ITk: Project status and news

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Milano, ITK Italia, June 8th 2015

Outline

- ✓ LHC Schedule and implications on ITK schedule
- ✓ [Descoping and costing exercise]
- ✓ ITK Layout
- ✓ Pixel organization for production

- News in Steve's talk at ITK General – June 4th

https://indico.cern.ch/event/379763/

- Module Production discussion – May 28th

https://indico.cern.ch/event/396129/

HL-LHC Timetable changes: Discussion

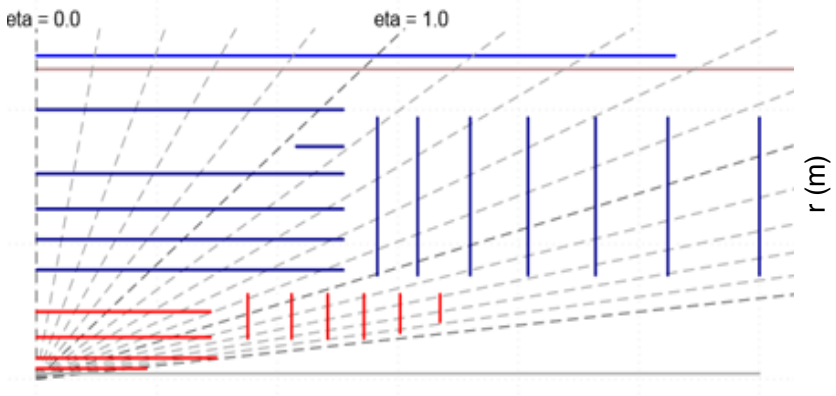
- ATLAS weekly on Tuesday 26th May. See Dave's presentation
- https://indico.cern.ch/event/395974/contribution/1/material/slides/0.pdf
- Slide 7: These changes are still under discussion within CERN and not public.
- How would the ITk respond in general and for the TDRs in particular?
  - Unanimous response = We do not want to slip the ITk timetable by 1 year.
  - There was a discussion of slipping by 6 months.
  - For now we hold the existing TDR timetable, the production timetable continues to be discussed as we accumulate more information about the production time, layout and costing.
  - We will now look at possible slippages to the TDRs at the time of (and probably as part of) the Lankford review on 23rd November (1 whole day). This will also avoid the potentially embarrassing possibility of slipping the schedule twice in less than 12 months.
  - Today the schedule is still:
    - *Layout TF report in Q1 2016*
    - Strips TDR in Q4 2016
    - *Pixel TDR in Q4 2017*
    - Decommissioning report in Q4 2017

Layout definitions: requirements

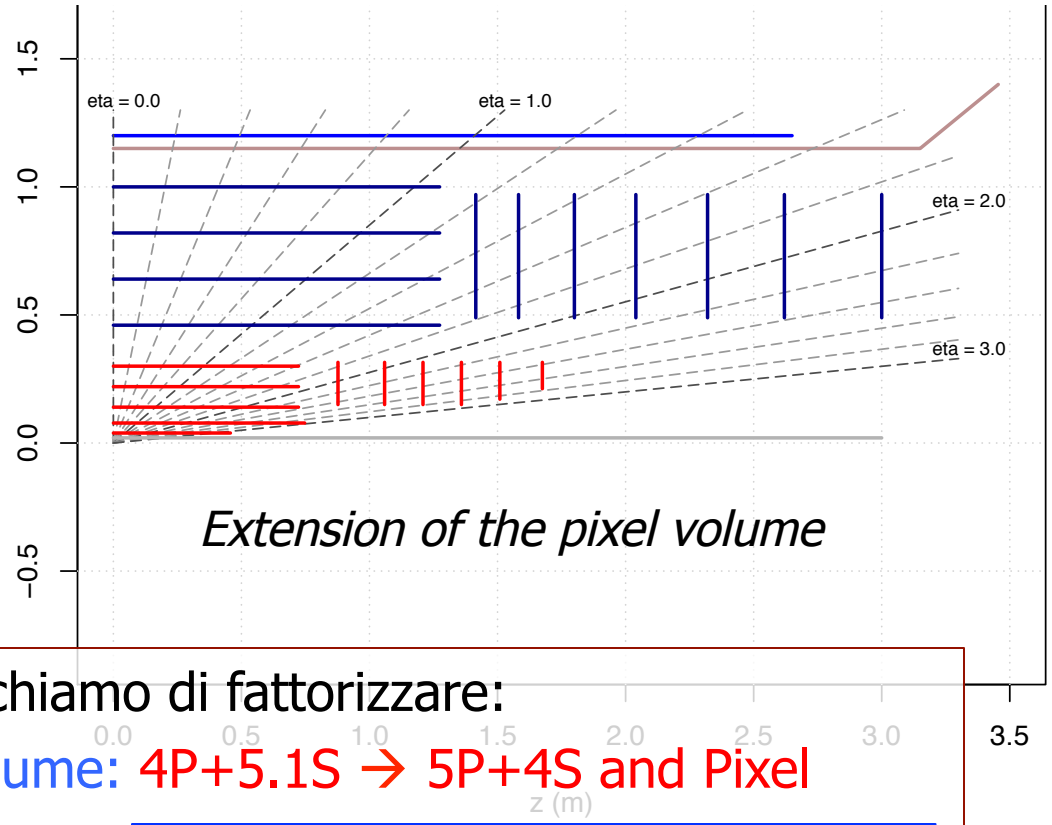
- ✓ La definizione del layout non dipende direttamente ne' dalle tecnologie scelte per i sensori ne' dalle ottimizzazioni per supporti e servizi.

- ✓ Idealmente descrive la posizione migliore dei sensori per ottenere le perfomance richieste e inclusi i requirements di disegno.
  - Per questo la definizione dei Requirements e' cruciale e ci si sta lavorando da alcuni mesi
  - → in CDS tra una settimana, prima versione (tracking requirements noti fino a $|\eta|<2.7$)
    - https://twiki.cern.ch/twiki/bin/view/Atlas/ITkLayoutTaskForce

Layout definitions: critical items



Letter of Intent



Extension of the pixel volume

- ✓ Due i temi principali che cerchiamo di fattorizzare:
  - Extension of the pixel volume: 4P+5.1S → 5P+4S and Pixel radius to ~39 mm
  - Forward region:
    - Transition Barrel → Endcap
    - High-η coverage
    - **New Baseline:** η coverage 2.7→ x.y

Schedule:
- *June 23rd: discussion of new baseline*
- *mid-Sep: definition of new baseline*
- *mid-Nov: discussion of layouts*

Towards the pixel volume extension

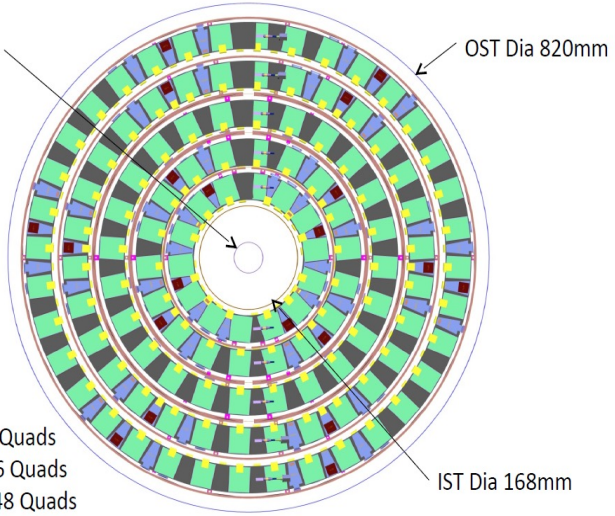
Key ingredients for the decision:

- ✓ Feedback from detector communities
  - Motivations (pixel and strips)
  - Strip: impact and optimization of the end-cap; (Short vs Long strip)
  - Project feasibility (pixel)!
- ✓ Costing 'neutrality'
  - Pixel increase ~ 12 MChF; Strips optimization ~ 10MChF
- ✓ Physics motivations
  - Measurements: Track efficiency and fakes rejection, space points seeding, flavour tagging in dense environment, conversions, strip occupancy.
  - Tools: single particles+pile-up in full sim, Tide*; … use Run 1 experience to extrapolate to HL-LHC case.
  - Layout: focus on barrel region

Pixel

✓Ci sono diversi aspetti da considerare:

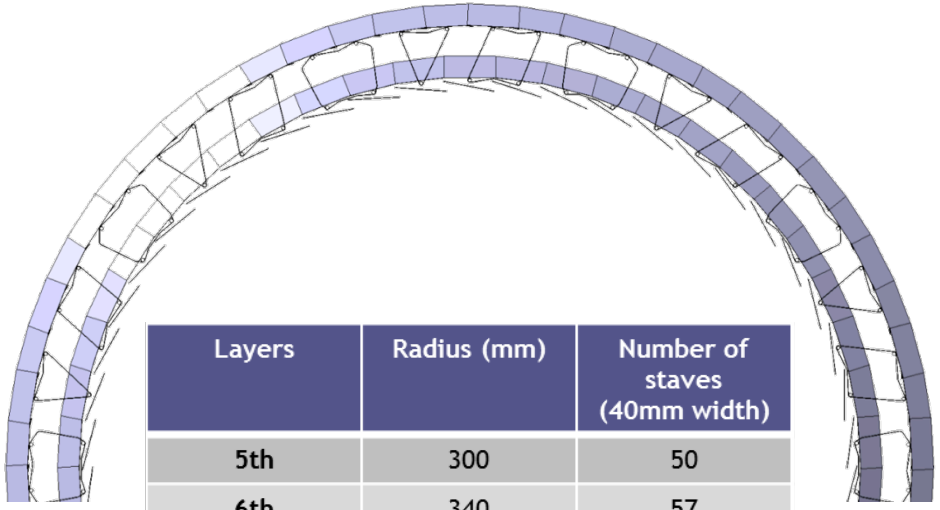
- Come ridistribuire i 5 layes di Pixel e i 4 layers di Strip nei relativi volumi.
- Come estendere la coperture in R dei Pixel rings.
- Quale tecnologia adottare per il quinto layer?
- Dobbiamo tenere spazio per un sesto layer, nel caso una tecnologia molto piu' economica degli ibridi classici si materializzi in tempo.



Active areas:
Layer 1 R95 to R135 - 28 Quads
Layer 2 R150 to R190 - 36 Quads
Layer 3 R212.5 R252.5 - 48 Quads
Layer 4 R275 to R315 - 60 Quads
Layer 5 R337.5 to R377.5 72 - Quads

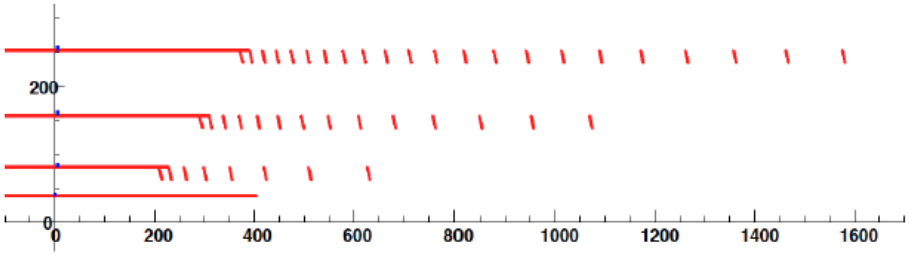
End-caps (5 rings)

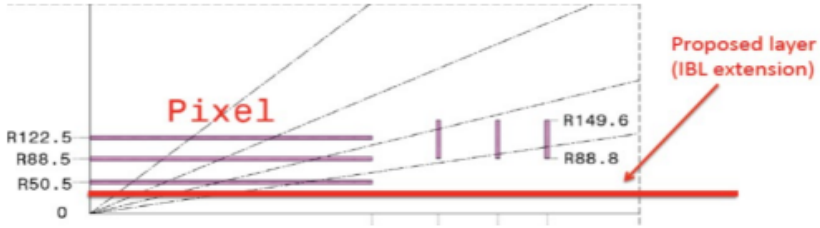
Barrel

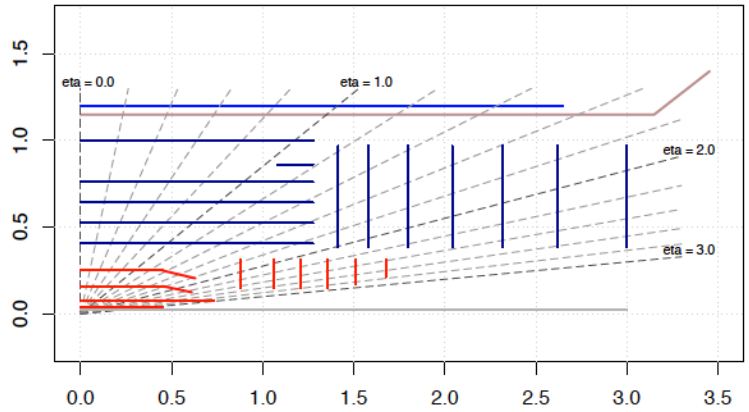


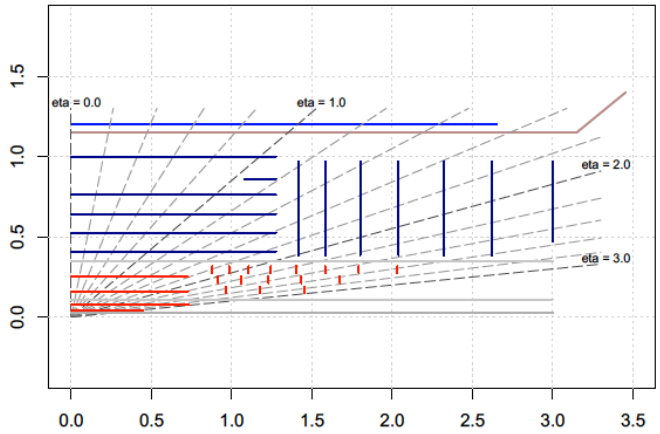
Layers	Radius (mm)	Number of staves (40mm width)
5th	300	50
6th	340	57

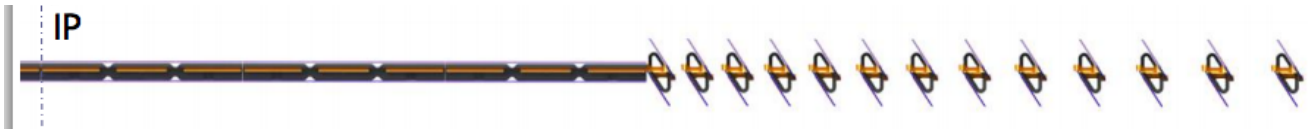
Forward region: Some Pixel options…









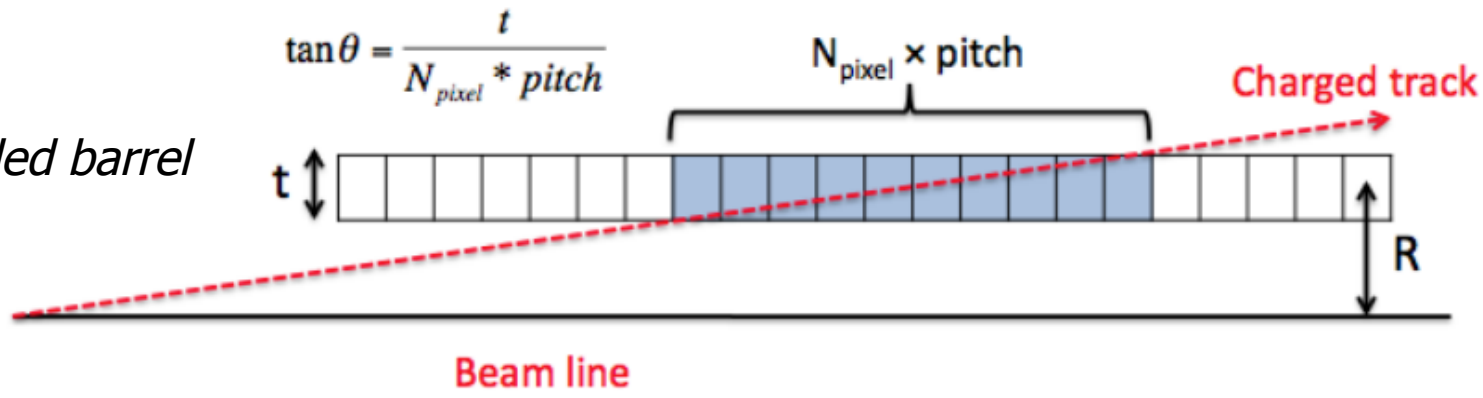


- ✓ It is not time yet to discuss in the ILTF the individual solutions as they can be optimized once they will get inputs from the requirements and performances.

Forward region

- ✓ We still need to define clear requirements based on physics performance expected in that region.
  - Not clear indications by the Large eta TF.
- ✓ Once we have the tracking requirements (fake rates, tagging, etc…) they can be tested in the layout options.
- ✓ An important ingredient is the optimization of the tracking exploiting the cluster shapes in the pattern recognition for all sorts of layouts.

Extended barrel



ATLAS Pixel Module Production

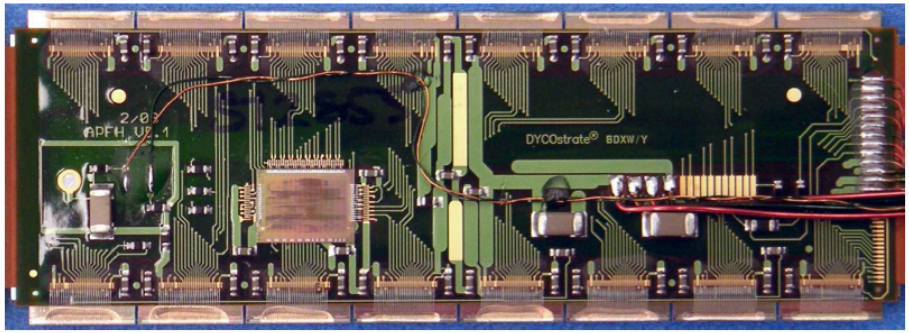
- ✓ LoI was ~ 10 m^2
- ✓ The options described (Extension of the pixel volume, very forward region at $|\eta| > 2.7$) substantially enlarge the surface up to 14-18 m^2
  - 12-13 k quad modules → ~200 modules/week for a production in 2 years

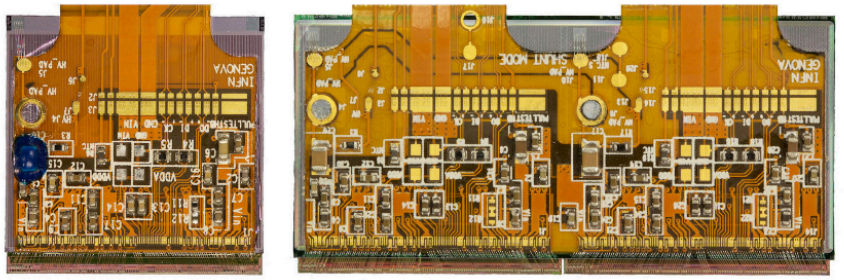
✓ Pixel Detector:

- Production: 2004-2006
- Surface: 1.73 m^2
- **1744** modules installed
- 16 FE chips per sensor tile

✓ IBL Detector:

- Production: ~2013
- Surface: 0.15 m^2
- **168 DC + 112 SC** modules installed
- 1 or 2 FE chips per sensor tile



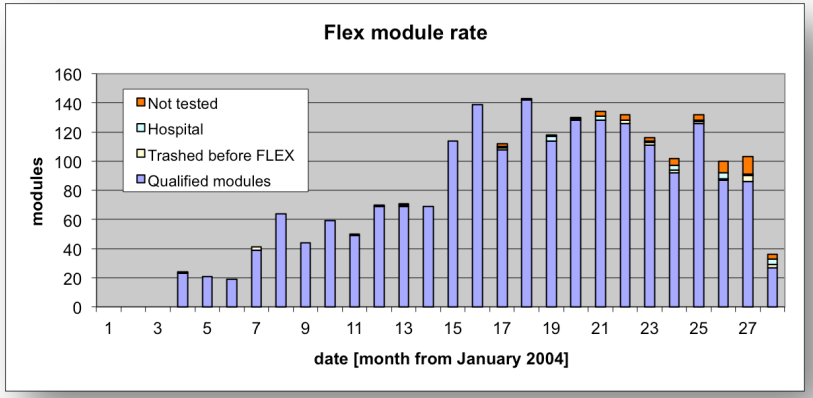


(a) (b)

ATLAS Pixel Module Production

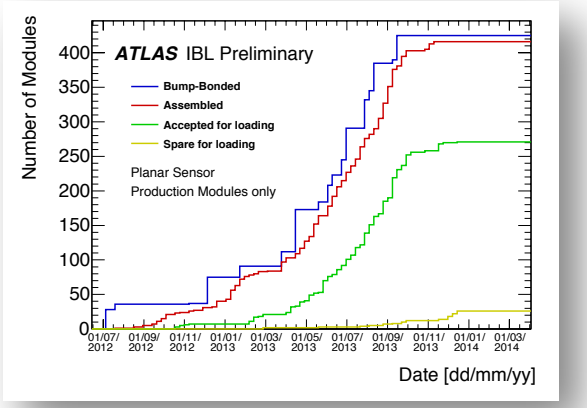
✓ Pixel Detector:

- Sites:
  - **3** Bare module QA sites
  - **5** Module Assembly sites
  - **5+1** Module QA sites
- Production peak:
  - 140 modules/month
- Paper: 2008 JINST 3 P07007



✓ IBL Detector:

- Sites:
  - ***No Bare*** module QA
  - **2** Module Assembly sites
  - **2** Module QA sites
- Production peak:
  - 50 DC + 25 SC modules/ month
- Jinst Paper in preparation.



Module assembly

First preliminary review of potential assembly sites last week:

- UK : 4 sites
- US : 4 prod sites + 1 test site
- Germany: 4 sites
- Swiss: 2 sites
- CERN : focus on loading and repair, could be a secondary assembly site
- Japan : at least 1 site
- Italy : at least 1 prod + 1 test site

- 20-30 modules/week per site looks feasible.
- Need to involve new groups (new potential productions sites). Look for commitments at institute/country level.
- Try to make the assembly procedure more efficient; standardize setups; look into industrial partnership for assembly.
- Speed-up testing procedure (more parallelism in the readout, look for common software solutions to facilitate data and hardware exchange).

Bump Bonding

Potentially a bottleneck. Several vendors on the market, but most of them must be qualified. In general, this is a low volume production (not much applications outside HEP).

- We are starting a review of the status of the BB provides already working with us. More should be contacted.
- Should we consider new approaches (e.g. bump deposition at the companies, but part of the flip-chip in institutes)?
- CMOS active sensors could alleviate the problems (capacitive coupling insisting on different companies/structures).
- We are planning a systematic test of BB providers, between end of 2015 and mid of 2016. Need to organize it carefully, both from technical and financial point of view (production size and time could vary from vendor to vendor, but we need to find resources to test a large number of providers).

Bump-Bonding vendors

- IZM : good experience in ATLAS. Starting tests of thin chip/sensors, high bump density. Estimated capacity : 30-40 mod/week
- Selex : good experience in ATLAS. Start testing high density / 12" wafers.
- HPK : testing the process on FE-I4 modules. Estimated capacity: 30-50 mod/week
- LETI/Advacam : testing the process with FE-I4 modules.
- RTI : new for ATLAS, but may projects in HEP (including bump densities similar to ITk). Estimated capacity : up to 100/week.

In general, bump deposition is not seen as a bottleneck, but the different techniques must be demonstrated with thin chips/ sensors, 12" wafers (FE-65), 50x50 μm^2 bump pitch.

Flip-chip is usually the bottleneck. We may consider doing part of it in some lab (using existing flip-chip machines, buying new ones or trying the have them with some form or leasing contract).

Module Assembly and testing

- ✓ Contributions for module production came from
  - Udine: QA of sensors
  - Milano: QA of all Selex bare modules

- ✓ Genova lab has been one of the assembly and testing sites in the past:
  - For the Pixel detector built ***892/1952*** of the Barrel modules, mainly from Selex. Some part of the QA has been dislocated to other labs towards the end of the production.
  - For IBL Bonn and Genova **have equally shared** the module assembly and qualification.
- ✓ An Italian cluster is certainly envisageable to optimize logistics with
  - sites testing sensors and bare modules (if necessary)
  - Genova concentrating on module assembling (one more site for assembly?) with other more sites supporting in testing.

Items che richiedono attenzione

- ✓ Bump-bonding e alternative (incollaggi capacitivi).
- ✓ Simulazione, tracking performance.
  - Abbastanza manpower sul layout, pochissimo su pixel.
  - Tools a disposizione: IdRes, FATRAS, single particle gun + pu, full simulation
- ✓ Supporti meccanici (soprattutto globali).
- ✓ Interconnessioni, trasmissione dati lungo gli staves.
  - ATLAS-CMS workshop on Reliability, Risk analysis and mitigation 20-21 luglio.
- ✓ Schemi di powering (la baseline e' serial powering).
- ✓ Sistemi di readout: interfaccia con TDAQ, track trigger, ottimizzazione dei test dei moduli

Contributo italiano …

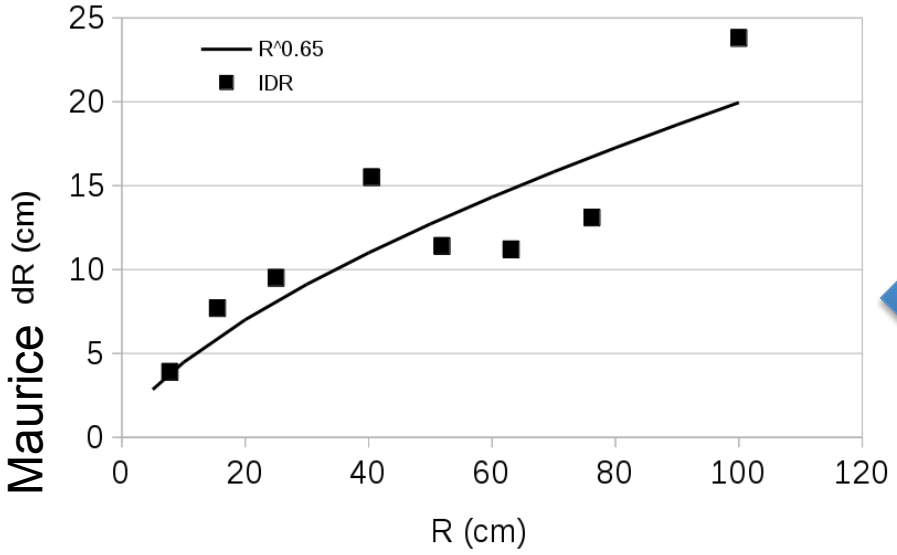
Nel contesto della pianificazione del lavoro futuro, sarebbe importante anche per i gruppi INFN definire in modo più preciso le aree di interesse ed intensificare I contributi nei gruppi di lavoro ITk.

- ✓ Sensori 3D (FBK)
- ✓ Readout, sistemi di test
- ✓ Produzione, assemblaggio e test di moduli
- ✓ Bump-bonding (Selex)
- ✓ Simulazione e tracciamento
- ✓ Track trigger
- ✓ CMOS sensors (STM + …)
- ✓ Meccanica

spare

Towards June workshop: 5P+4S

- ✓ As a follow up of the upgrade week, discussion with detectors and agreed to test only the following two options fitting in the envelope of 380 mm for the pixel radius:
  - Same equidistant strip layers → a la Ingrid
  - Two options for the pixel to explore the sensitivity to fakes of interdistance between layers



Maurice

Efficiency of a seed with 3 space points resulting in a successful track candidate

<μ>	PPP	PPS	PSS	SSS
0	57%	26%	29%	66%
40	17%	6%	5%	35%

Andi S.

Towards June workshop: 5P+4S

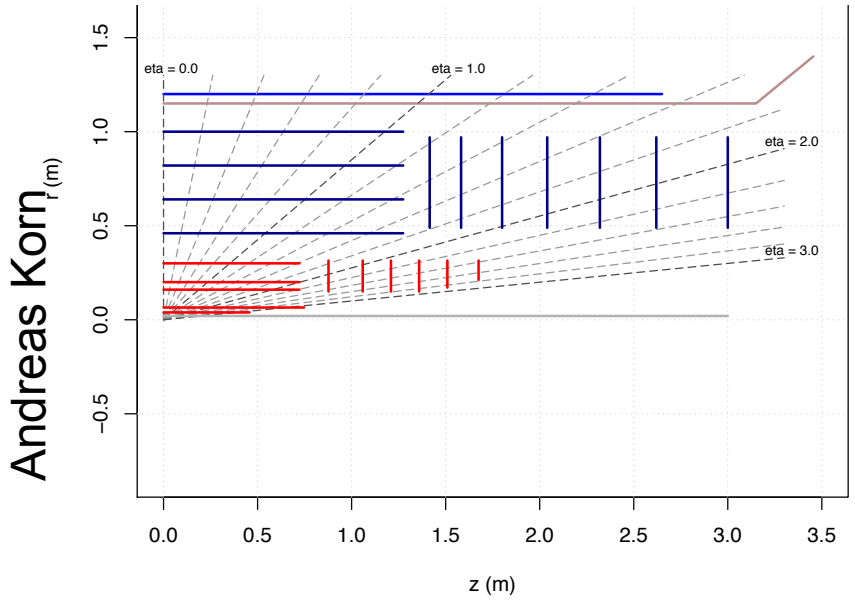
Layout 1 (pixel doublets/equidistant strips)

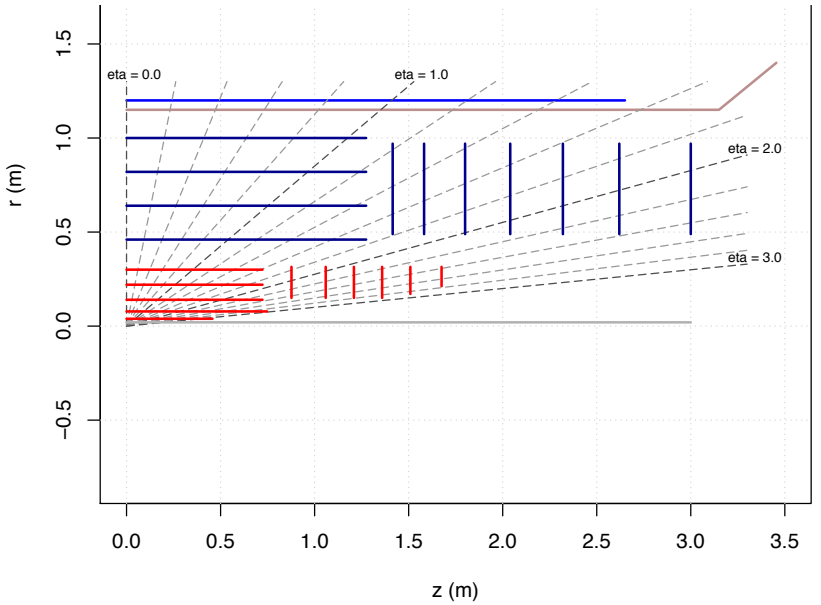
- Pixel radius (mm): 39, 65, 160, 200, 300
- Strip radius (mm): 460, 640, 820, 1000

Layout 2 (traditional)

- Pixel equidistance is impossible for costing
- Pixel radius (mm): 39, 80, 140, 220, 300 (*)
- Strip radius (mm): 460, 640, 820, 1000

(*) very close to Paolo's original proposal





Strips layout optimization

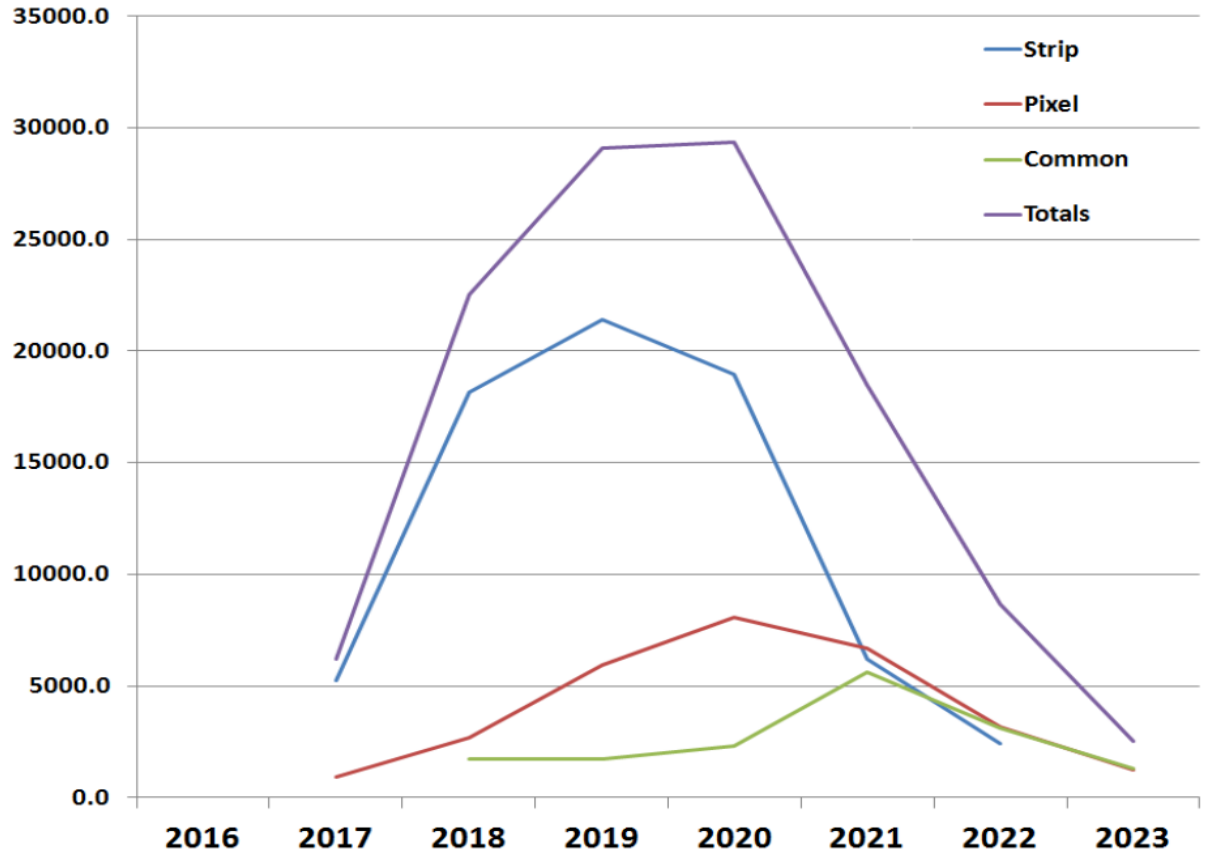
- ✓ Define barrel length, removal of stubs and endcap z-positioning is indicated as a priority for strip project.
  - Detector: give inputs to the minimum distance barrel -endcap and on bandwidth limitations
  - Occupancy in strips set a limit to the barrel length
  - Momentum resolution and hermeticity optimization
- ✓ IDres and FATRAS can evaluate these performances given inputs from Tide (it can give input to understand which the crucial occupancy) and detector.
- ✓ Propose to do these studies with Layout 1.

ITk descoping and costing exercise

- Il documento che definisce le opzioni per l'upgrade di fase II di ATLAS, con costi di 275, 235 e 200 MCHF, è in fase di rifinitura. Dovrebbe essere in circolazione per commenti nelle prossime 2-3 settimane.
- Come già detto, dal punto di vista ITk si tratta di un esercizio un po' formale. Le riduzioni identificate riguardano soltanto le Strips e l'estensione ad alto η (cioè oltre η=2.7).
- Entro la fine dell'anno dovremo avere una definizione del processo di approvazione dei TDR e una definizione dell'envelope finanziario (presumibilmente senza l'agreement formale delle FA).
- Se interpreto bene il pensiero del management, l'idea sarebbe di atterrare su un numero compreso tra 275 e 235 M, che possa consentire la realizzazione di un ITk completo (~125 M).

Profilo di spesa (Full ITk, η=2.7)

Totals



	2016	2017	2018	2019	2020	2021	2022	2023	
Strip		5260.00	18180.00	21420.00	18980.00	6200.00	2410.00		72450.0
Pixel		927.6	2661.6	5924.4	8055.9	6667.3	3152.3	1227.1	28616.3
Common			1700.0	1750.0	2300.0	5600.0	3100.0	1310.0	15760.0
Totals		6187.60	22541.64	29094.36	29335.94	18467.31	8662.30	2537.12	116826.3

Pixel Costing: updates

- Il modello di costo dei Pixels è ancora rudimentale. La parte relativa ai moduli è stata aggiornata con offerte recenti, quindi è realistica almeno per sensori planari. Il resto (meccanica, servizi,…) ha ancora grandi incertezze.
- Il costo dei moduli dipende dallo spessore. 150 μm è lo standard, ma si potrebbe risparmiare sui layers esterni usando 200 μm. Il bump bonding rappresenta comunque una frazione importante del costo:

  Sensor: 25-40 €/cm² FE chip: 14 €/cm² Bump Bonding: 40-45 €/cm²

	Sensors	FE	BB	On-det el	Mechanics	Services	Power supplies	Other	Tot Mod	Tot
Layer 1-2	919.42	246.82	935.22	718.34	333.50	801.16		227.92	2101.45	4182.37
Layer 2-3	2693.24	922.99	3412.06	1158.08	1656.11	1373.72		379.77	7028.29	11595.97
Rings	2361.32	806.20	2980.33	708.70	1307.50	1259.60		295.25	6147.85	9718.90
Other		1366.00				369.28	1383.74			
	5973.98	3342.01	7327.61	2585.12	3297.11	3803.76	1383.74	902.94	16643.59	28616.27
Cost / m^2	627.83	351.23	770.09	271.68	346.51	399.76	145.42	94.89	1749.16	3007.43

Module assembly rates

- ✓ Both for pixel and IBL, assembly of 4 modules/day was a good rate.
- ✓ Need to foresee indeed, beside the gluing, all the sequent actions as wirebonding, pull test, documentation and first electrical tests.
- ✓ Bottleneck in the past was due to testing and mainly debug of problematic modules.
  - Keeping a rate of 10 qualified module/week was achievable with 7/7

- ✓ If testing is optimized, assembly and debug will become the possible bottlenecks.