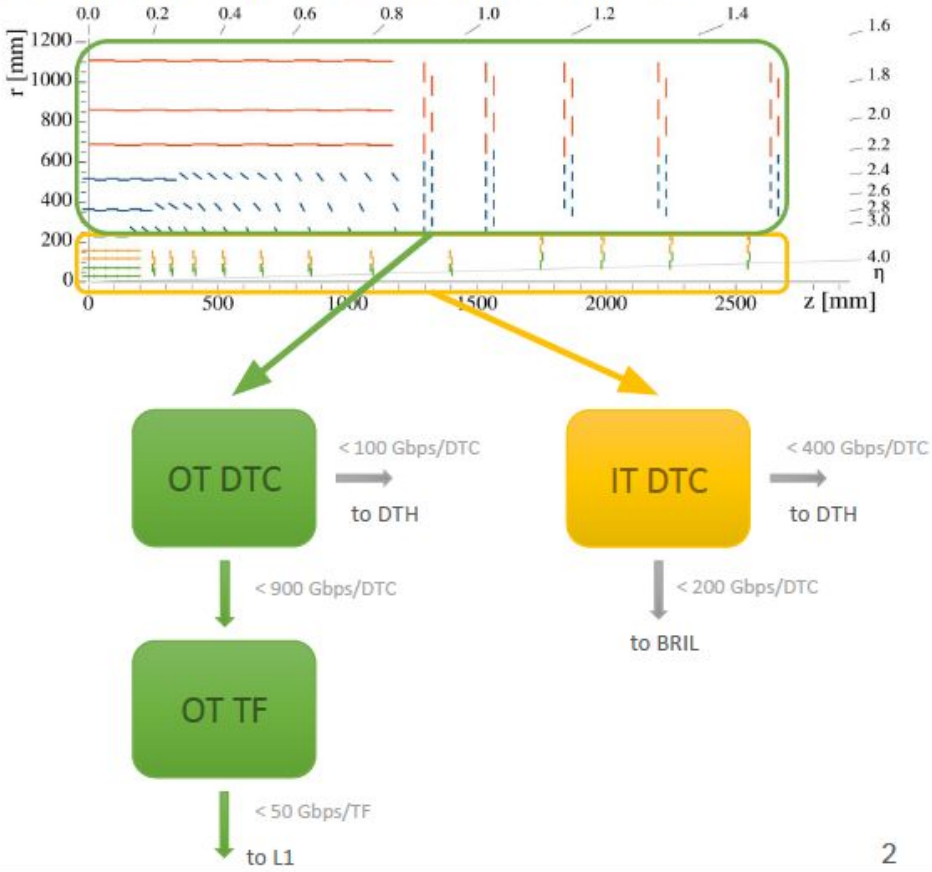
➔ DPS WG organizes development of the three Ph2 backend systems & related infrastructure

Outer Tracker

- DTC (Data, Trigger and Control) system
  - L1 data readout to CMS DAQ
  - Module configuration & control
  - Trigger (stub) data pre-processing
  - Stubs to Track Finding system
- TF (Track Finder) system
  - Track reconstruction from stubs at 40MHz
  - Tracks to L1 Trigger system

Inner Tracker

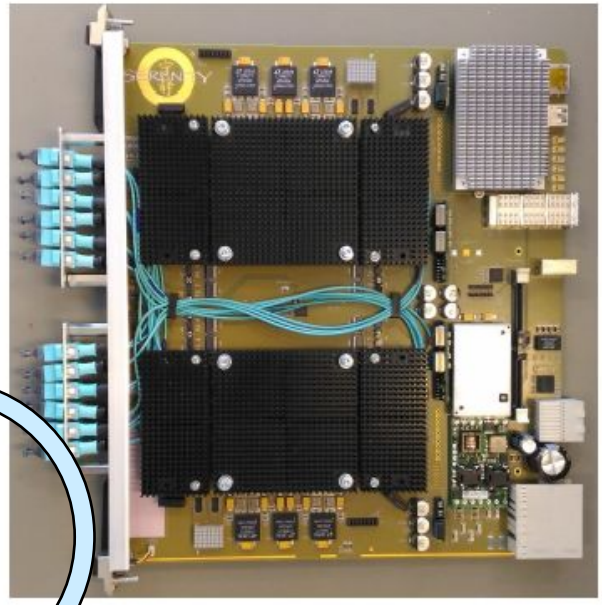
- DTC (Data, Trigger and Control) system
  - L1 data readout to CMS DAQ
  - Module configuration & control
  - Limited cluster data (from TEPX) to BRIL



Hardware & Infrastructure Firmware

Serenity Status

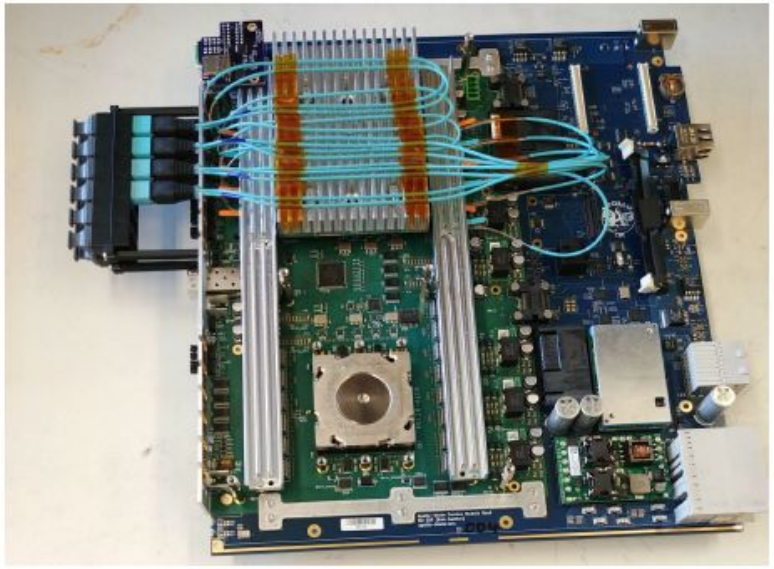
- 15 v1.1 boards produced, awaiting additional FPGA daughter-cards
- Well tested, thermal performance optimised, mature f/w & s/w for dev
- To-do : lpGBT validation, long term aging studies of interposer tech, v1.2?



Serenity Collaboration including Imperial, RAL, Pisa, KIT + many others]

Apollo service/command modules

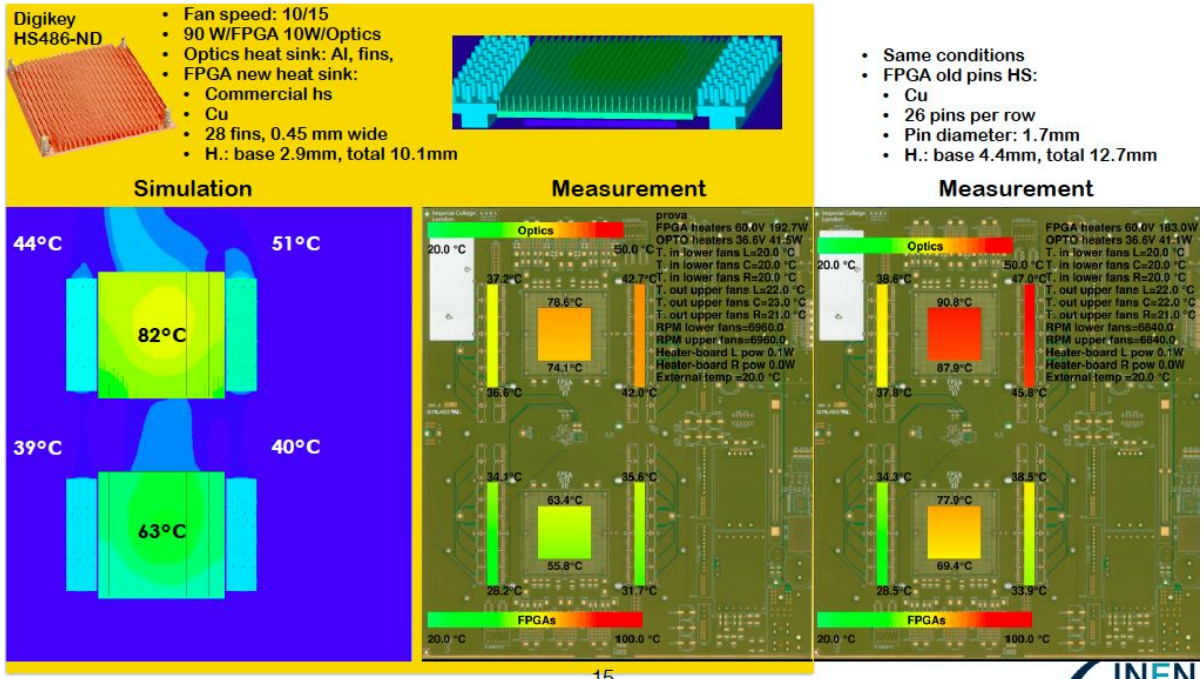
- Docking successful
- Power, IPMC, Zynq working in shelf
- Fireflies powered, prelim i2c testing complete
- VU7P & KU15P both programmed and running test f/w



[Cornell U., Boston U.]

Contributo di Pisa

- **Test alla TIF dei prototipi**
  - Responsabilità: UK + Pisa (F. Palla e G. Fedi)
- **Serenity ATCA board**
  - Studio del cooling e prototipizzazione dell'heat-sink della parte di FPGA (2x100 W) e della parte di connettività ottica (72 connettori Fireflies)



G. Fedi, P.G. Verdini

TIF Integration

B186/TIF Integration

Current setup

- 2 TIF blue racks
  - one for 2019 test-stand
  - one for long-term rack layout evaluation
- Brand new dual-star Schroff ATCA shelf w/ shelf manager
- 2kW temporary 48V PS, 9kW brand new 48V PS (under eval)
- F125 Ethernet Hubs
- Vadatech uTCA crate
- PC blade for system control/access
- PC blade for firmware building
- 1 Serenity v1 card

Next h/w to arrive:

- FC7 with TCDS mezzanines (this week)
- Apollo v1 (July)
- Serenity v1.1 (July)
- DTH-P1 (tbc)

[Imperial , Pisa, Northwestern, RAL]

Attività 2020

- **Continuazione del test alla TIF**
  - Sistema completo, inclusivo dell'algoritmo di trigger con simulazione di tutto il rivelatore
- **Costruzione e validazione dei prototipi**
  - Pisa:
    - dissipatori FPGA e ottica della board,
    - Contributo allo studio della meccanica della board
    - Interfaccia con la ditta di produzione (Somacis nelle Marche) per i test di validazione della board
- **Personale coinvolto: F. Palla, G. Fedi, P.G. Verdini, M. Piendibene, F. Bosi (+S. Donato??)**

Development and checkout of prototype boards	Oct 2017	Jul 2019
Development of OT BE specifications	Mar 2018	Jan 2020
Operation of integrated test system for prototype board validation	Jul 2019	May 2020
Prototype board readout of proto-modules	Jul 2019	May 2020
OT DP system specs defined	Jan 2020	Jan 2020
OT DP prototype boards validated	May 2020	May 2020
Development and checkout of pre-production boards	May 2020	Jan 2022

Pisa: riepilogo impegno Tracker Upgrade

- Inner Tracker (pixel) (2018-25)
  - Pixel R&D (2017-20)
  - Silicon sensor qualification (2021-24)
  - Bare Modules testing (2022-24)
    - 108 mod 1x2 ROC L1 BPIX
    - 1020 mod 1x2 ROC L2 Bpix (252) + R1&R2 EPIX (768) (da definire)
  - Struttura meccanica (x tutto inner tracker barrel) (2018-23)
- Outer Tracker (PS) (2018-24)
  - Module burn-in and calibration (1956 PS modules) (2020-23)
  - Module integration on rings and testing (72 rings) (2023-24)
- L1 Track Trigger electronics (2018-23)
  - Sviluppo FW
  - Test delle boards di trigger
    - Richiede laboratorio "grigio" con crate ATCA
- RD53 chip development
- Safety system & DCS (Detector Control System)
  - Sviluppo prevalentemente al CERN

Personale upgrade production (draft documento CTS) 2018-25

	Profile	2018	2019	2020	2021	2022	2023	2024	2025	ToT	Task
PISA											
Azzurri Paolo	RI	0.05	0.05	0.1	0.2	0.3	0.3	0.3		1.3	OT 7
Bagliesi Giuseppe	PR	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.4	2.6	OT 6,7
Bianchini Lorenzo	RI	0.1	0.1	0.2	0.3	0.3	0.3	0.3	0.3	1.9	OT 7
Boccali Tommaso	RI	0.05	0.05	0.3	0.4	0.4	0.4	0.4	0.4	2.4	OT 6,7,9
Ciocci Maria Agnese	PA	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4	2.6	IT 1
Dell'Orso Roberto	PR	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	3.0	IT 1, 8, 16
Giassi Alessandro	RI	0.2	0.2	0.3	0.4	0.4	0.4	0.4	0.4	2.7	OT 7
Ligabue Franco	RU	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4	2.6	OT 7
Messineo Alberto	PA	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	3.0	IT 1, 16
Palla Fabrizio	DR	0.25	0.3	0.3	0.3	0.4	0.4	0.4	0.4	2.8	OT 10
Rizzi Andrea	PA	0.15	0.25	0.3	0.4	0.4	0.4	0.4	0.4	2.7	OT 6,7,9
Rolandi Luigi	PO	0.05	0.05	0.1	0.1	0.1				0.4	OT 7
Spagnolo Paolo	RI	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	1.8	IT 1
Tenchini Roberto	DR	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.4	2.6	OT 7
Venturi Andrea	PR	0.2	0.2	0.3	0.3	0.4	0.5	0.8	0.8	3.5	OT 6,7
Verdini Piero Giorgio	PR	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	3.0	OT 11; IT 11
Basti Andrea	TE mecc	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	3.1	IT 8; OT 8
Beccherle Roberto	TE ele	0.75	1	1	0.7	0.5	0.3	0.2	0.1	4.6	IT 2
Magazzu' Guido	PT ele	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.2	2.9	OT 10
Moggi Andrea	TE mecc	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	3.2	IT 8; OT 8
Piendibene Marco	TE ele	0.1	0.3	0.3	0.4	0.4	0.45	0.5	0.2	2.7	OT 10
Raffaelli Fabrizio	DT mecc	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	2.4	IT 8; OT 8
Tecnico 1	Tec				0.6	0.6	0.6			1.8	IT 1
Tecnico 2	Tec				0.6	0.6	0.6			1.8	IT 16
Tecnico 3	Tec				0.6	0.6	0.6			1.8	OT 6
Tecnico 4	Tec					0.8	0.8	0.8		2.4	OT 7
Post Doc 1	AdR	0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.5	3.6	tbd
Post Doc 2	AdR	0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.5	3.6	tbd
Dottorando 1	PhD		0.3	0.3	0.3	0.3	0.3	0.3	0.3	2.1	tbd
Dottorando 2	PhD		0.3	0.3	0.3	0.3	0.3	0.3	0.3	2.1	tbd
Dottorando 3	PhD		0.3	0.3	0.3	0.3	0.3	0.3	0.3	2.1	tbd
request to INFN	AdR			0.5	1	1	0.5			3.0	OT 10
request to INFN	AdR				1	1				2.0	IT 1
request to INFN	AdR							1	1	2.0	OT 9
request to INFN	AdR				1	1	1			3.0	OT 6
request to INFN	AdR					1	1	1		3.0	OT 7
request to INFN	AT			1	1	1				3.0	IT 8
request to INFN	AT				1	1	1			3.0	IT 16
TOTAL FTE/year		5.4	7.3	10.6	16.5	18.6	16.2	13.1	10.3		

TASK	#
Sensor Quality Control	1
ASIC's Quality Control	2
FE Hybrid Quality Cont	3
On-Detector Service El	4
Module Production	5
Module Burn-in	6
Integration of sub-ass	7
Mechanics	8
DAQ software	9
L1 track finder	10
Safety System	11
Power system	12
Power cables	13
Commissioning	14
Installation	15
Bump bonding quality	16

Profile	Label
Ricercatore INFN	RI
Ricercatore CNR	RC
Ricercatore Universitar	RU
Primo Ricercatore INF	PR
Professore Associato	PA
Dirigente Ricercatore	DR
Tecnologo	TE
Primo Tecnologo	PT
Dirigente Tecnologo	DT
Tecnico	Tec
Assegno Tecnologico	AT
Assegno di Ricerca	AdR

Richieste strumentazione/infrastrutture

Infrastructures requested to INFN

The infrastructures requested to INFN for the CMS Tracker upgrade are listed in Figure 30 are intended to either complement or renovate the equipment of the participating institutes; despite most of them are explicitly thought in terms of Tracker activities, it is largely foreseeable a future usage.

Description	Location	Comments and Motivations	Task associated	Cost [ke]	INFN Contrib. [kE]	Year
Wire bonding machine	BARI	Replacement of old machine. Already bought	OT 5	150	100	2017
Wire bonding pull tester	BARI	New for wire bonding testing	OT 5	8,5	8,5	2018
Upgrade for Module assembly	BARI	Glue dispenser robot with volumetric control	OT 5	26	26	2019
Climatic chamber	CATANIA	For OT hybrid burn-in	OT 3	40	40	2019
Wire bonding machine	FIRENZE	Replacement of old machine	IT 5	192	112	2017
Probe station	FIRENZE	Silicon sensor receptiom test	IT 5	100	50	2019
Wire bonding machine	PERUGIA	Replacement of old machine	OT 5	150	150	2018
3D Measuring machine	PERUGIA	Update of machine for module survey	OT 5	20	20	2018
8" Probe station	PERUGIA	Replacement of old machine for sensor QA	OT 1	250	250	2018
Upgrade for Module assembly	PERUGIA	Glue dispenser robot with volumetric control	OT 5	26	26	2019
Probe station maintenance	PISA	Pixel Silicon sensor Qualification center	IT 1	35	35	2018
X-ray test station	PISA	For diagnostic of bump-bonding connection and calibration	OT 7	50	50	2018
Termo-camera	PISA	Verification during OT module assemb ly	OT 7	27	27	2018
Cold Box	PISA	Burn-in of OT modules	OT 7	25	20	2019
3D Measuring machine	PISA	Module integration on OT rings	OT 7	60	35	2018
Stocking of mechanical structure	PISA	To store and manipulate OT rings	OT 7	30	30	2019
Climatic chamber	PISA	For testing of sub-assembly of OT rings	OT 7	112	112	2018
12" probe station	TORINO	New for wafer level testing of IT ASIC	IT 2	480	200	2018
Cold box	TORINO	Burn-in of IT modules	IT 7	25	20	2019
X-ray test station	TORINO	For diagnostic and final calibration of IT modules	IT 7	50	50	2018
			Total	1857	1361,5	

N.B. Espansione camere pulite finanziata e in corso

Tier2 Pisa: stato e richieste

Richieste 2020 Tier2

- Italia: 13% di CMS
- 1 TBN = 140€
- 1 HS06 = 10€
- **Si aggiunge un "gettone" del 20%*Assegnaz.(2018) per le CPU di LNL, Pisa, Roma per recuperare extra-costo acquisto CPU**

N.B. incontro con referee e' stato a Napoli 12 e 13 giugno, numeri provvisori
Recupero gia' nel 2020 d-pledge 2019 che era stato ritardato al 2021

Recup. pledge	Fraz. pledge PON													
1	0.25													
	recupero D-pledge 2019 (kHS06)	recupero D-pledge 2019 (TBN)	Dismissioni 2019 (not granted)	Dismissioni 2020	Totale dismissioni CPU	Dismisioni 2020 disco	Totale CPU	Totale disco	CPU (euro)	Disco (euro)	Recupero pledges CPU 2018 (Eur)	Rete	Server	Totale (euro)
			kHS06	kHS06	kHS06	TBN								
Bari	2.75	217.5	0.00	4.6	4.60	640	7.35	857.5	73500	120050		5206.25	6774.25	205530.5
Pisa	2.75	217.5	2.55	4.75	7.30	120	10.05	337.5	100500	47250	8400	4196.25	5171.25	165517.5
Legnaro	2.75	217.5	4.05	6.9	10.95	704	13.70	921.5	137000	129010	18800	7335.25	9310.35	301455.6
Roma1	2.75	217.5	2.45	5	7.45	0	10.20	217.5	102000	30450	10600	3821.25	4635.75	151507
Totali	11	870	9.05	21.25	30.30	1464	41.30	2334	413000	326760	37800	20559	25891.6	824010.6

N.B. Bari viene finanziato tramite PON, quindi i numeri sono «virtuali» per la CSN1

Pisa: responsabilita' CMS 2020

A	B	C	D	E	F
NOME	**LIVELLO**	**SEDE**	**RUOLO**	**Commento**	**Mesi Uomo**
Tommaso Boccali	L2	PI	Computing steering group		4
Tommaso Boccali	L2	PI	Ecom2X convener		4
Giuseppe Bagliesi	L2	PI	Facilities Services convener, Resp. Nazionale Comp., delegato nazionale nel CRB		5
Enrico Mazzoni	L3	PI	Resp. tier2 Pisa		2
Paolo Azzurri	L2	PI	SMP Convener		4
Gacomo Fedi	L3	PI	BPH – Spectr.&Properties convener		2
Lorenzo Bianchini	L3	PI	BPH – SMP - V convener		2
Konstantin Androsov	L3	PI	tauID trigger convener		2
Piero Giorgio Verdini	L3	PI	TK safety coordinator		2
Piero Giorgio Verdini	L3	PI	TK DCS coordinator		1
Fabrizio Palla	L3	PI	LHC HF working group convener		2
TOTALE					30

CMS Pisa: Anagrafica 2020

	FISICI	Contratto	Qualifica	% Totale
1	Androsov Konstantin	Associato	Post-doc	100
1	Azzurri Paolo	Dipendente	Ricercatore	90
1	Bagliesi Giuseppe	Dipendente	Primo Ricercatore	95
1	Bertacchi Valerio	Associato	Perfezionando SNS	100
1	Bianchini Lorenzo	Dipendente	Ricercatore	90
1	Boccali Tommaso	Dipendente	Primo Ricercatore	100
1	Castaldi Rino	Associato (anz.)	Dirigente di Ricerca	0
1	Chowdhury Suvankar	Associato	Borsista SNS	100
1	Ciocci Maria Agnese	Associato	Prof. Associato	90
1	Dell'Orso Roberto	Dipendente	Primo Ricercatore	90
1	Di Domenico Maria Rosaria	Associata	Dottoranda Siena	100
1	Donato Silvio	Dipendente	Ricercatore	100
1	Fedi Giacomo	Associato	Borsista	100
1	Giannini Leonardo	Associato	Perfezionando SNS	100
1	Giassi Alessandro	Dipendente	Ricercatore	100
1	Grippo Maria Teresa	Associato	Post-doc	100
1	Ligabue Franco	Associato	Ricercatore	95
1	Manca Elisabetta	Associata	Perfezionanda SNS	100
1	Mandorli Giulio	Associato	Perfezionando SNS	100
1	Messineo Alberto	Associato	Prof. Associato	80
1	Negin Shafiei	Associata	Dottoranda	100
1	Palla Fabrizio	Dipendente	Dirigente di Ricerca	75
1	Parolia Shubhi	Associata	Dottoranda	100
1	Rizzi Andrea	Associato	Prof. Associato	100
1	Rolandi Luigi	Associato	Prof. Ord. SNS	85
0	Scribano Angelo	Associato (anz.)	Prof. Ord. Siena	0
1	Spagnolo Paolo	Dipendente	Primo Ricercatore	80
1	Tenchini Roberto	Dipendente	Dirigente di Ricerca	90
1	Tonelli Guido Emilio	Associato	Prof. Ordinario	90
0	Turini Nicola	Associato	Ricercatore	0
1	Venturi Andrea	Dipendente	Primo Ricercatore	100
1	Verdini Piero Giorgio	Dipendente	Primo Ricercatore	90
30				
Totale: CMS Ricercatori				**27.4**

	TECNOLOGI	Contratto	Qualifica	% Totale
1	Arezzini Silvia	Dipendente	Primo Tecnologo	30
1	Basti Andrea	Associato	Tecnologo	30
	Bosi Filippo	Dipendente	Tecn.	0
1	Beccherle Roberto	Dipendente	Tecnologo	100
1	Ciampa Alberto	Dipendente	Primo Tecnologo	50
1	Magazzu' Guido	Dipendente	Primo Tecnologo	30
1	Massa Maurizio	Dipendente	Tecnologo	20
1	Mazzoni Enrico	Dipendente	Tecnologo	55
1	Moggi Andrea	Dipendente	Tecnologo	30
1	Morsani Fabio	Dipendente	Primo Tecnologo	20
1	Piendibene Marco	Associato	Ingegnere unipi	20
1	Raffaelli Fabrizio	Dipendente	Dir. Tecnologo	20
11				
Totale tecnologi				**4.05**

Fase2 → Ric. 6.6 + Tecnol. 2.7 = 9.3 FTE

DRAFT!

Gran totale richieste finanziarie

DRAFT!

	Consumi k€
Metabolismo	47.175
Macchine CERN	8
RD50	2
RD53	2
Camere Pulite	5
Totale Consumi	**64.175**

	Missioni k€
Metabolismo ME	119.51
Metabolismo MI	31.45
Responsabilita'	114
EPR	102.6
Fase2 e test beam	34.2
Totale Missioni	**401.76**

	Tier2	
CPU	100.5	rimpiazzi e nuovi acquisti: 10.05 kHS06
CPU	8.4	recupero exrtra costo CPU 2018
Storage	47.5	rimpiazzi e nuovi acquisti: 337.5 TBN
Server	5.2	server per storage + CPU
Rete	4.2	infrastrutture rete per storage+CPU, richieste tramite CCR
Totale Tier2	**165.8**	**(di cui 4.2 chiesti tramite CCR)**

FASE 2		
	Consumi	
IT	20	S.J Tooling per realizzazione prototipi L4, L1
IT	5	meccanica per test moduli QUAD prodotti
IT	30	S.J. Bump Bonding per full size 3D sensors
	Inventariabile	
OT kE	18	PS SY4527B + booster + 1 A7435 + 2 A2519
	CORE	
OT	18.2	CORE Tracker/1.1.5 OT Infrastructure/ Module Burn set-up
OT	70	CORE Tracker/1.1.5 OT Infrastructure/ Sub-struct integr: 300W CO2 Cooling Plant, di cui 20 SJ

Backup

heterogeneous framework HLT

Very promising proposal, that can provide several benefits to HLT and to the CMS

Transition to a heterogeneous framework and reconstruction software, and synergy with HPC centres

But is not committing CMS for the future

within the next 3-5 years other approaches may become realistic

other accelerators: other GPUs, FPGAs, TPUs

other solutions: dedicated nodes, remote offloading, are already being studied within CMS

Plan is to identify the time line, milestones and criteria to take the final decision

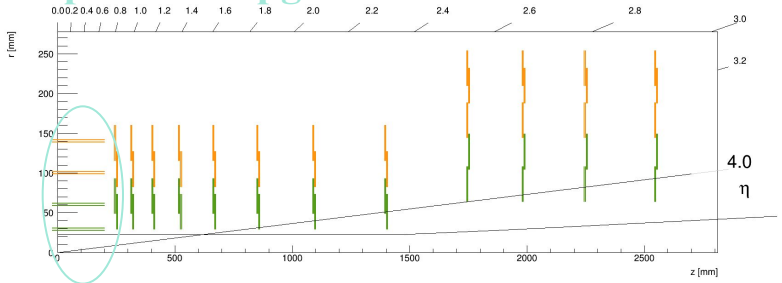
First to invest resources in the development (from R&D to Engineering)

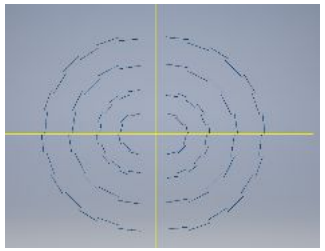
And finally, a little before 2021, to purchase the HW

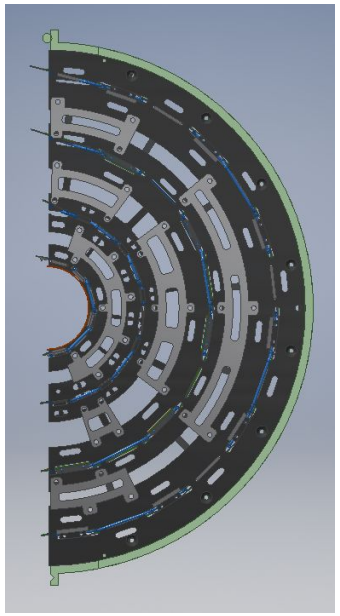
BACKUP
MECCANICA

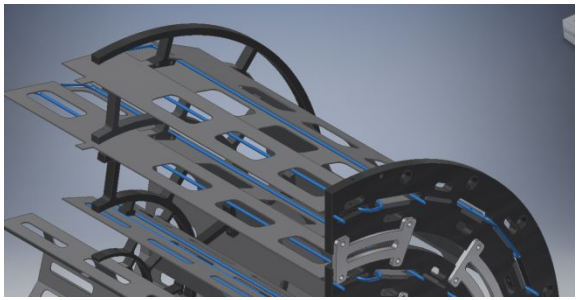
- pictures

CMS phase-II Upgrade - Inner Pixel Detector

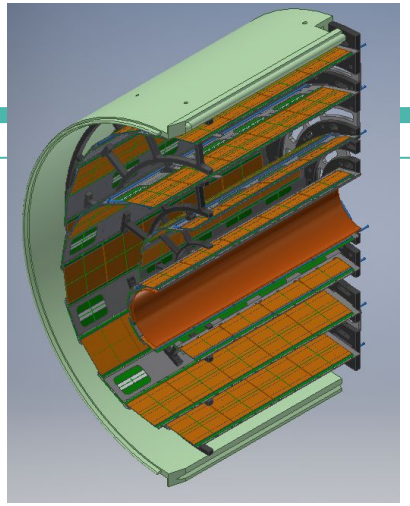


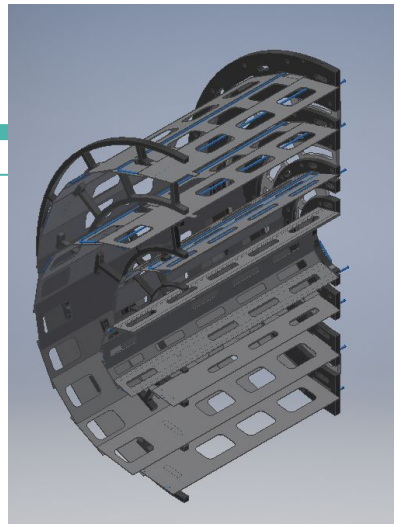


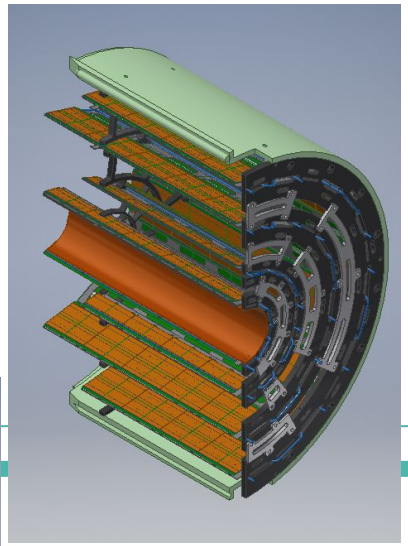


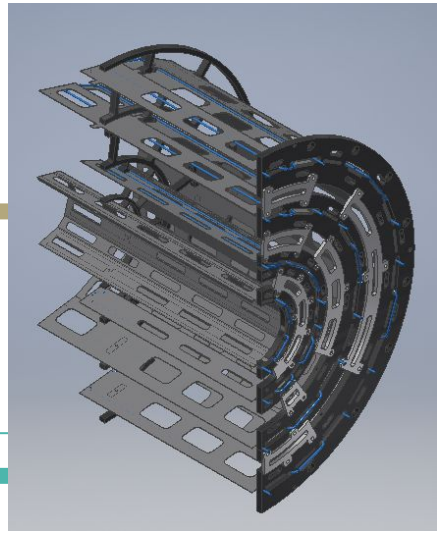


CMS phase-II TBPX detector

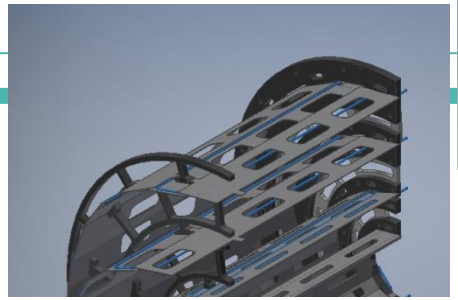


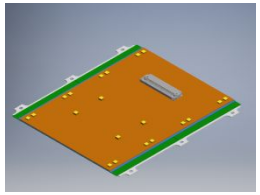


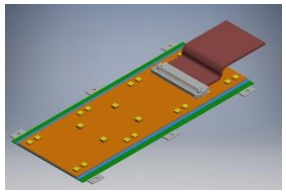




- Pixel detector.
- 4 Layers.
- Raggi: 29,60,102,143 mm
- Lunghezza tot. = +/-200 mm
- 4 Sottostrutture.
- 2 tipi di moduli: (1x2) e (2x2) chips.
- 324 moduli (1x2)
- 432 moduli (2x2)





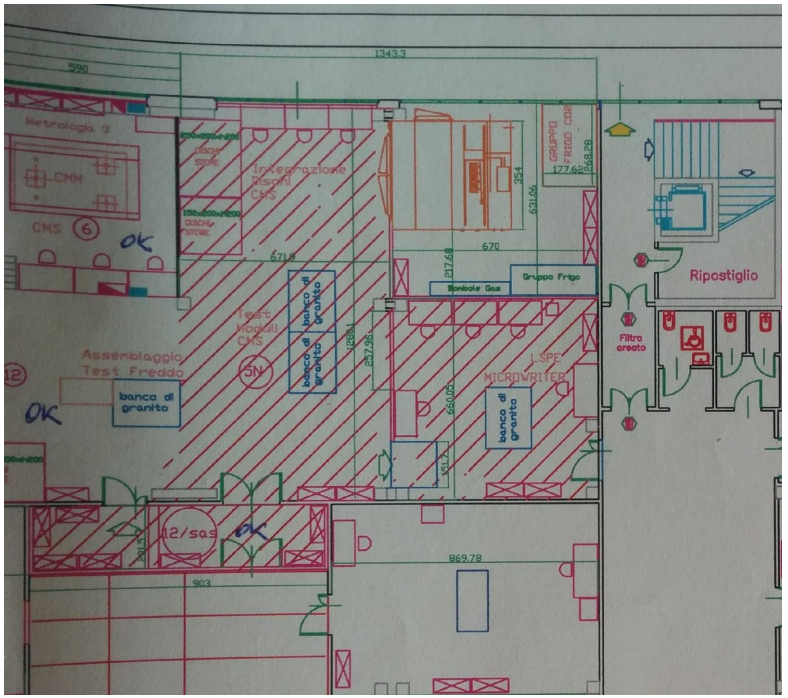


BACKUP RD53

Backup Pixel

Espansione clean room

- **L'attuale configurazione e gli spazi nella clean room non sono adeguati per la fase di costruzione dell'upgrade OT di fase-2 di CMS**
- **P**reventivo dettagliato **in arrivo (o gia' disponibile)**
  - Capitolato preparato da Filippo
- Spostamento dell'area grigia (ingresso) all'interno dell'atrio
  - Secondo ingresso con doppia porta (per accesso rings)
- Camera climatica 3m x 3m
  - Spazio nel retro per cooling CO2 (sistema Marta 300 W - 1m x 1m circa)
- **Cooling a CO_2 (-40 C)**
- CMS non necessita di sistema di misura con precisione del micron (refurbishing CMM S.Piero)
  - Contatti con la ditta Hexagon per l'acquisto di un braccio articolato con testa intercambiabile (precisione 50-100 micron)
- Possibili sinergie con dipartimento e Universita'
  - Investimenti su macchinari di interesse generale (bando unipi grandi strumentazioni)



Fusione CMS - Totem II

TOTEM-CMS-CERN MoU

- Dal punto di vista dei M&O A, l'MoU stabilisce che, per le founding agency, nulla cambi rispetto alla attuale situazione. Quindi prevede che, per i nuovi membri provenienti da TOTEM, non ci sia trasferimento di fondi a CMS nel biennio 2018-2019.
- Mentre per il 2020 e 2021, prevede che sia TOTEM stesso a trasferire a CMS i fondi nella percentuale del 25% e 50% rispettivamente. Questo per garantire a TOTEM le risorse per preparare ed effettuare l'ultima presa dati a 14TeV.
- Dal 2022, il 100% dei M&O A verranno trasferiti direttamente a CMS, dalle founding agency, dato che l'ultimo anno di presa dati di TOTEM si prevede sia il 2021.

N.B. Vedi talk di Nicola Turini Per maggiori dettagli

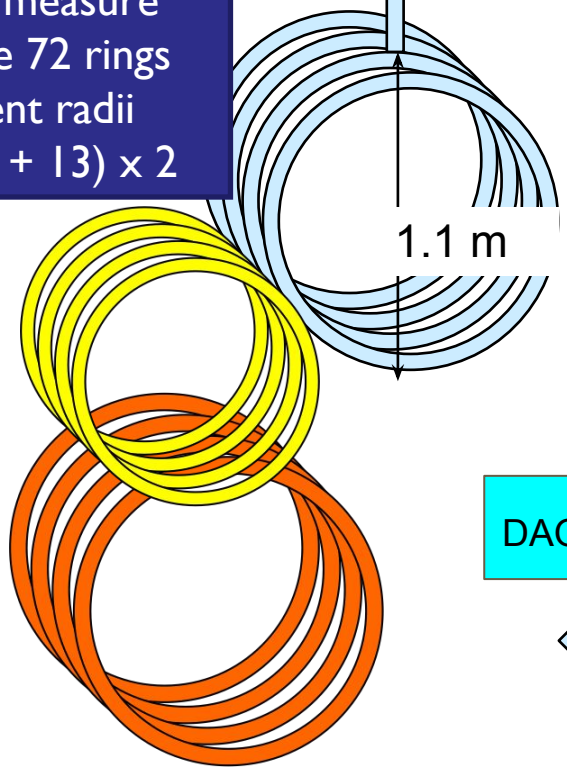
Outer Tracker: workflow

TBPS Typical flow

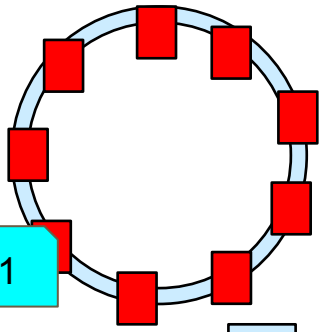
2 teams on item 2
1 team on item 3
Working simultaneously

1

Receive, measure and store 72 rings of different radii (11 + 12 + 13) x 2



DAQ & PS 1

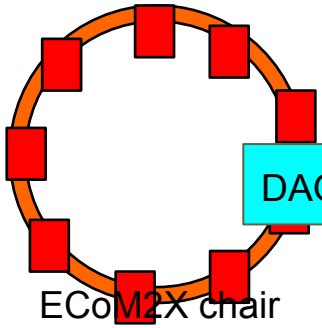


2

Mount, cable and test individually each of the Silicon pT-modules on it (front and back)

2 teams working simultaneously

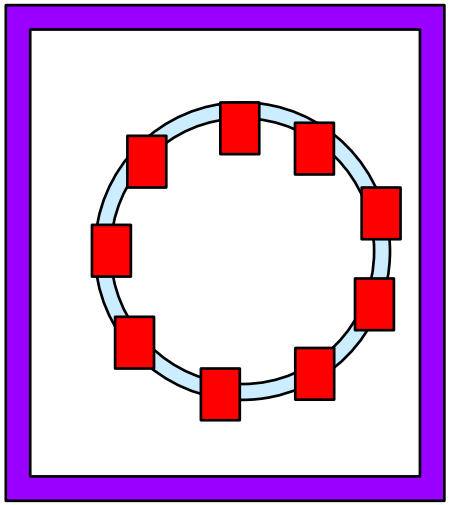
DAQ & PS 2



ECoM2X chair

3

Burn-in the assembled rings (one at at the time) in the cold room.
Full ring test (implies DAQ crate and power racks)



DAQ & PS 3

4

If test is good store the ring
If not rework and retest