R&D Proposals for ATLAS Phase II

CSN 1 – 21 maggio 2014

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on behalf of ATLAS-I

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1) Track Trigger Update (1)

ATLAS trigger per fase 2:

++purezza a parità di efficienza

(es.: soglia e/μ singolo ~20 GeV)

→ fattore 4 di riduzione rate:

L0 (←fase 1 L1): 500 kHz (→ 1-2 MHz)

100 kHz Jet/MET + 400 kHz leptoni/fotoni

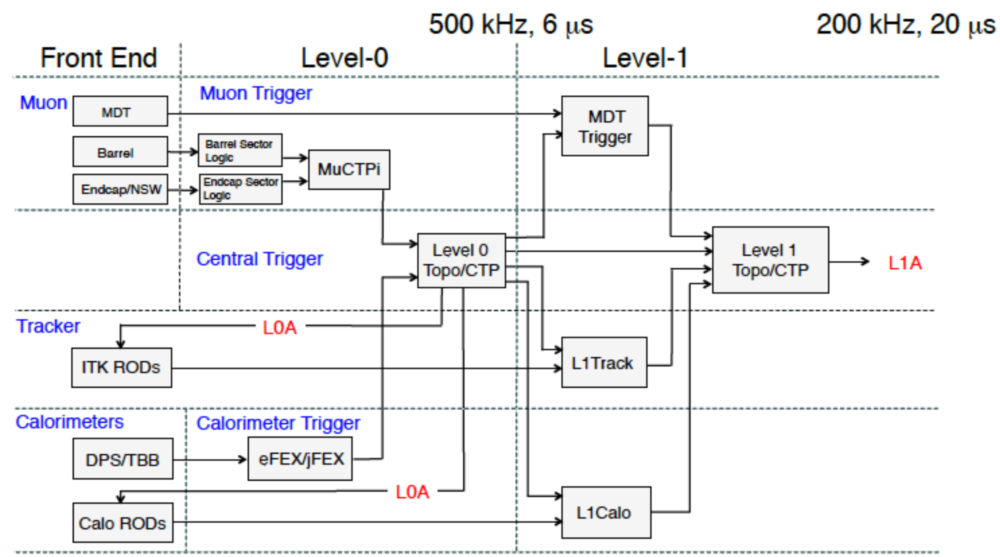
L1 (L0 + TT): 200 kHz (→ 400 kHz)

100 kHz Jet/MET + 100 kHz leptoni/fotoni

Track Trigger (2)

Trigger

- già prima di fase II:
  - L1 topological trigger
  - L1 calo trigger ad alta precisione
  - Fast tracking a L2



Implementazione

- L0 rate 500kHz (1MHz)
- Regional readout (~10% rivelatore)
- Minimum p_T ~5 GeV
- Full pixel + strip tracking

Track Trigger (3)

- Breakdown del progetto:
  - WP1: simulazione/sviluppo algoritmi
  - WP2: banda passante: dimostratore ATCA (FPGA Mezzanine Card)
  - WP3: chip memoria associativa
  - WP4: packaging (1 AM + 1 FPGA, integrati direttamente su di uno stesso "pacchetto")

WP1 & WP2 → +CMS; WP3 & WP4 → +ATLAS

Track Trigger (4)

- Punti specifici per ATLAS (domande referee):
  - Interferenze distruttive con FTK → vedi profilo temporale impegno: basso nel 2015, a regime nel 2016

    (sinergia, non competizione)
  - Fuori dall'Italia non vediamo progetti alternativi né conflitti veri, sviluppi tutti ampiamente sinergici
  - Possibili Call/FIRB di Gr. V (meglio FIRB):
    - Parte di WP3 e/o WP4

2) Tracker Update (1)

- Riporto solo le risposte alle questioni sollevate dai referee:
  - HV-CMOS → call/finanziamento in Gr. V
    - Corretto ma ... run STM 2014 (160 nm BCD8) ?
      - chiederemmo finanziamento one-shot ~50 k€ s.j. (per run STM) [era 20 kE] + 12.5 k€ (FE + assemblaggio)
    - In alternativa (no STM): co-partecipazione a iniziative di colleghi di altri paesi [20 kE]
    - Interesse anche da parte di Lfoundry [per ibridizzazione]

* Iniziativa recente ma molto interessante *

Tracker (2)

- Competizione e/o collaborazione ?
  - Entrambe le cose:
    - collaborazione con gruppi stranieri su tutti gli item
    - contatti con industrie nazionali su sensori e ibridizzazione
  - Priorità richieste 2014:

    1) sensori 3D: 64kE (già assegnati)

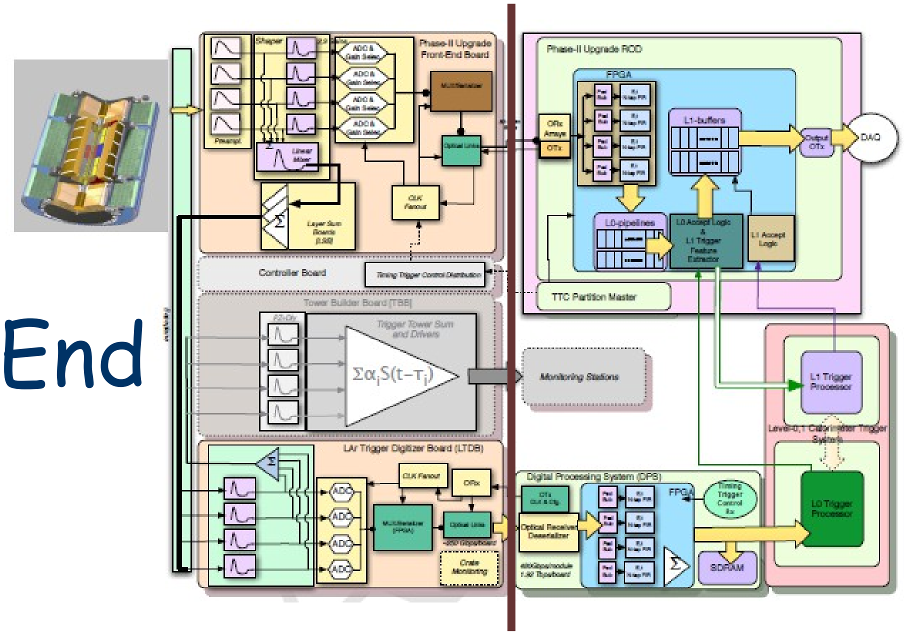
    2) HV/HR: 12.5k, BB: 37.5k + 6k(50%), MOD: 11k, Cooling: 20k

    → attività in corso!

    3) HV/HR: run 20k/50kE→ 2015 (o fine anno!) ok

3) LAr (1)

Front-End



Back-End

- all data, for both trigger and readout, off at 40 MHz
  - Free-running readout of all 182k channels (→ total BW 140 Tbps)
  - Improved, more complex trigger algorithms
  - Off-detector buffers and pipelines for increased trigger latency or purely software based triggers
- → both Front-End and Back-End must change

LAr (2)

- Interessi del gruppo di Milano:

    1) low-voltage power distribution architecture (in continuità con quanto fatto per fase I)

    2) triggering

1) power distribution

- Fase I: 7 diversi livelli di tensione dal main converter

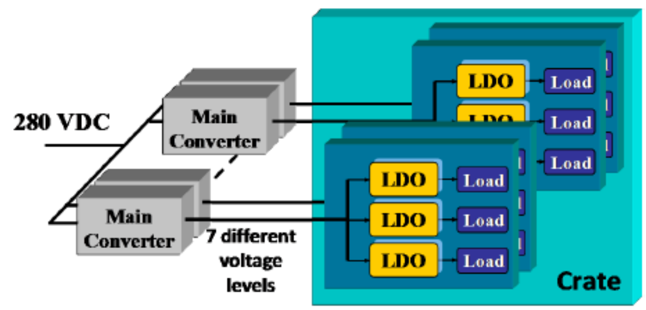


Figure 2. Present implementation of the ATLAS LAr calorimeters power supply network.

- Fase II: un singolo livello di tensione a 12 o 24 V (on-board ni-POL per generare tutti i livelli necessari)

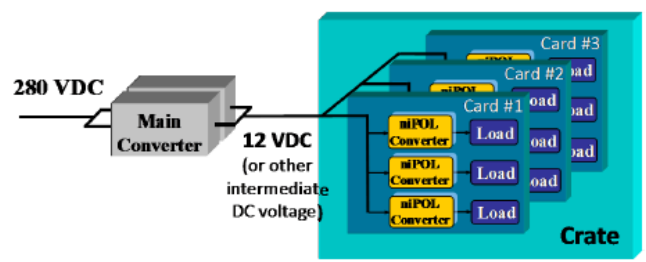


Figure 3. Proposed power supply distribution system (niPOL = non-isolated Point of Load).

LAr LV Power Distribution (1)

- Much larger effort for Phase II powering (than for Phase I)
- 24 LTDBs -> 1534 FEB2s
- FEB2s more complex layout (lower voltages with high precision)
- 58 LVPS to be redesigned and produced

LAr LV Power Distribution (2)

- Partire dalle competenze sviluppate con il progetto di Gruppo 5 Apollo, aggiornandolo per tempi e problemi della fase II. Possibili strade (in alternativa):
  - Soluzione custom (schede CAEN) con transistor di potenza GaN al posto dei Si MOSFET
  - Nuove architetture commerciali (es. Vicor ComPAC)

- Interesse da parte di altri gruppi del progetto Apollo
- Interesse di altri gruppi LAr
- Interesse di altri sottorivelatori

LAr Trigger

40 MHz full readout

→ possibilità di implementare algoritmi più complessi e selettivi già al livello 1

→ nuova architettura di trigger

Il gruppo di Milano intende contribuire sia al progetto della nuova architettura che allo studio di algoritmi

LAr Trigger – Piano di lavoro

- Setup:
  - ATCA crate + FPGA dedicated board (possibly on AMC mezzanine)
  - Acquire 1-2 (different) FPGAs
  - Build a ROD injector to simulate input data flow
- Goal:
  - Handle the expected data flow
  - Format and partition the data
  - Write algorithms to select "LVL 1" objects
  - Study performance (wrt simulations): efficiency, latency, …
  - Identify/Track possible points of failure / bottlenecks

LAr Trigger - Sinergie

- Diversi istituti LAr/L1Calo potenzialmente interessati → da contattare
- Sinergie con altri sotto-sistemi ATLAS sono possibili (o meglio probabili) → da identificare
- Abbiamo un AR finanziato per 2 anni all'interno del PRIN 2013 HTEAM

LAr Trigger - Richieste

	2015	2016	2017	Total:
DC powering	20	20	20	60
LAr trigger	20	15	8	43
				103

- DC powering
  - 2015: 10 kE for modifying the CAEN prototype with GaN MOSFETs
  - 2015: 10 kE to acquire commercial modules
  - 2016: 5 kE for a test setup (test loads, …)
  - 2016: 15 kE for radiation tests of components and modules
  - 2017: 20 kE to build a full prototype
- LAr trigger
  - 2015: 20 kE for the test setup (ATCA crate, board components)
  - 2016: 15 kE for the FPGA dedicated board
  - 2017: 8 kE for the ROD injector

LAr - Milestones

- DC powering:
  - 2015: Validation of GaN devices and commercial power bricks
  - 2016: Test and comparison of custom or commercial solution
  - 2017: Complete design and ready for production of full prototype with LAr specs

- LAr Trigger
  - 2015: Start ATCA test setup assembly; finalize board design; start simulation: definition of both physics channels and needed samples;
  - 2016: board production; setup ready for algorithm studies and optimization
  - 2017: complete performance tests with ROD injector; finalize simulation studies

LAr - Manpower

LAr R&D: 10 people / 6 FTE

DC powering:

- M. Lazzaroni (responsible) and M. Citterio + 2 technicians → natural evolution of the APOLLO R&D for Phase I

Trigger:

- L. Carminati, F. Tartarelli, S. Mazza and the PRIN AR: test-stand setup and development of algorithms
- M. Citterio (+ electronics workshop): test-stand setup and board design.
- R. Turra, C. Pizio, S. Resconi, M. Fanti: simulations of full trigger chain performance.

FTE breakdown

Maintenance	Phase I	Phase II
0.5	3	2.5

Name		% LAr
L. Carminati	RU	50
M. Citterio	DT	20
M. Fanti	RU	50
M. Lazzaroni	PA	70
S. Mazza	Ph.D. student	60
C. Pizio	AR	50
S. Resconi	Ric	50
F. Tartarelli	PR	100
R. Turra	AR	50
1 AR PRIN (to be hired)	AR	100
		10 persons/6 FTE

4) Tile

- Elettronica di FE (criticità per HL-LHC):

  radiation hardness, triggering, aging

  → nuova elettronica (mini-drawers) → dimostratore (4 m.d.)

  3 diversi progetti per la parte analogica

  Dimostratore:

  - evidenziare e risolvere problemi nuovi progetti (scelta finale)
  - acquisire esperienza verso fase II
  - valutare potenzialità trigger digitale
  - confrontare prestazioni trigger digitale .vs. analogico

Tile FE Demonstrator

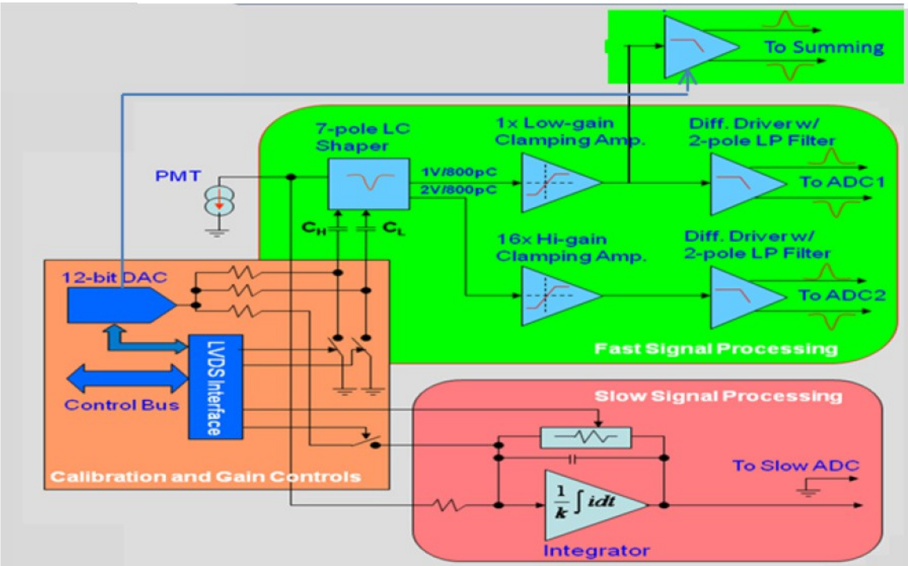
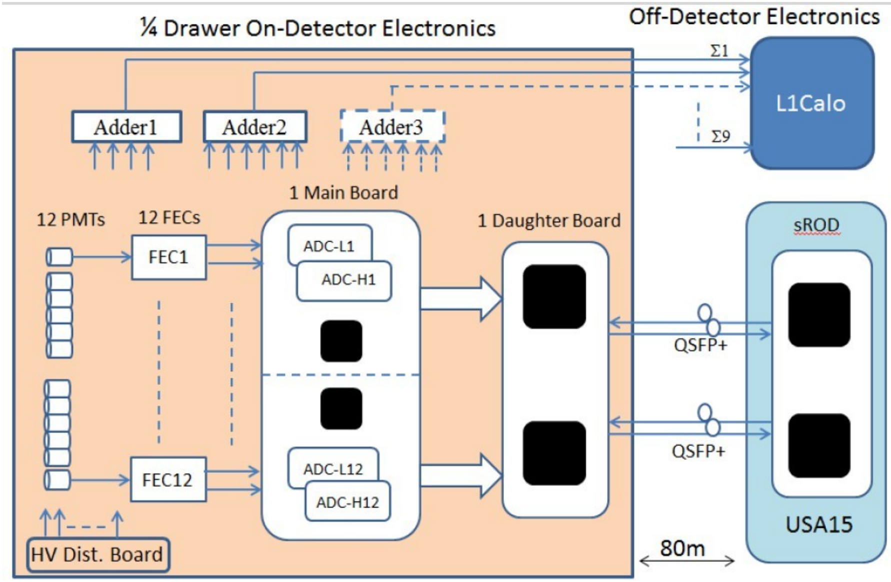
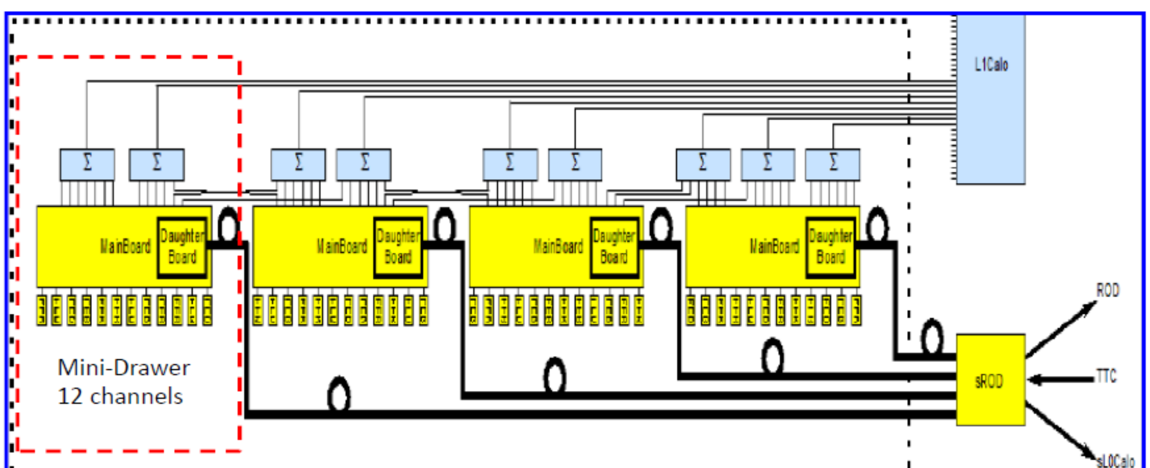


Diagramma a blocchi FE analogico



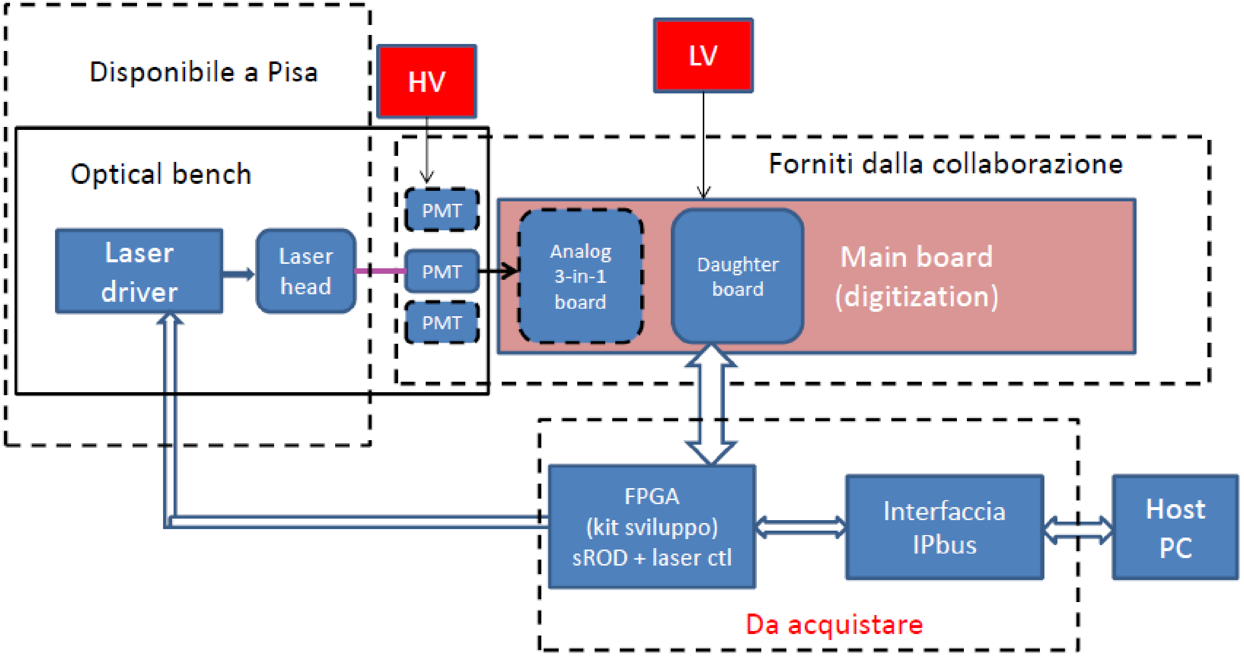
FE card



dimostratore

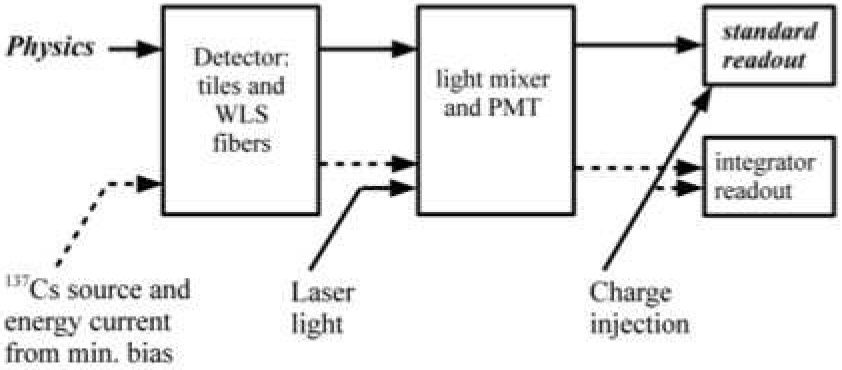
Tile FE Demonstrator (2)

Pisa si propone come istituzione responsabile di definire un protocollo di qualificazione e confronto tra le 3 opzioni e di effettuare i test dei vari prototipi in sede

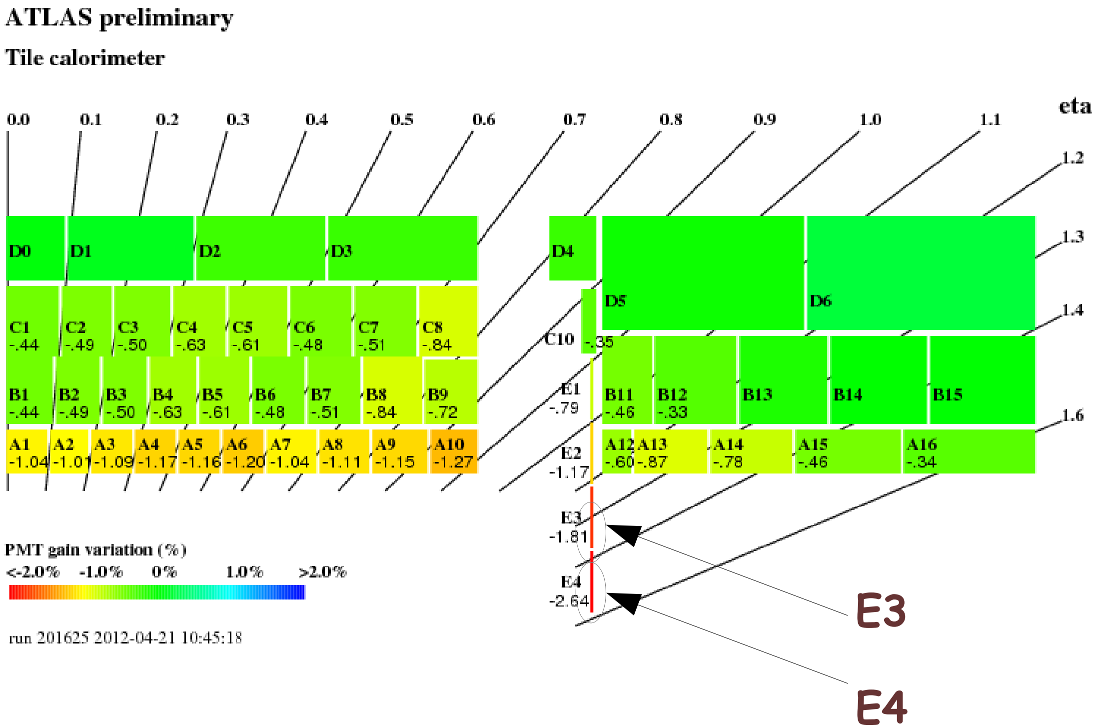


Tile PM Stability and Aging

- Andamenti non capiti risposta PM (G peggiora ma poi recupera)
- Preoccupazione per stabilità futura (grandi correnti da integrare)
- Necessarie analisi approfondite (es. variazioni G, variazioni Q.E., ...)

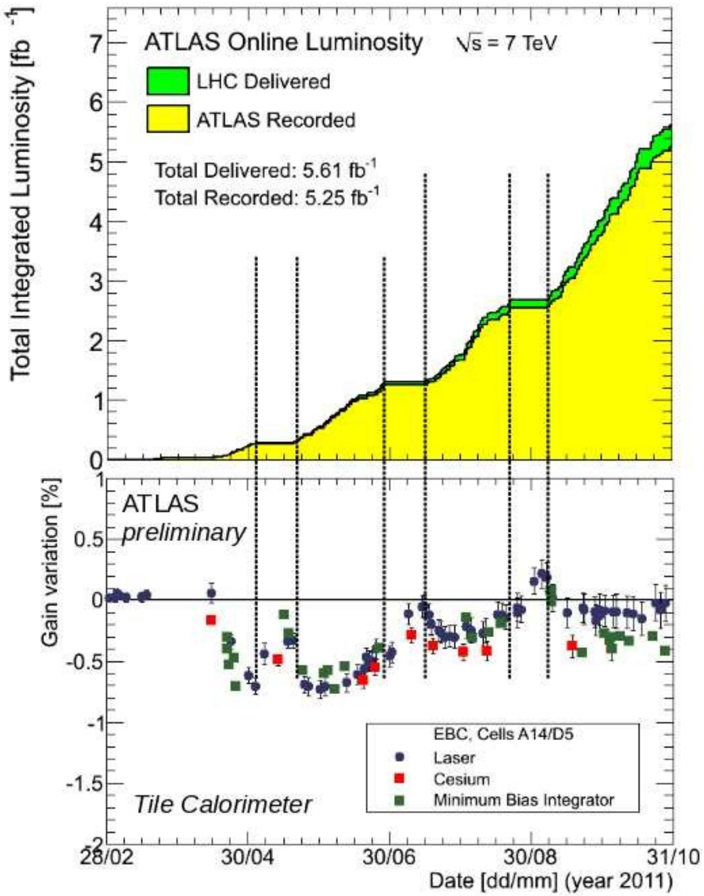


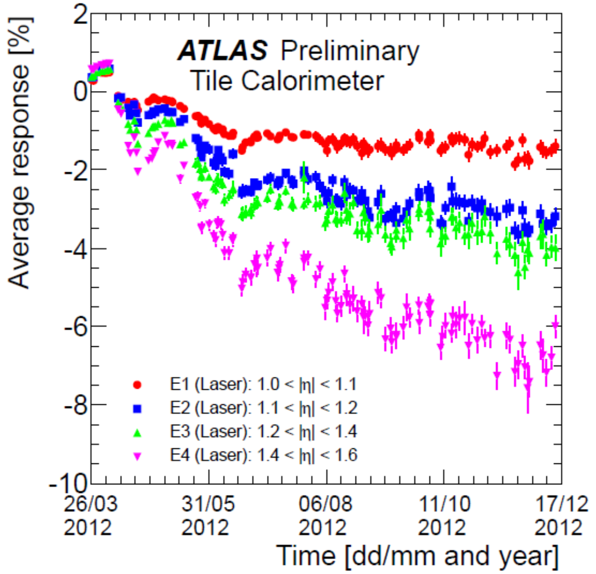
sistema di calibrazione TileCal



Δ(2012-2010) risposta PM (laser)

PM Gain Drift





Evoluzione temporale
celle interne

celle scintillatori E (gap/crack)

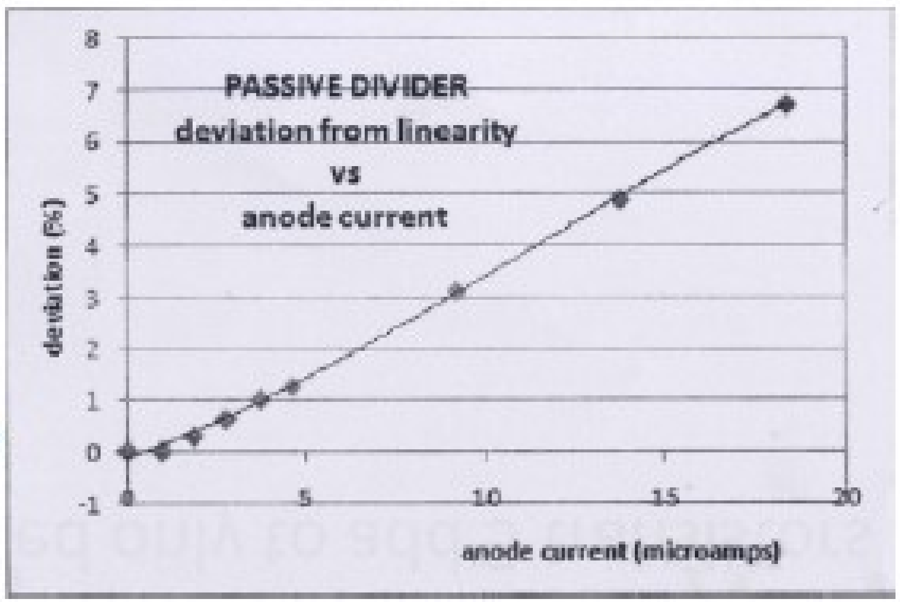
22 fb^{-1}

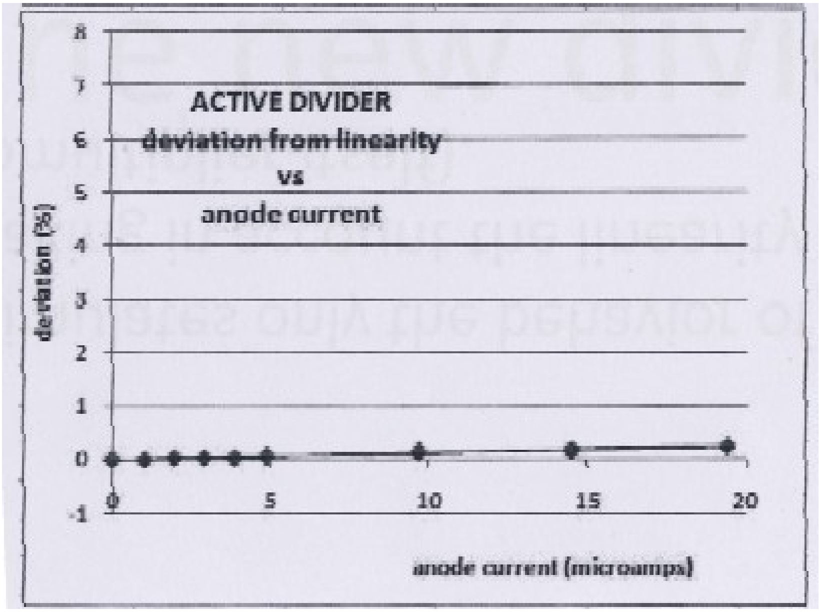
dose 200 x celle più esposte

Effetti da riprodurre e spiegare

PM Linearity

- Correnti anodiche > 5 μA danno deviazioni di linearità O(%)





- Partitori attivi dovrebbero permettere di lavorare con decine di μA

→ implementazione e validazione di partitori attivi

PM Test Stand

- Piano di lavoro
- test di lunga durata (mesi di funzionamento ad alte correnti anodiche, fino a 100 μA) di linearità di risposta, stabilità del guadagno ed efficienza quantica
- verificare con sorgenti radioattive l'andamento in funzione della dose integrata per alcuni PM

Profilo di Spesa e Impegno FTE

Anno	Attivita` prevista	Adeguamento laboratorio	FTE	Spesa stimata
2014	Contatti e avvio progetto	-	0.4	-
2015	Assemblaggio moduli di read-out e definizione del protocollo di test FE e PMT	Acquisto sistema di read-out + metabolismo	1.8	15 keuro
2016	Qualificazioni del FE + Test PMT + partecipazione test demonstrator	Canali HV per PMT + metabolismo	2.3	20 keuro
2017	Test di alta intensita` con sorgente e LASER; conclusione test FE	Sistema di movimentazione della sorgente + metabolismo	2.3	20 keuro
2018	Prosecuzione test di lungo termine sui PMT; partecip. test integrazione	Metabolismo	2.3	5 keuro

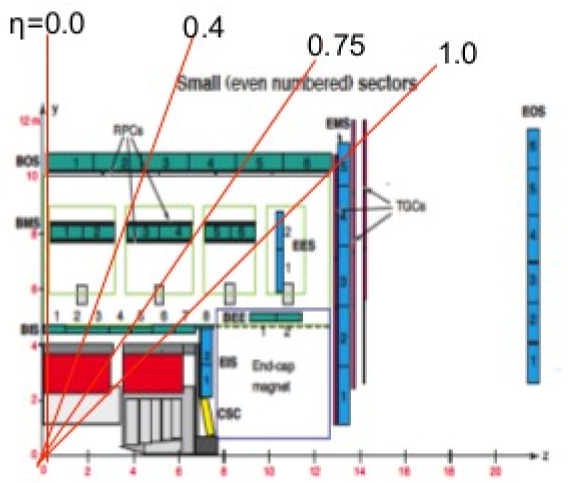
Personale 2015	Posizione	% INFN 2015 sull'upgrade
V. Cavasinni	P.O.	40%
S. Leone	I° Ric.	30%
C. Roda	R.U.	20%
F. Scuri	I° Ric.	60%
M. Spalla	PhD	30%
		1.8 FTE tot.

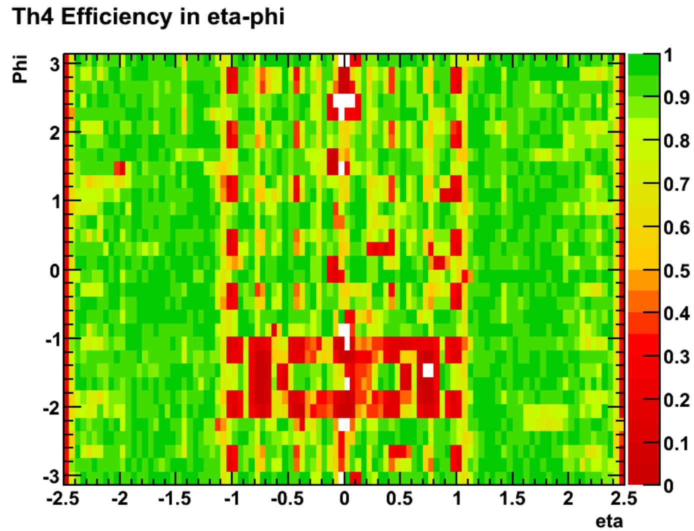
*) T. Del Prete, pensionato associato INFN pensa di contribuire al 50% del suo tempo

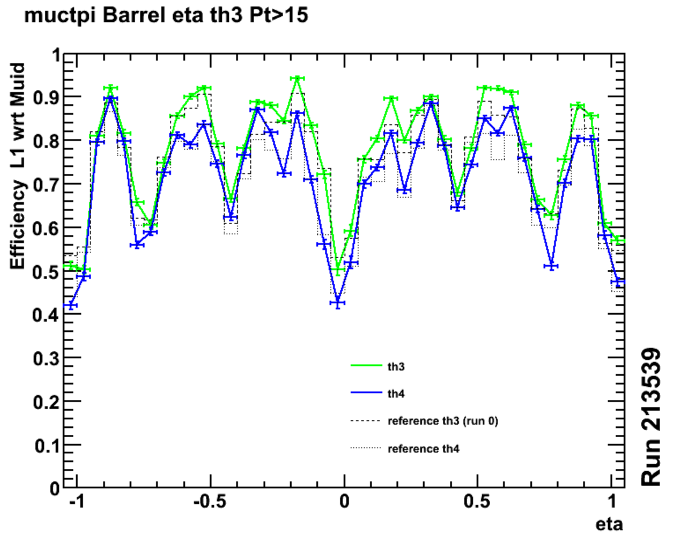
Milestone

- 2015 : preparazione apparato sperimentale a Pisa
  - definizione protocollo di test per schede FE
  - definizione protocollo di controllo per partitori attivi
- 2016 : inizio test prototipi schede FE
  - preparazione test con sorgente
  - certificazione partitori attivi.
- 2017 : finalizzazione test schede FE e decisione
  - inizio test PMT con sorgente
- 2018 : certificazione rad-hard PMT con nuovi partitori
  - risultati test a lungo termine di un campione significativo di PMT

5) RPC Phase II Proposal







High-Pt trigger acceptance limited at ~**72%** (only in barrel!) due to non-instrumented regions in:

a) feet + elevators (partial recovery in LS1)

b) toroid (and ribs) in BM chambers of small sectors

Not projective holes → 3/3 coincidence required for trigger

→ add inner BI RPC chambers

→ use 3/4 request

Trigger requirement	Acceptance wrt muon reconstruction, $\eta_{muid}<1.05$
RPC1 && RPC2 && RPC3	**72%**
RPC0 && (RPC1||RPC2) && RPC3	82%
any 3 out of 4 chamber layers	**88%**
(any 3 out of 4) || (inner && outer)	96%

Requirements

Qualification tests done for $L=10^{34}$ cm^{-2} s^{-1}, 10 years of running at max background rate of **100 Hz/cm^2** (with safety factor of 5 wrt simulation)

Expected max rate in new inner layer ~**1 kHz/cm^2** (with a 1.5 safety factor):
need to improve the long term RPC rate capability

Limited space available: ~5cm

Reduced gas gain:
- thinner gap 2 → 1 mm
- thinner electrodes 1.8 → 1.2 mm
- increased amplification and lower noise in FE electronics

Improved spatial and time resolution:
- timing improved by reducing gap thickness
- use ToT and charge centroid to improve spatial resolution

Reduced detector thickness
- higher-quality mechanical structures

1. Electrodes

Lower resistivity materials:

- construction of **low resistivity HPL** electrodes → higher rate
- Investigation of **low resistivity glass** electrodes and chamber developed by Chinese Tech. Univ. → higher rate + multigap (timing)

Thinner electrodes to improve S/N ratio, spatial resolution and to reduce stress (HV working point) and aging

- construction of gas volumes with thin HPL electrodes
- construction of multi-gap RPC based on thin HPL electrodes

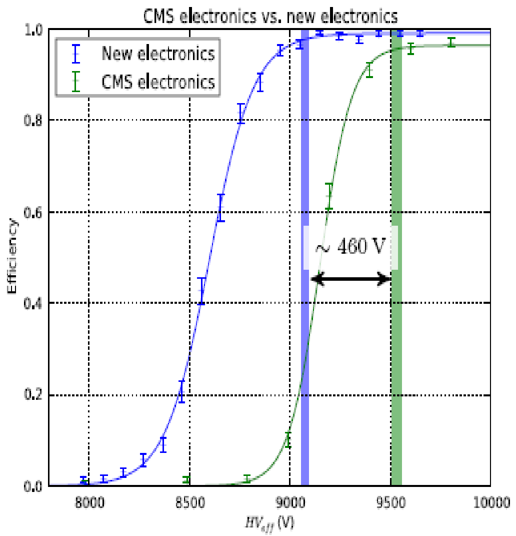
2. Chamber Prototypes

- small set (<~10) of reduced size prototypes (thin, multi-gap, different resistivity...) for common tests at GIF++ and in labs

- module -1 prototypes fitting all specific requirements of the two experiments:
  - Test at GIF++ and in the lab.

- technological improvements:
  - gas and HV connections / mechanics / strips / cooling / ...

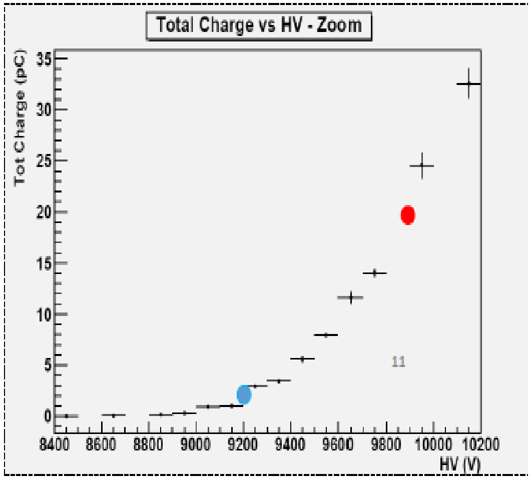
3. New FE Electronics

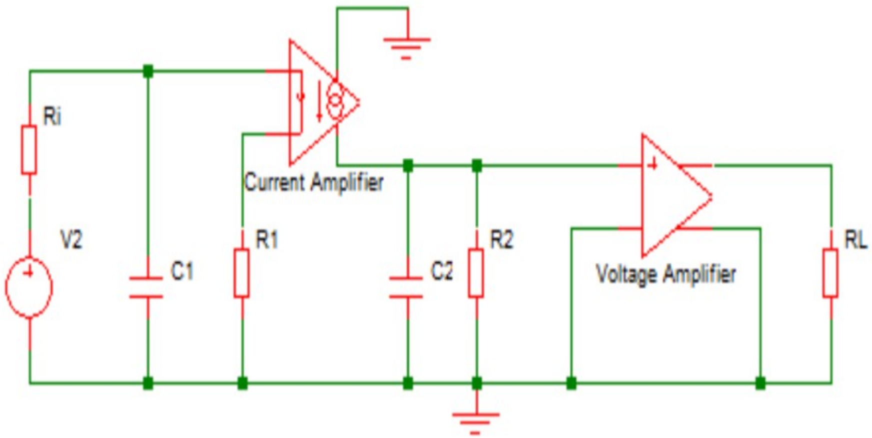


Prototype developed by R.Cardarelli

Tests on 2mm gaps

- CMS: turn-on efficiency curve shifted by ~460V
- ATLAS FE: x7 reduced charge;
  fully efficient up to 7 kHz/cm^2 at GIF

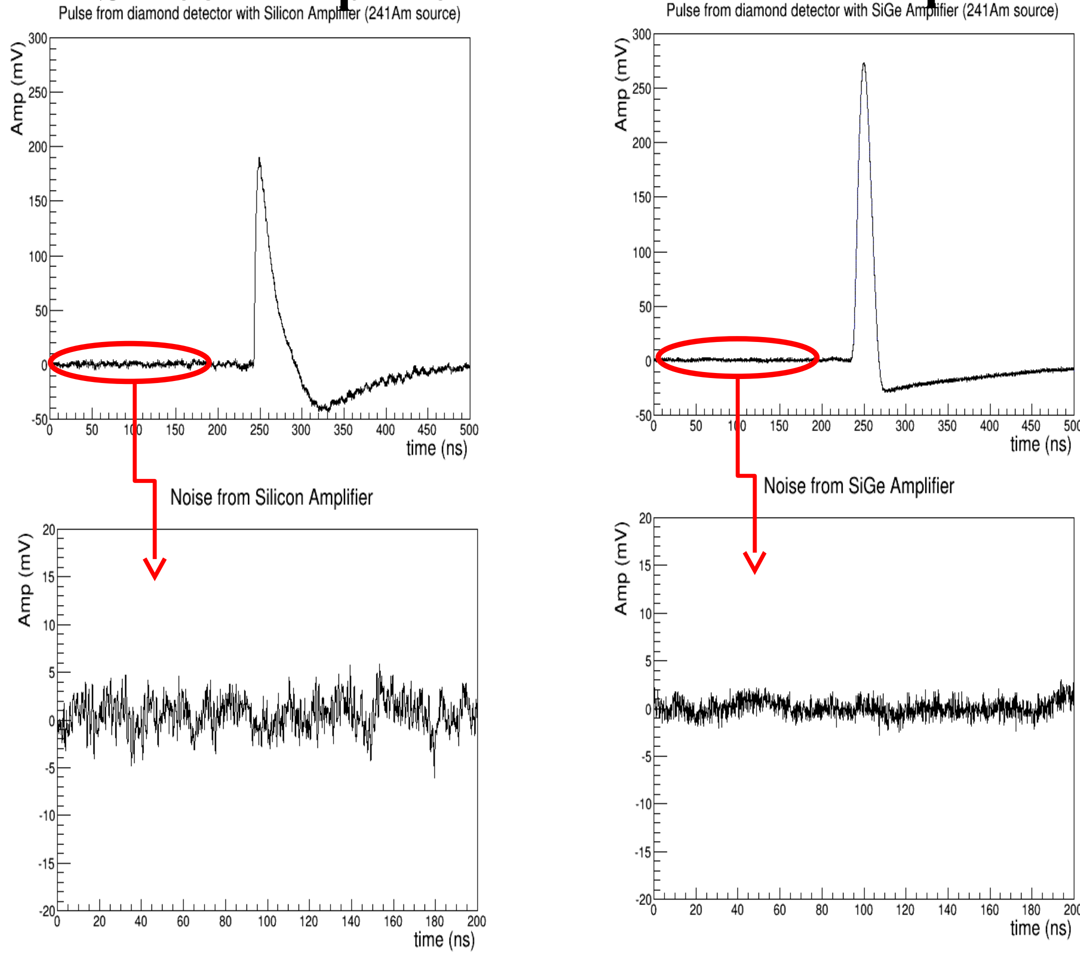




The same scheme can be used for both Si and SiGe technology

Si .vs. SiGe Signal-to-Noise

Silicon amplifier | **SiGe amplifier**



Signal:
x1.4 improvement

Noise

4. The Quest for Eco Gases

- **The European Community has limited the industrial production and use of gas mixtures with Global Warming Power > 150 (GWP(CO_2) = 1)**
  - ✓ This is valid mainly for industrial (refrigerator plants) applications
- **$C_2H_2F_4$ is the main component of the present RPC gas mixture:**
  - ✓ GWP($C_2H_2F_4$) = 1430, GWP(SF_6) = 23900, GWP(iC_2H_{10}) = 3.3
- $C_2H_2F_4$ and SF_6 Crucial to ensure a stable working point in avalanche
- ✓ **Similar problem for CF_4 (GWP = 5800) used in GEMs for time resolution**
- On the physical and chemical properties of this components we:
  - ✓ Designed FE electronics and chambers
  - ✓ Did all performance, ageing and calibration tests

Eco Gases: Plan

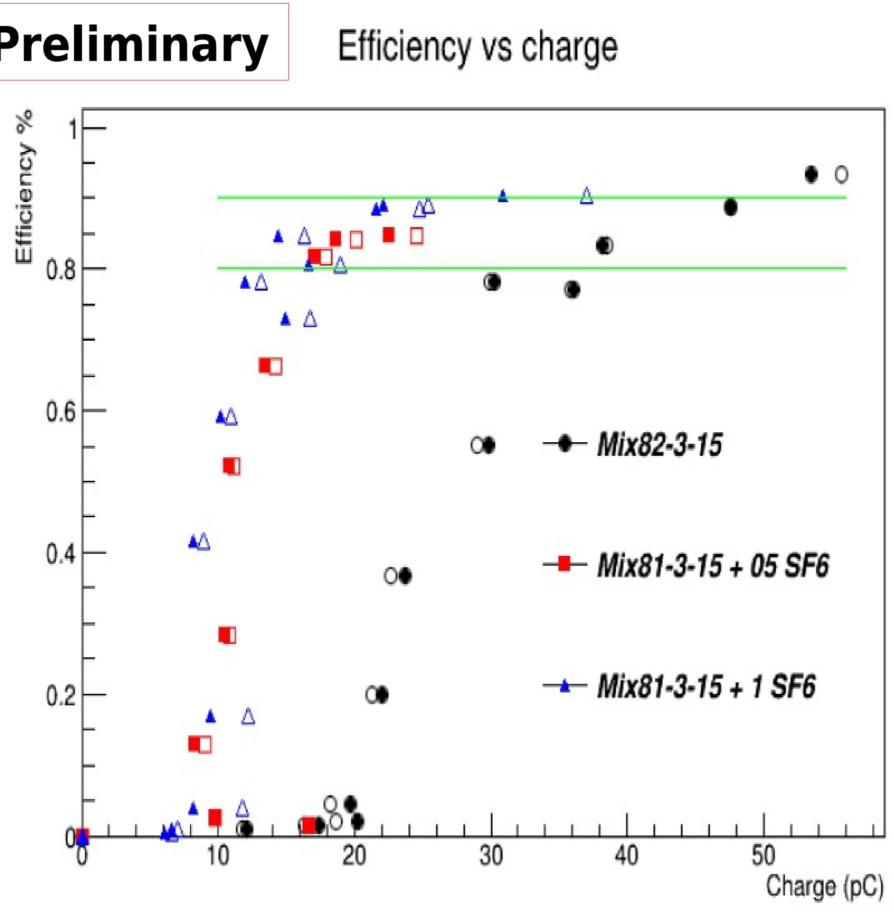
- Test molecules similar to $C_2H_2F_4$ but with lower GWP
  - **$C_3H_2F_4$ – tetrafluoropropene (GWP=4)**
    - ✓ **Should replace $C_2H_2F_4$ as automotive air-conditioning refrigerant**
  - ✓ $C_2H_4F_2$ – difluoroethane (GWP=120)
    - ✓ Also studied to replace $C_2H_2F_4$ as a refrigerant
  - ✓ $C_2HF_3Cl_2$ (GWP=93),
  - ✓ others …
- Plan to measure all the detector response parameter (time, charge spectrum, streamer separation, noise, efficiency, possibly drift velocity, etc)
  - **HUGE PARAMETER SPACE, NEED TO DIVIDE MEASUREMENTS BETWEEN FACILITIES**
- Test at the GIF++ will follow on a short list of candidates ecogases to measure the performance in a realistic environment
  - ✓ Rate capability, performance under stress, HF yield → already being setup at GIF
  - ✓ New ageing tests (to be performed also at GIF++)

First results on new RPC gas mixtures

Huge R&D program needed to analyze all proposed gases and variants, first with cosmics, then at GIF

***** Of general interest also outside LHC/CSN1 *****

Preliminary



Single-gap ATLAS prototype, average charge vs. efficiency

5. Irradiation tests

- Aging test on detectors and materials at GIF++

  - strong gamma-ray source

  - muon-beam

  - cosmic ray telescope

- Beam test facility at Frascati

  - rate, efficiency, time resolution, sensitivity to photons and neutrons

    ($E\gamma$<700MeV, En= 1-10 MeV)

- Test of FE electronics (aging and SEE) at various facilities (GIF++, Louvain, Lund, ...)

  - verify currently installed boards for 10-year equivalent dose at HL-LHC)

6. New Trigger Electronics

Current trigger electronics can't met Phase II requirements:

- L0 / L1 rates and latencies
- GBT for timing signals
- Felix readout system

- Proposal:
  - Replace on-chamber electronics with Data Collector Transmitter (DCT) boxes to send data off-detector
  - FPGA (no ASIC)
  - New sector logic boards in USA15

→ more flexibility, reliability, …

Trigger R&D Requests

R&D:
- 2 commercial FPGA evaluation boards (3 k€ ciascuna)
- 2 adapter boards (1 k€ ciascuna)
- 1 prototype (5 k€)

Total R&D: 13 k€ (2015: 6 k€ - 2016: 2 k€ - 2017: 5 k€)

Manpower

Detector:

- Bologna (2.0): Bellagamba (0.2), Boscherini (0.4), BruniA (0.2), Polini (0.2), Chiarini (0.2), Gessi (0.2), Guerzoni (0.2), Serra (0.4)
- Roma2 (4.0): Cardarelli (0.5), Aielli (0,5), Liberti (0.5), Paolozzi (0,5), Pastori (0,5), Santonico (0,5), Camarri (0,7), Di Ciaccio (0,3)

Trigger:

- Bologna (0.5): Corradi (0.3), Massa (0.2)
- Napoli (0.5): Izzo (0.3), Perrella (0.2)
- Roma1 (1.1): Vari (0.4), Safai Tehrani (0.2), Luci (0.2), 1-tecnico (0.3)
- Roma2 (0.2): Liberti (0,2)

Financial Requests 2015-2017

		ATLAS/CMS keuro	ATLAS/CMS comments	CMS keuro	CMS comments	ATLAS keuro	ATLAS comments
ITEM	**TASK**	**233**		**23**		**21**	
Electrode	Tot	**35**		**10**			
	HPL	20	development low Res thin (10) and Proto (10)				
	Glass			10	2 CMS-like chambers, 1 multigap		
	Transportation	5	from company to Lab				
	Resistivity Meas	10	production resistivity and long term conductivity				
Chamb/Proto	Tot	**58**		**8**		**8**	
Thin/multi Gap	Chamber prod.	35	scaling from small to full size				
	Multiplet mech. frame	4	precision frame for 4 chambers + local gas distrib syst				
	Gas comp. & distrib.	4	design and test of new gas I & T				
	prototype -1			8	CMS layout prototype	8	ATLAS layout prototype
	Consumable	15					
Front-end	Tot	**56**		**5**		**13**	
	Chip prototype	45	Chip design and development				
	Adaptor board		for CMS and ATLAS exp.	5	chip/DAQ board	13	On chamber LVL1 Roma 1
	Test in lab	11	Single Event Effects				
Eco-gas	Tot	**36**		**0**		**0**	
	Gas	20	unit cost 2 Keuro				
	Consumable	2					
	equipment	4	flowmeters				
	interaction w/ materials	10	chemical materials and sensors				
GIF++, BTF, etc	Tot	**48**		**0**		**0**	
	Electronics	12	DAQ/DCS epool rent				
	RPC user gas system	10					
	Cables and sensors	4					
	Gas use	12					
	Running test consumable	8					
	Trolley and support	2					

Funding Profile (preliminary!)

Task	2014	2015	2016	2017	TOTALE
Electrode		20	25	0	**45**
Chamb/Proto		10	28	36	**74**
Front-end		56	12	6	**74**
Eco-gas	10	6	10	10	**36**
GIF++		20	14	14	**48**
	10	**102**	**89**	**66**	**277**

Milestones - preliminary proposal:

12/2015 First set of prototypes - construction and test
12/2015 FEE - channels certification
12/2016 Certification of prototypes at GIF++ (10 years HL-LHC)
12/2016 Choice of a new eco-frendly RPC gas mixture
12/2016 FEE - production of prototypes
12/2016 trigger - test of DCT evaluation board
12/2017 trigger - DCT prototype board construction

6) RPC BIS 7-8

- Regione di transizione Barrel-EndCap $1<|\eta|<1.3$
  - alto flusso di protoni
  - copertura di trigger solo EC TGC → alto rate di fake:

    ~12.5 kHz in Phase I
  - single muon trigger total budget ~ 20 kHz

    → necessaria reiezione >90% (goal ~95%)

Possibili soluzioni

- TileCal muon trigger
- RPC BIS7-8

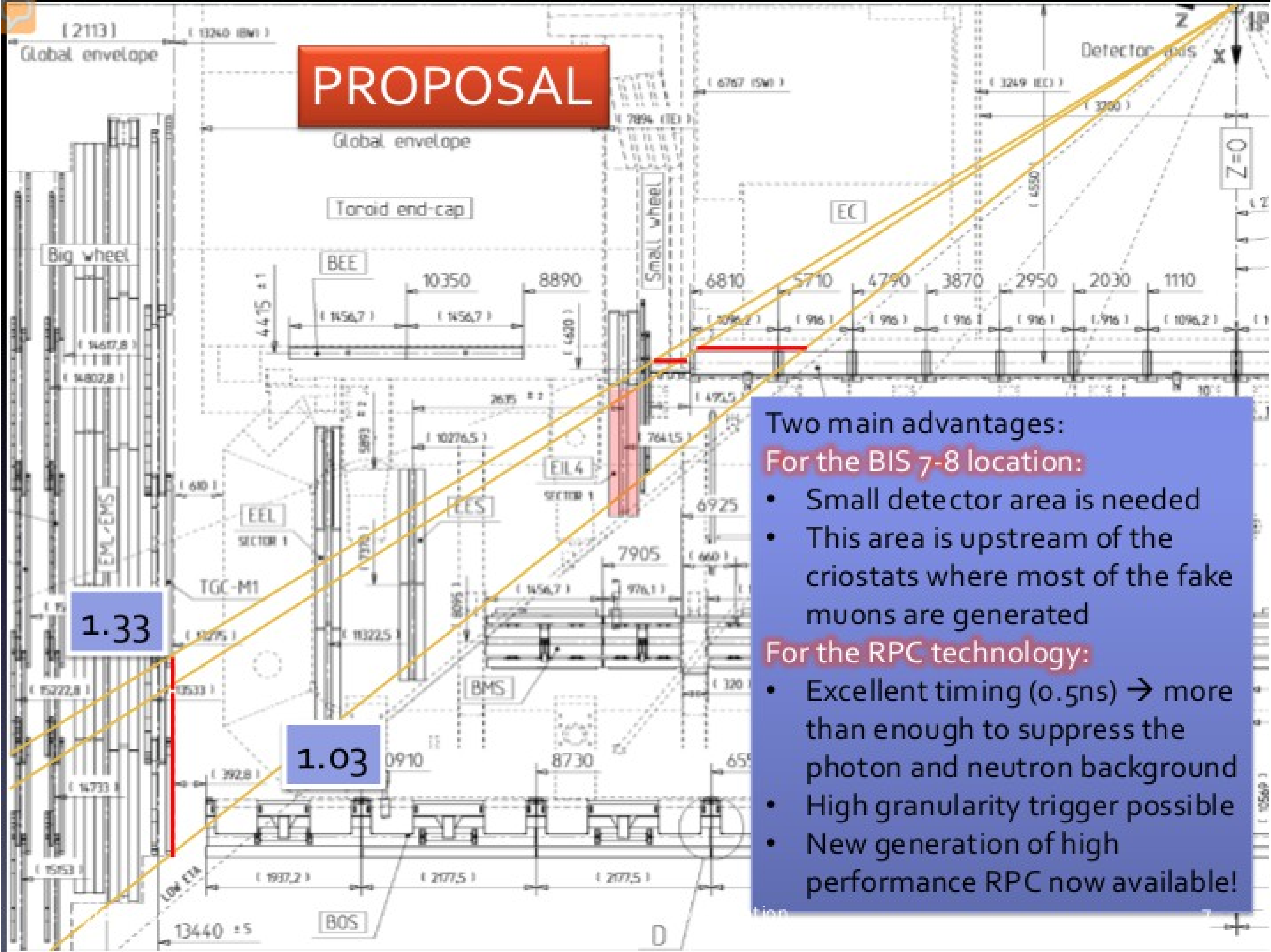
→ fake rate ~1.2 kHz (~5% rate μ L1)

		BIS78 +EIL only	BIS78 +EIL+Tile	TILE stand-alone
Efficiency		83%	99%	99%
Phase-I .μ=80 L=3*10^{34} cm^{-2}s^{-1}	**Total Rate (kHz)**	0.8	1.4	3.0
	Bkg rate (kHz)	0.6	1.2	2.8
Phase-II .μ=140 L=7*10^{34} cm^{-2}s^{-1}	**Total Rate (kHz)**	1.9	3.1	5.9
	Bkg rate (kHz)	1.5	2.7	5.5

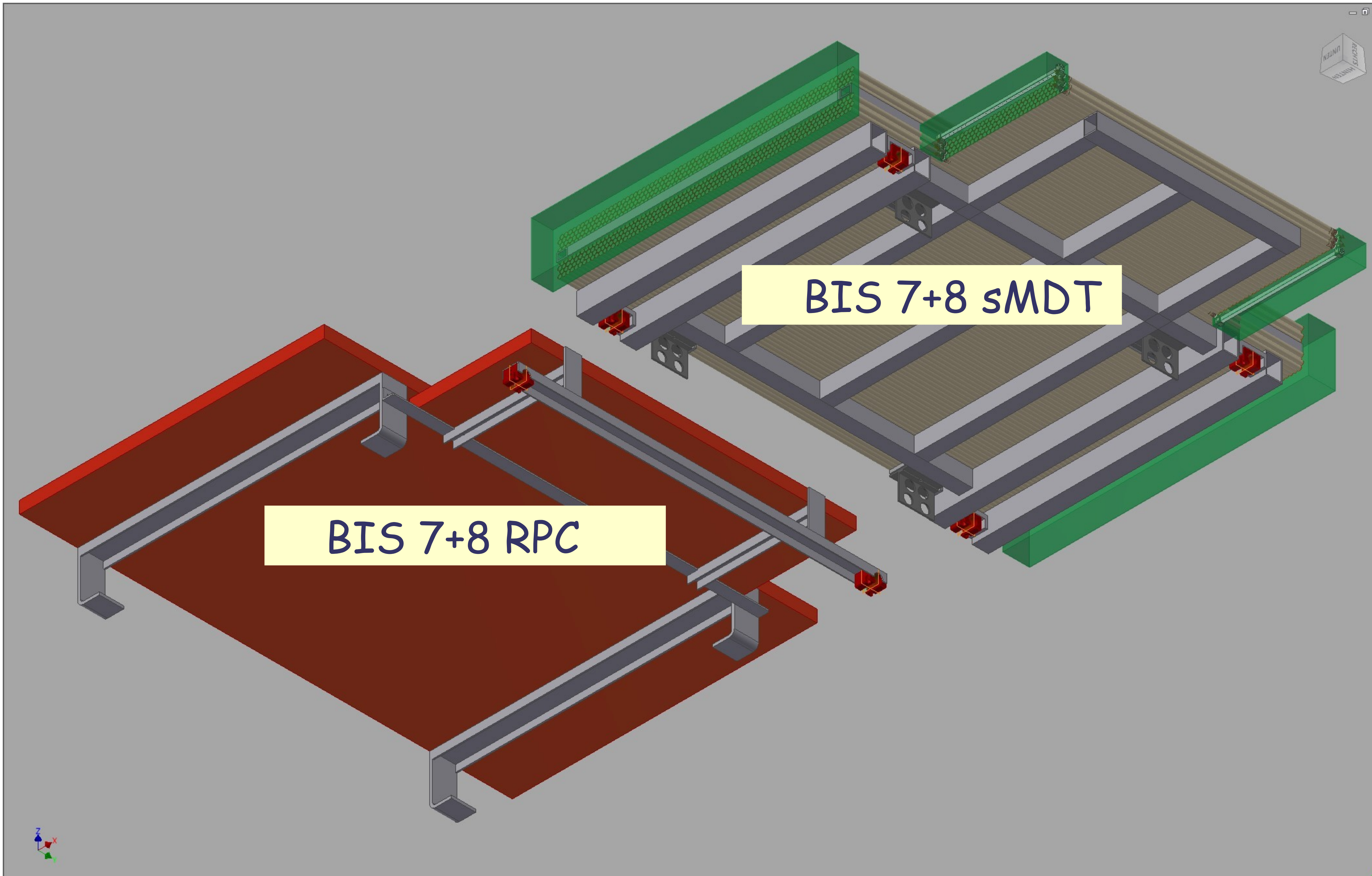
- No BIS7-8: fake rate ~ 2-3 kHz (~10% rate μ L1)

→ dal 95% al 90% di "good muons" (-5%)

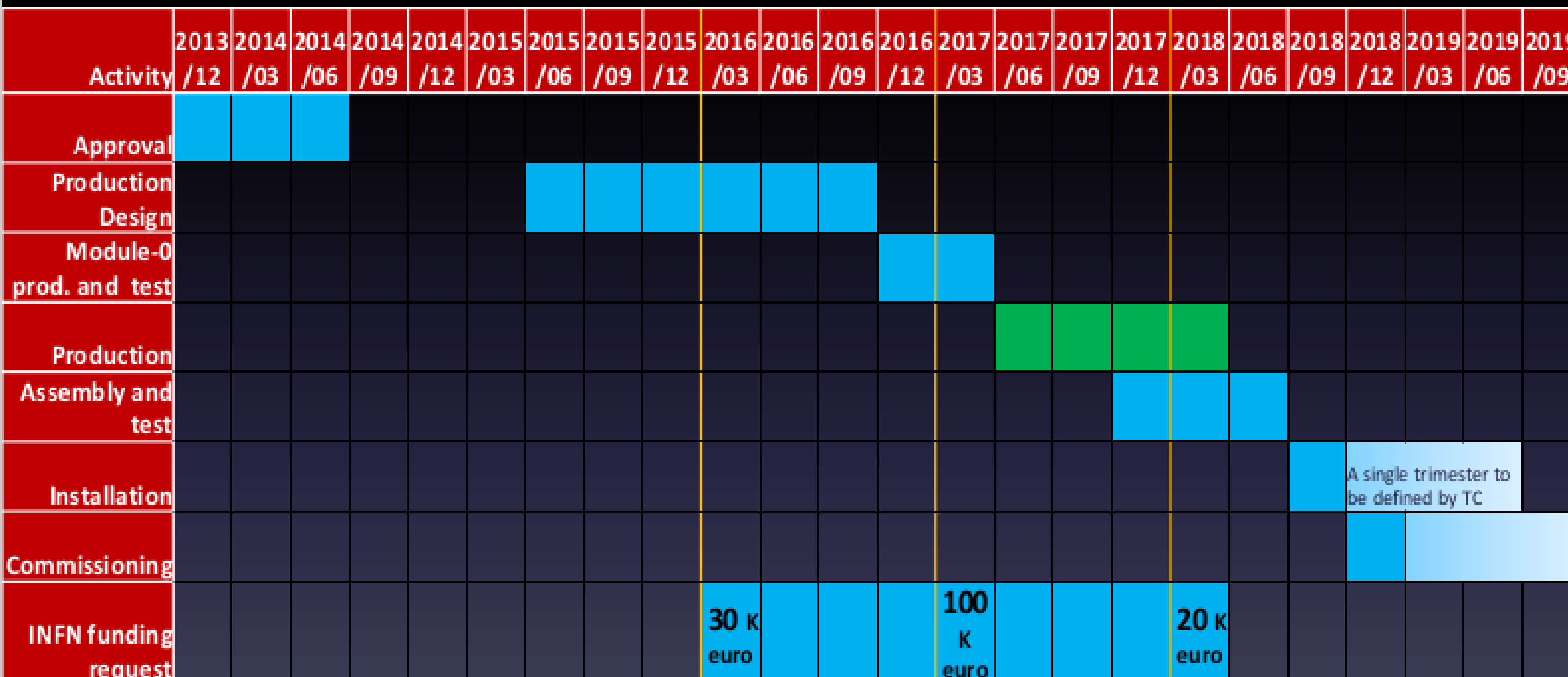
- Rapporti poco diversi per Fase II


PROPOSAL
Global envelope
Global envelope
Toroid end-cap
Big wheel
Small wheel
EC
BEE
EIL4
EEL
EES
BMS
BOS
TGC-M1
EML/EMS
Detector axis
Z=0
10350
8890
6810
5710
4790
3870
2950
2030
1110
6925
7905
8730
13440 ±5
1.33
1.03
Two main advantages:
For the BIS 7-8 location:
• Small detector area is needed
• This area is upstream of the criostats where most of the fake muons are generated
For the RPC technology:
• Excellent timing (0.5ns) → more than enough to suppress the photon and neutron background
• High granularity trigger possible
• New generation of high performance RPC now available!

Baseline Layout



Project schedule



ATLAS Schedule

- Project reviewed positively by ATLAS referees in 2013
- ATLAS TC assessed project compatibility on 04/2014
- Final formal discussion on 8/5/2015 USC
- Awaiting for EB approval
- FA awaited by ATLAS to give a sign of "likely" funding assignment
- Possible CB approval on 20/6/2014 ATLAS week in Sibiu
- Installation scheduled on 2018 (LS2)
- Run in 2020 (RUN 3)

Manpower

INFN: 10 FTE out of 26 physicists and technicians

- Bologna: simulation; performance study, production drawings, DCS
- Roma1 and Napoli: trigger electronics integration (PAD)
- Roma2: front-end-electronics, gas volume and chamber design

MPI: approx. ~10 FTE (including sMDT construction)

- system layout, mechanics, integration, station assembly and test

UMICH: 2.5 FTE out of 4 physicists and engineers

- trigger simulation, serializer, readout and DAQ

USTC: 2 FTE out of 4 physicists

- funds available for construction, expressed interest for RPC R&D

Cost Estimate and Sharing

- Total core cost: ~440 kCHF
  - 32 x (3-layer detector + strip panels + supports) ~240 kCHF
  - 6k FE electronics channels ~80 kCHF
  - Cabling and services ~60 kCHF
  - Trigger: 16 PAD boxes + fibers ~60 kCHF
- Based on (4 unit) BME chamber construction costs, extrapolated to a larger (32 unit) system → should have some margin
- Cost Sharing:
  - INFN (apply for ~150 keuro)
  - MPI (chamber mechanics: ~150 keuro)
  - USTC (~150 k$ available for CORE and R&D finalization)
  - UM (in-kind participation as DOE can't finance barrel costs)