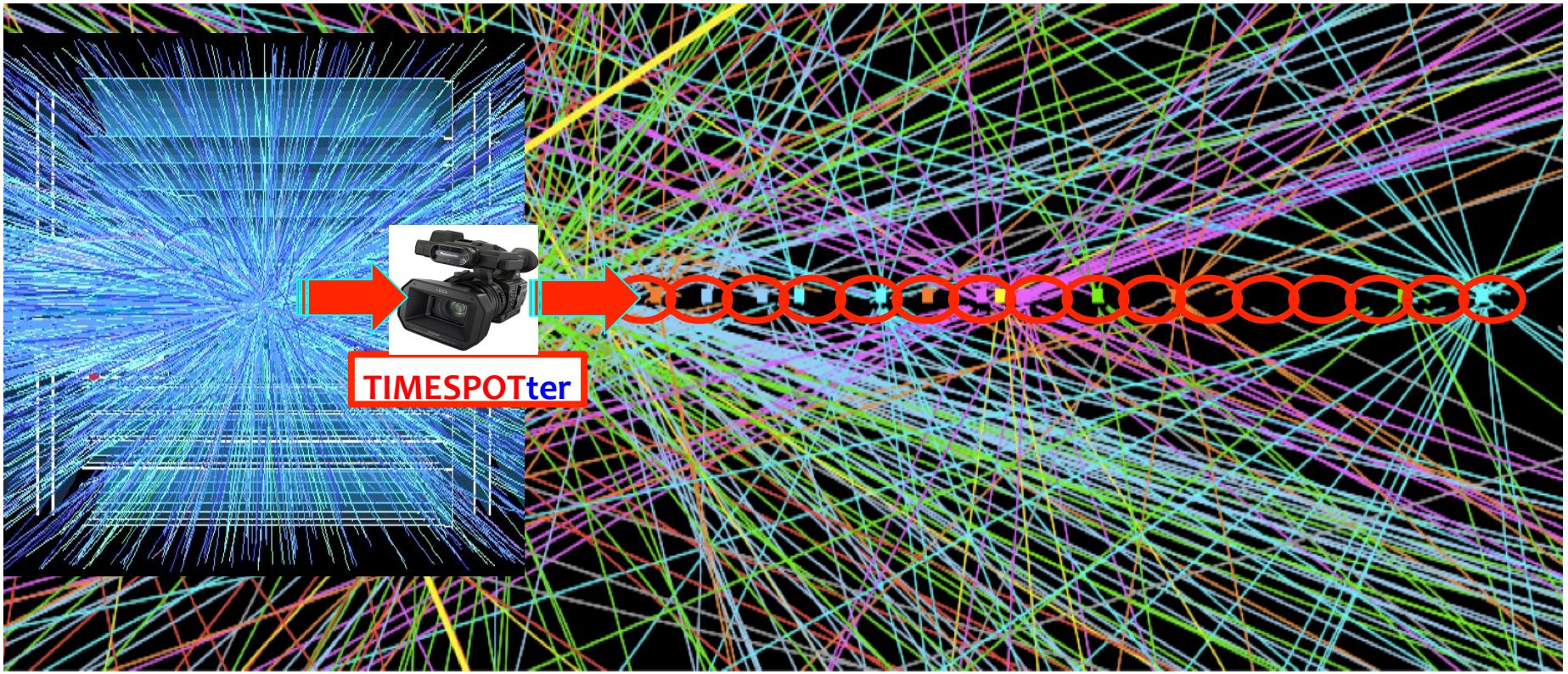
TIMESPOT

TIME & SPace real-time Operating Tracker

Project for the developement of a silicon and diamond 3D tracker with timing facilities

financed by INFN for the years of activity: 2018, 19, 20

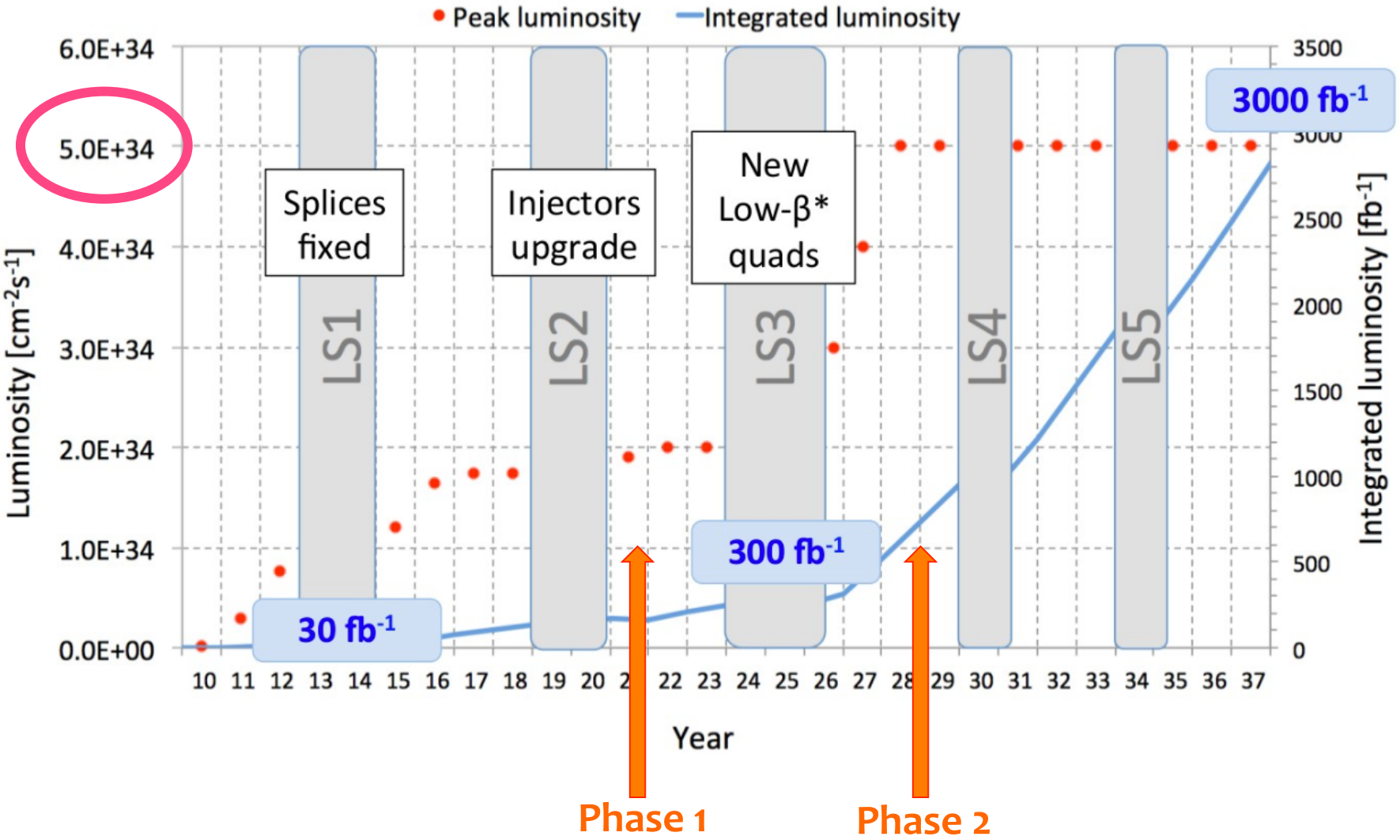


Introduzione

- **Un breve promemoria sulla struttura e scopo del nostro progetto**
- **La riunione di oggi: programma e obiettivi**
- **Alcune note organizzative da discutere**

Scientific Motivation

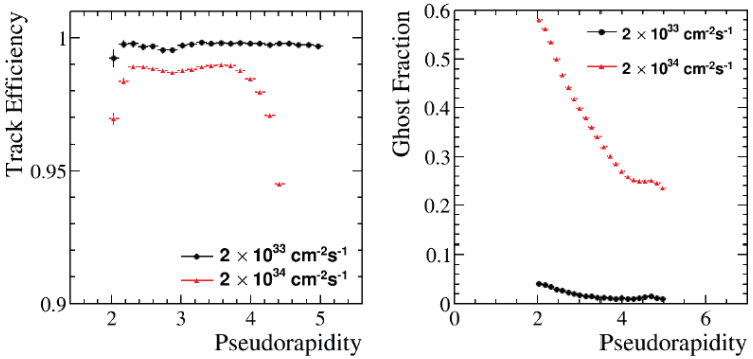
LHC upgrade program



PV reconstruction can be (partially) recovered with smaller pixels…

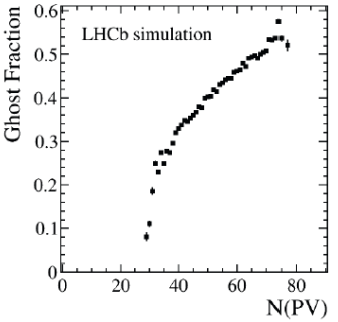
But PV tracks start to merge

Phase-I VELO performance breaks down at Phase-II luminosity ($L=2\times10^{34}$)



Tracking efficiency reduced to 96% (not so bad)
+ less flat

Ghost rate explodes (~2% → 40%)

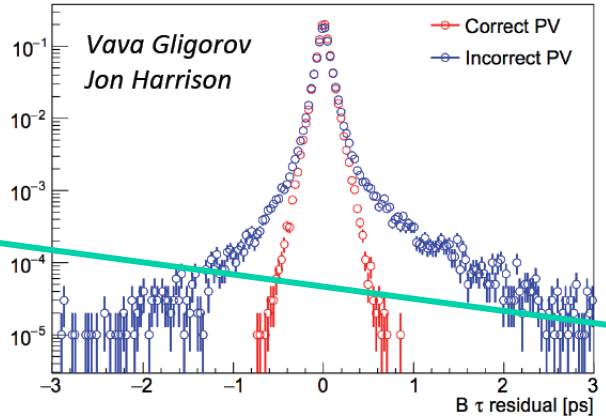


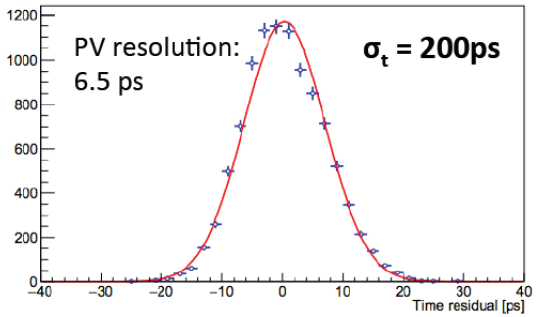
Mark Williams 13

Assigning incorrect PV to track → poorly measured lifetime

Becomes a dominant systematic for time-dependent analyses

Can be recovered by adding timing information to tracks ✔





Preliminary study with time information added to all VELO hits

e.g. 200ps per-hit resolution → 6.5ps PV resolution (8.5ps for 2-body SV)

Timing starts to be crucial already at 2×10^{34}

Beyond the Phase-1 Upgrade: VELO Summary 30 May 2017 Mark Williams 17

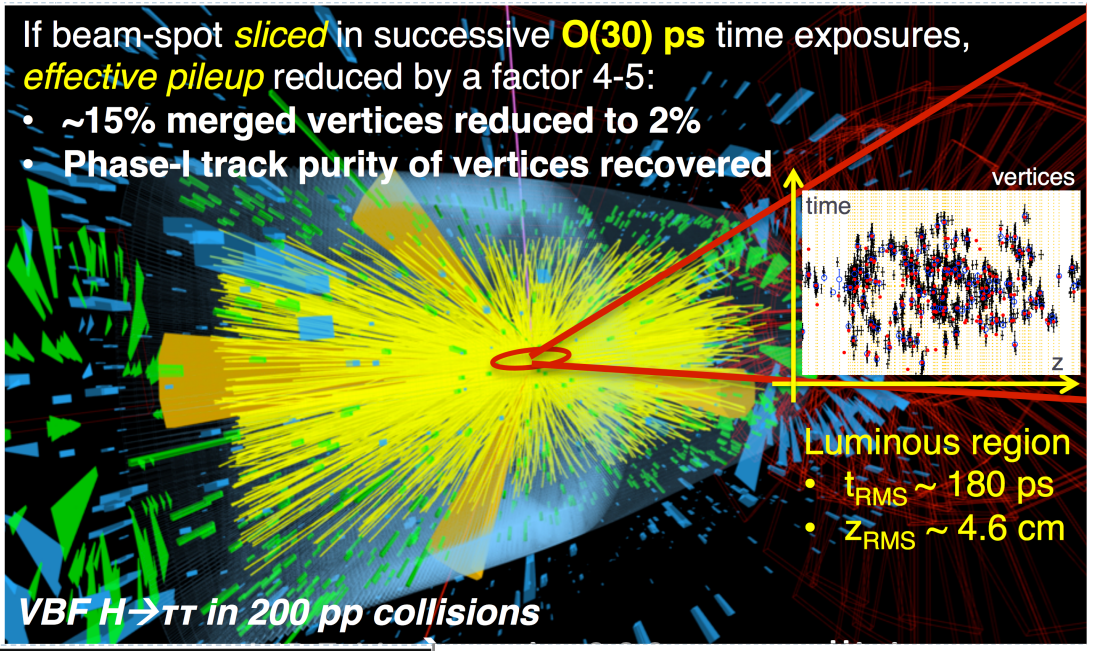
The urge for timing in tracking

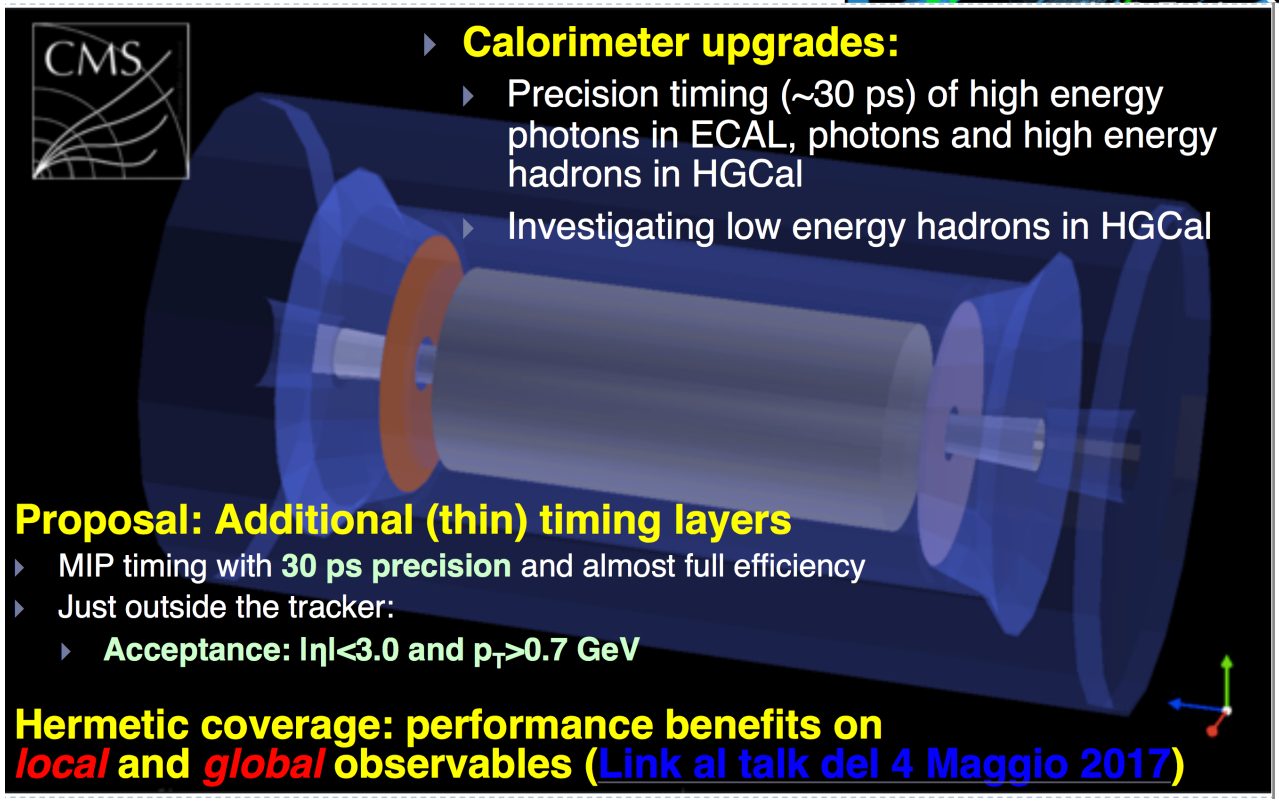
MIP Timing Detector

CMS proposal, 2017

(Slides by T. Tabarelli de Fatis INFN-MiB)

Mitigate vertex mis-reconstruction due to pile-up





Barrel Timing Layer: LYSO + SiPM

Endcap Timin Layer: LGAD

CMS phase2 proposal presently under discussion

New Dimensions in Silicon Pixel Detectors

19 October 2017
Sackville Street Building
Europe/London timezone

… Crescente interesse per pixel con timing in Hi-Lumi…

	…e — *G41, Sackville Street Building*	*Dr. Mark WILLIAMS* — 09:30 - 09:35
	Experience from the GigaTracker at NA62 — *G41, Sackville Street Building*	*Dr. Massimiliano FIORINI* — 09:35 - 10:00
10:00	**Applications at CMS and Atlas** — *G41, Sackville Street Building*	*Dr. Richard BATES* — 10:00 - 10:25
	Applications at LHCb — *G41, Sackville Street Building*	*Dr. Paula COLLINS* — 10:25 - 10:45
	Applications in Materials Science — *G41, Sackville Street Building*	*Dr. Richard PLACKETT* — 10:45 - 11:10
11:00	**Coffee** — *G41, Sackville Street Building*	11:10 - 11:30
	Applications in Medical Physics — *G41, Sackville Street Building*	*Dr. Michael TAYLOR* — 11:30 - 11:55
12:00	**LGAD Detectors: Overview** — *G41, Sackville Street Building*	*Dr. Amedeo STAINAO* — 11:55 - 12:20
	LGAD Detectors: Radiation Hardness — *G41, Sackville Street Building*	*Dr. Gregor KRAMBERGER* — 12:20 - 12:45
	3D Silicon Sensors with Timing — *G41, Sackville Street Building*	*Dr. Adriano LAI* — 12:45 - 13:10
13:00	**Lunch** — *B4 (Council Chamber), Sackville Street Building*	13:10 - 14:10
14:00	**Proposal for a 4D tracker with 3D silicon** — *G41, Sackville Street Building*	*Dr. Adriano LAI* — 14:10 - 14:35
	CMOS Detectors with Timing — *G41, Sackville Street Building*	*Dr. Gianluigi CASSE* — 14:35 - 15:00
15:00	**Developments with timepix** — *G41, Sackville Street Building*	*Dr. Xavier LLOPART* — 15:00 - 15:25
	Closing coffee — *G41, Sackville Street Building*	15:30 - 16:00
16:00		

Meeting di Manchester ad Ottobre:
Promosso da LHCb con contributi estesi (ATLAS, CMS, NA62, UFSD, Timepix …)

System Requirements

1. **Space resolution:** tens of μm
2. **Radiation hardness:** > 10^{16} 1 MeV n_{eq}/ cm^2 (sensors) and > 1 Grad (electronics)
3. **Time resolution:** ≤ 100 ps
4. Real time track reconstruction algorithms and devices

The TIMESPOT Project criteria

- Attack the problem using a system approach (time resolution concerns the complete system, not only sensors)
- Start from state-of-the-art devices, gather together esperts from different fields (rad-hard sensors, ultra-scale μ-electronics, real-time algorithm developers) and…

In a 3-4 years program:

- Study and optimize/finalize existing technologies towards high time resolution
- Conceive and build a tracking demonstrator integrating sensors, electronics and real-time processors in a single system

TIMESPOT: che cosa vogliamo fare

1. Partire da esperienze già consolidate e da metodologie già in nostro possesso in diversi esperimenti e tecnologie
2. Finalizzare le esperienze già mature nella direzione dello sviluppo di un micro-vertice con misura del tempo
3. Pubblicare (copiosamente) sui risultati intermedi (e finali) di caratterizzazione tecnologica e algoritmi di ricostruzione, che si mostrano di grande interesse per la nostra comunità scientifica (fisica delle alte energie, ma anche studi specifici su sensori innovativi)
4. Non limitare il lavoro a studi di principio ma spingerlo verso la realizzazione di un dimostratore funzionante, eventualmente di dimensioni ridotte
5. Realizzare un dispositivo completo di tutte le sue parti, dal sensore alla acquisizione e pre-processing delle tracce

TIMESPOT: che cosa NON vogliamo fare

- Il nuovo tracker di "fase 3" di ATLAS o CMS o LHCb
- Il nuovo RD53++ o CHIPX28
- Il nuovo FutureFTK

Tutte queste cose possono essere (speriamo!) conseguenze dei risultati di TIMESPOT ma appaiono oggi al di là delle sue concrete possibilità di realizzazione in un programma di ricerca tri/quadriennale

TIMESPOT Work Packages

WP1: 3D silicon sensors: development and characterization
Coordinator: GF Dalla Betta (TIFPA)
RU: Cagliari, Ferrara, Genova, Padova, TIFPA, Torino.

WP2: 3D diamond sensors: development and characterization
Coordinator: S. Sciortino (Firenze)
RU: Firenze, Genova, Perugia.

WP3: Design and test of pixel front-end
Coordinator: V. Liberali (Milano)
RU: Cagliari, Milano, Torino

WP4: Design and implementation of fast tracking devices
Coordinator: N. Neri (Milano)
RU: Bologna, Milano.

WP5: Design and implementation of high speed readout boards
Coordinator: A. Gabrielli (Bologna)
RU: Bologna.

WP6: System integration and tests.
Coordinator: A. Cardini (Cagliari)
RU: All

Sviluppo dispositivi
Specialmente anni 1° e 2°

Integrazione di Sistema
Specialmente anni 2° e 3°

TIMESPOT: Richieste finanziarie

ITEMS	2018	2019	2020	Totals
Travel expenses	62	72	67	201
Consumables	186,5	172,5	77	436
Instrumentation	39	0	0	39
SW licenses	6	6	6	18
System construction	16	16	70	102
Man power	69	92	23	184
Totals per year	**378,5**	**358,5**	**243**	**980**

La risposta della CSN 5 è stata molto positiva e incoraggiante: per il 2018 assegnati 356 k€, con un taglio (minimo) ~ 9%

Gantt diagram, Milestones (Mx) and Deliverables (Dx)

WP	Activity	Tasks	2018 Q1 1	2	3	Q2 4	5	6	Q3 7	8	9	Q4 10	11	12	2019 Q1 1	2	3	Q2 4	5	6	Q3 7	8	9	Q4 10	11	12	2020 Q1 1	2	3	Q2 4	5	6	Q3 7	8	9	Q4 10	11	12
1	3D silicon sensors for timing: development and characterization	Optimization studies and device modeling																																				
		Design & submission of 1st prototype							M1																														
		Producion of 1st prototype																																				
		Testbench characterization of 1st prot.													D4																							
		Design & submission of 2nd prototype																		M6																		
		Producion of 2nd prototype																																				
		Testbench characterization of 2nd prot.																									D9											
2	3D diamond sensors for timing: development and characterization	Optimization studies and device modeling																																				
		Fabrication of 1st prototype									M2																												
		Testbench characterization of 1st prot.											D2																									
		Fabrication of 2nd prototype																M5																				
		Testbench characterization of 2nd prot.																		D8																		
		Fabrication of 3rd prototype																						M9														
		Testbench characterization of 3rd prot.																									D11											
3	Design and test of front-end IC for pixel readout	Design of front-end & test structure mini@sic										M3																										
		Design of TDC cell & readout IF mini@sic										M3																										
		Prod & packaging of 1st mini@sic prototype																																				
		Test-bench preparation (test PCB)																																				
		Tests on front-end & test structure mini@sic																D5																				
		Tests on TDC cell & readout IF mini@sic																D6																				
		Design and submission of pixel IC																				M7																
		Production of pixel IC																																				
		Tests of pixel IC																									D12											
		Design and submission of pixel IC (2nd version)																												M14								
		Prod of pixel IC (2nd version)																																				
		Tests on 2nd version																																				D15
4	Design and implementarion of fast tracking devices	Optimization of 4D algorithm																																				
		Definition of device architecture													M4																							
		Simulations at device level																																				
		Emulated tracks and DAQ/Retina boards																									M13											
		Emulated tracks at high rates and TDAQ/Track board																												M15								
		Integration with demonstrator and test beam																																				D16
5	Design and implementarion of high speed readout boards	Construction of 4 Pixel-ROD board for DAQ							D1																													
		Firmware optimization for TIMESPOT DAQ use																																				
		DAQ system for TIMESPOT lab tests													D3																							
		Design of new TDAQ board with real time track rec.																					M8														
		TDAQ/Track board production																																				
		TDAQ/Track board tests																									D13											
		Integration with demonstrator and test beam																																				D16
6	System tests and integration, demonstrator tests	Organization of test beams and assembly (bonding) procedures																																				
		Rad. resistance tests on 1st sensor prototypes																								M10												
		Rad. resistance tests on 1st F/E ASIC																								M11												
		Sensor & FE assembly (mini@sic prototype)																	D7																			
		Radiation tests on 1st F/E assembly																								M12												
		B-Bonding of pixel ASIC																									D10											
		Tests on sensor-bonded pixel IC																												D14								
		1-layer system test (sensor+F/E+TDAQ)																																		M16		
		Full system demonstrator test																																				D16

Date delle produzioni e test di sensori ed elettronica da discutere, chiarire e decidere

Obiettivi della riunione di oggi

1. Conoscerci meglio e fare gruppo. Stabilire connessioni personali e operative all'interno dei singoli WP e non.
2. Focalizzare gli obiettivi globali e specifici, in particolare per il 2018.
3. Condividere, per ciascun WP, la visione delle persone direttamente coinvolte e stabilire dei traguardi puntuali nella scaletta temporale
4. Darci un calendario di incontri
5. Confrontarci su esigenze e proposte dei singoli gruppi e persone.

Passeremo in rassegna i singoli WP, con maggiore spazio assegnato ai primi 3, quelli più sotto pressione nel 2018.

Il tempo sarà poco per entrare in tutti i dettagli e prendere tutte le decisioni necessarie

→ pianificheremo degli incontri a breve per definire meglio il programma di lavoro

…altre questioni pratico-organizzative nella discussione conclusiva alla fine del meeting

RU	WP#	Item Description	Financial year (k€)				RU used infrastructures
			2018	2019	2020	chapter	
Bologna		FTE	2,1	2	2		CAD licenses for design and simulation of FPGA-based electronics and PCB. Electronics lab with advanced tools for in-depth digital tests of high speed electronics.
	5	4x Components for TDAQ PCB	16	0	0	sys	
	5	Components for DAQ board re-work	2	0	0	cons	
	5	Motherboard PCI-express	2	0	0	instr	
	5	Components supply for DAQ & Track PCB	0	10	0	sys	
	4,5,6	DAQ and Track-finding board	0	0	30	sys	
	4,5,6	Travel expenses	7	7	7	travel	
		Tot Bologna	27	17	37		
Cagliari		FTE	4,5	6	5		CAD licenses for IC design. CAD licenses for sensor modeling. Electronics lab for system tests (both digital & analog). Probe stations for sensor characterization
	1	Components for probe station update	10	4	0	cons	
	1	Components & consumables for sensor die test	5	3	2	cons	
	1	TCAD license maintenance	2	2	2	lic	
	1	ps Pulsed laser for timing tests on sensors	30	0	0	instr	
	3	mini@sic TSMC 28nm (1st prot digital part)	22	0	0	cons	
	3	Packaging for standalone IC tests	5	0	0	cons	
	3	IC Verification at IMEC	5	0	0	cons	
	3	Test bench consumables for pixel IC prototype	3	5	5	cons	
	6	Consumables for radiation tests	0	5	0	cons	
	6	Construction of proto tracker demonstrator	0	6	20	sys	
	3	Man power (AdR)	23	23	0	mpower	
	1,3,6	Travel expenses	17	20	18	travel	
		Tot Cagliari	122	68	47		
Ferrara		FTE	1	1	1		CAD license for sensor modeling. Multi-core CPU for sensor simulation
	1	TCAD license maintenance	2	2	2	lic	
	1,4	PC for TCAD modeling & PCI express	5	0	0	instr	
	1,6	Travel expenses	3	2	2	travel	
		Tot Ferrara	10	4	4		
Firenze		FTE	2	2,5	2,5		Laser-based diamond sensor fabrication facility. Laboratory for complete characterization of solid state sensors.
	2	CVD material	9	19	0	cons	
	2	Notch filters for Raman lab	7	0	0	cons	
	2	Update and maintenance graphtization sys.	3	3	2	cons	
	2	Consumables for electric characterization tests	13	10	7	cons	
	2	Amplifier for timing tests	2	0	0	instr	
	2,6	Travel expenses	7	8	8	travel	
		Tot Firenze	41	40	17		

Genova		**FTE**	0,3	0,6	1		High fluence X-ray source for radiation tests on sensors & electronics
	1,2	New W anode for X-Ray source	3,5	0	0	cons	
	1,2	PIN diode for X-source dose calibration	1	0	0	cons	
	1,2	consumables for X-Ray source running	0	3	2	cons	
	1,2	Travel expenses	0	1	2	travel	
		Tot Genova	**4,5**	**4**	**4**		
Milano		**FTE**	3,1	4	3		CAD licenses for IC design. CAD licenses for design and simulation of FPGA-based electronics. Electronics lab for system tests (both digital & analog).
	3	mini@sic TSMC 28nm (1st prot analog part)	22	0	0	cons	
	3	mini@sic TSMC 28nm (2nd prot)	0	22	0	cons	
	3	IC Verification at IMEC	5	5	0	cons	
	4	Packaging for standalone IC tests	5	5	0	cons	
	4	Test bench consumables for fast tracker PCB	5	0	0	cons	
	4,5	DAQ and Track-finding board	0	0	20	sys	
	3	Man power (AdR)	23	23	0	mpower	
	3,4,6	Travel expenses	12	14	12	travel	
		Tot Milano	**72**	**69**	**32**		
Padova		**FTE**	1	1	1		Laboratory for complete characterization of solid state devices
	1	Consumable for Si test lab	4	3	2	cons	
	1	microbeam trigger syst. (p-therphenyl+SiPM)	1	1	0	cons	
	1	Contribution to microbeam pos. Monitor	2	0	0	cons	
	1,6	Travel expenses	2	2	2	travel	
		Tot Padova	**9**	**6**	**4**		
Perugia		**FTE**	1	2	2		CAD licenses for device modeling
	2	TCAD license maintenance	2	2	2	lic	
	2	Man power (AdR)	0	23	23	mpower	
	2,6	Travel expenses	2	4	4	travel	
		Tot Perugia	**4**	**29**	**29**		
TIFPA		**FTE**	3	3	2		CAD licenses for device modeling. Laboratory for complete characterization of solid state devices
	1	Consumables for electric characterization tests	2	6	0	cons	
	1	Consumables for test beams	0	0	5	cons	
	1	Si-Si DWB	12,5	12,5	0	cons	
	1	Prelim. Tests on trench etching @ FBK	7,5	0	0	cons	
	1	2 x 3D-trenched batch @ FBK	27	27	0	cons	
	1	Prototype bump bonding	0	30	18	cons	
	1	Man power (AdR)	23	23	0	mpower	
	1,6	Travel expenses	9	9	7	travel	
		Total TIFPA	**81**	**107,5**	**30**		
Torino		**FTE**	1,25	2,5	2,5		CAD licenses for IC design. Laboratory for complete characterization of solid state devices
	1,6	Consumables for electric characterization tests	5	4	2	cons	
	6	Consumables for test beams	0	5	5	cons	
	3	mini@sic TSMC 28nm (3rd prot)	0	0	22	cons	
	3	Design review at IMEC	0	0	5	cons	
	1,3,6	Travel expenses	3	5	5	travel	
		Total Torino	**8**	**14**	**39**		
		TIMESPOT total requested budget	**378,5**	**358,5**	**243,0**		**980,0**
		Total no personnel requests	**309,5**	**266,5**	**220,0**		**796,0**