Attività LHCb - 2016

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INFN - Sezione di Milano

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Physics highlights and Run II perspectives

Run I data sample

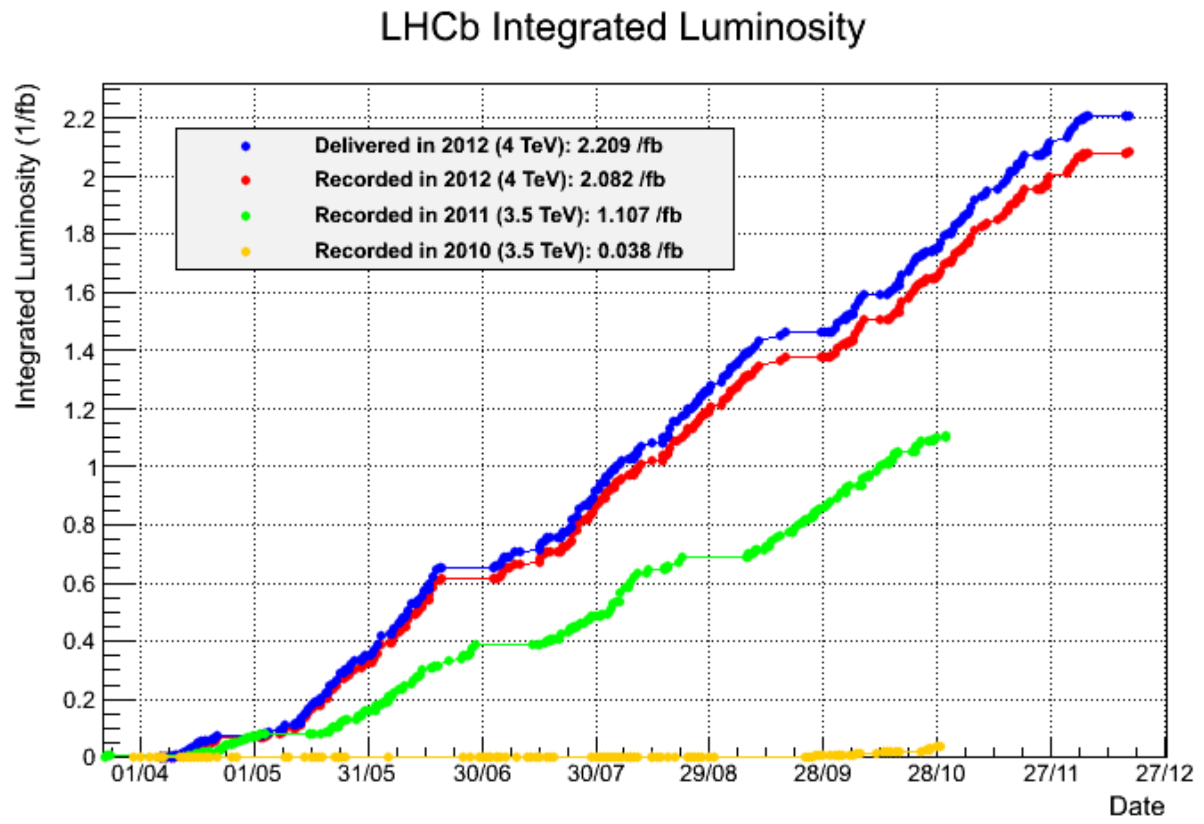
- Integrated luminosity
  $1 fb^{-1} + 2 fb^{-1}$ at 7 and 8 TeV

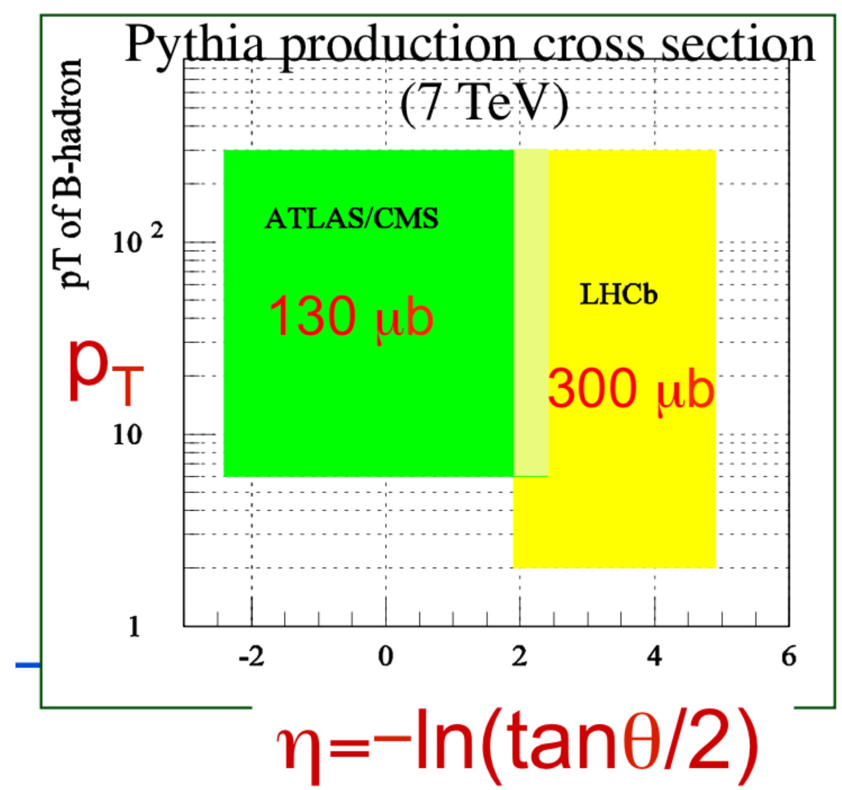
- Quark pairs within detector acceptance

  - 59 x 10^{11} $c\bar{c}$

  - 26 x 10^{10} $b\bar{b}$

- Large production of *B* mesons and *b*-baryons, i.e. 1 Λ_b every 2 B^0

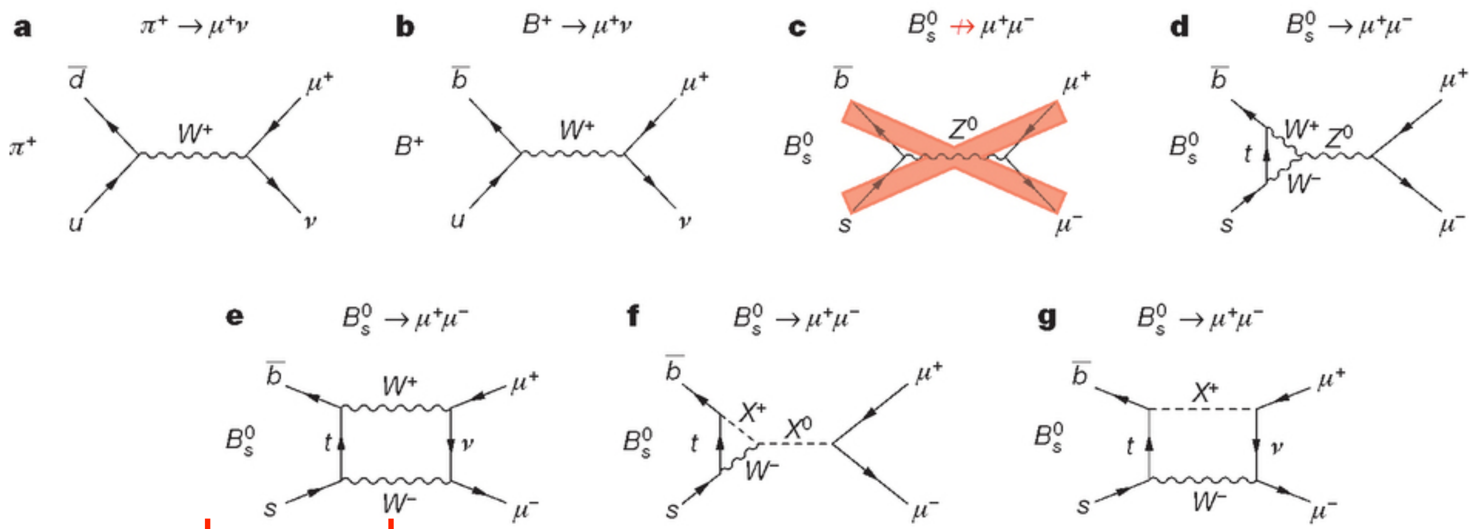




Observation of $B_s^0 \to \mu^+\mu^-$ decay

- Very rare in Standard Model due to
  - absence of tree-level FCNC
  - helicity suppression
  - CKM suppression

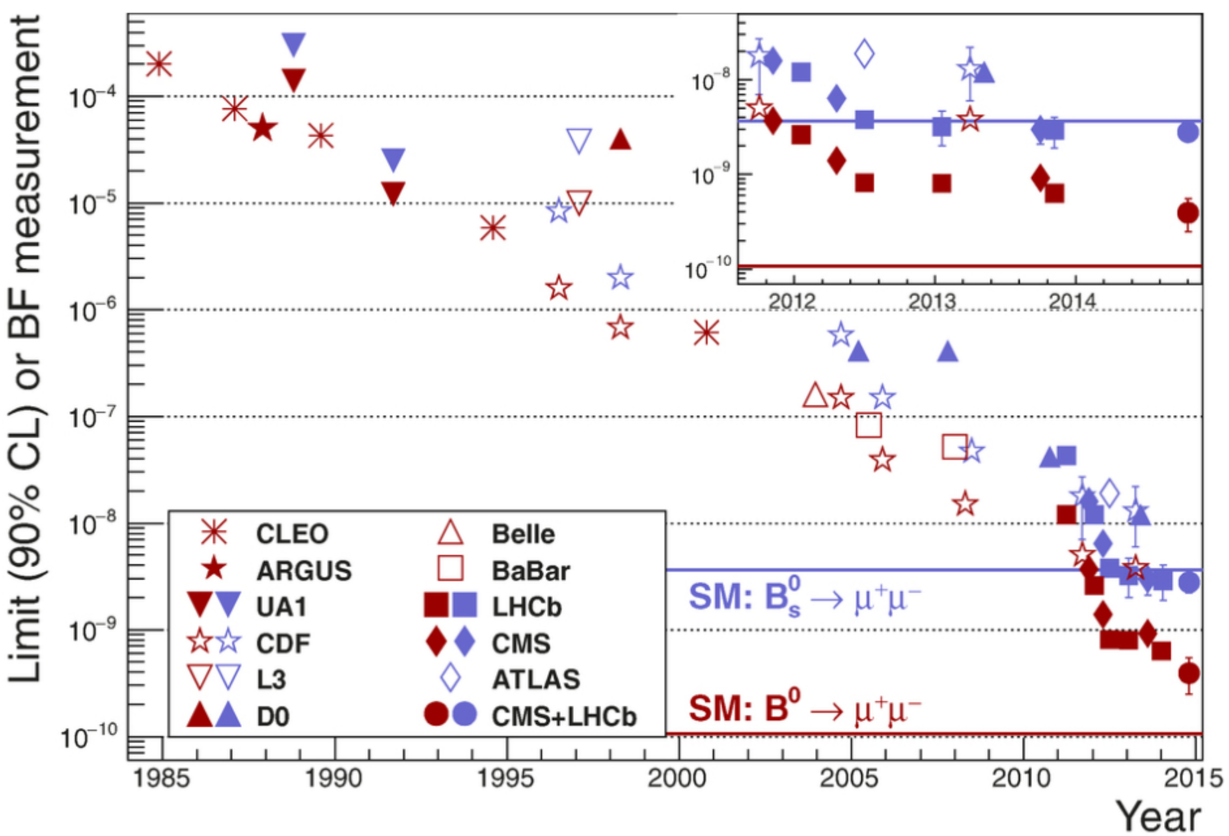
Nature 522 (2015) 68



... features not necessarily reproduced in extended models

$\mathcal{B}(B_s \to \mu^+\mu^-)_{SM} = (3.66 \pm 0.23) \times 10^{-9}$

Searched for over 30 years!



Observation of $B_s^0 \to \mu^+\mu^-$ decay

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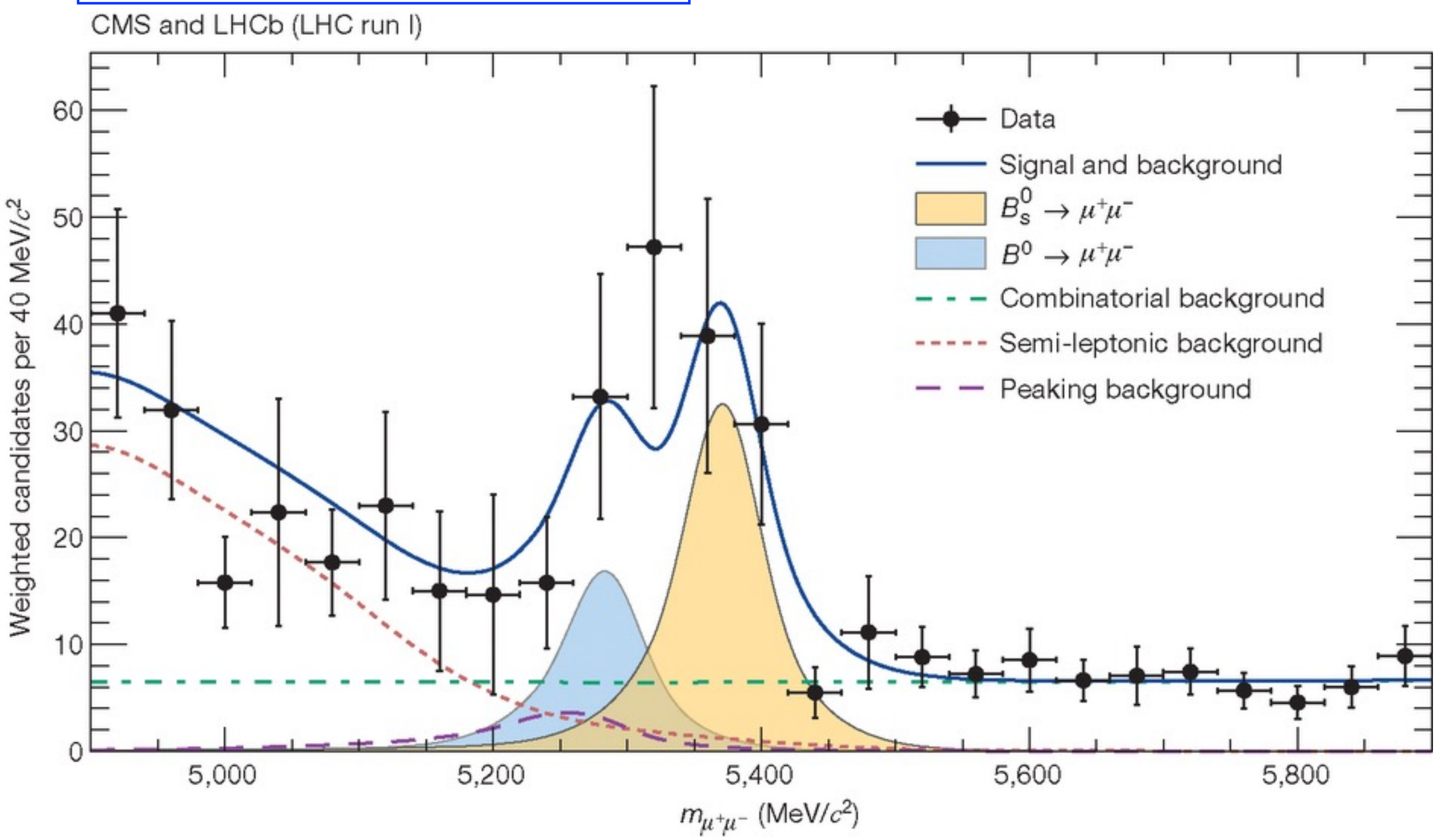
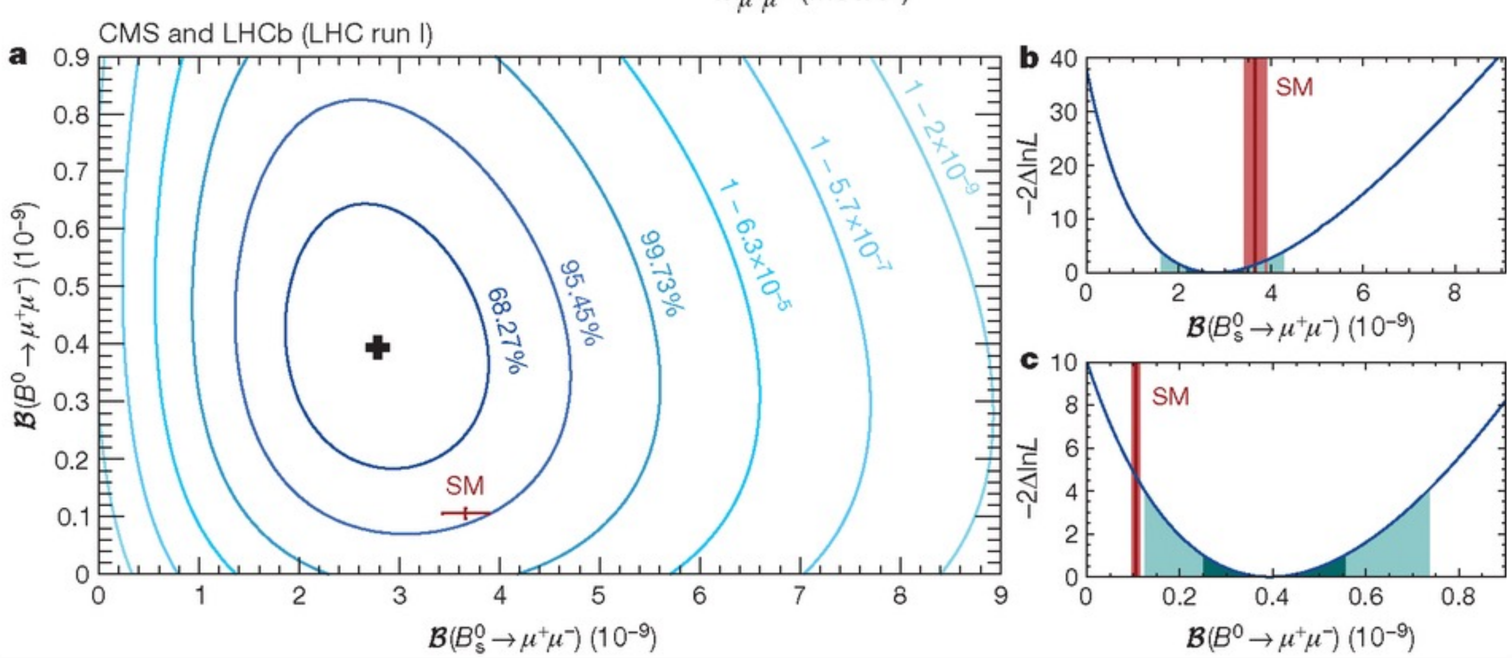


- Combination of CMS and LHCb data results in first observation of $B_s \to \mu^+\mu^-$ and first evidence for $B^0 \to \mu^+\mu^-$



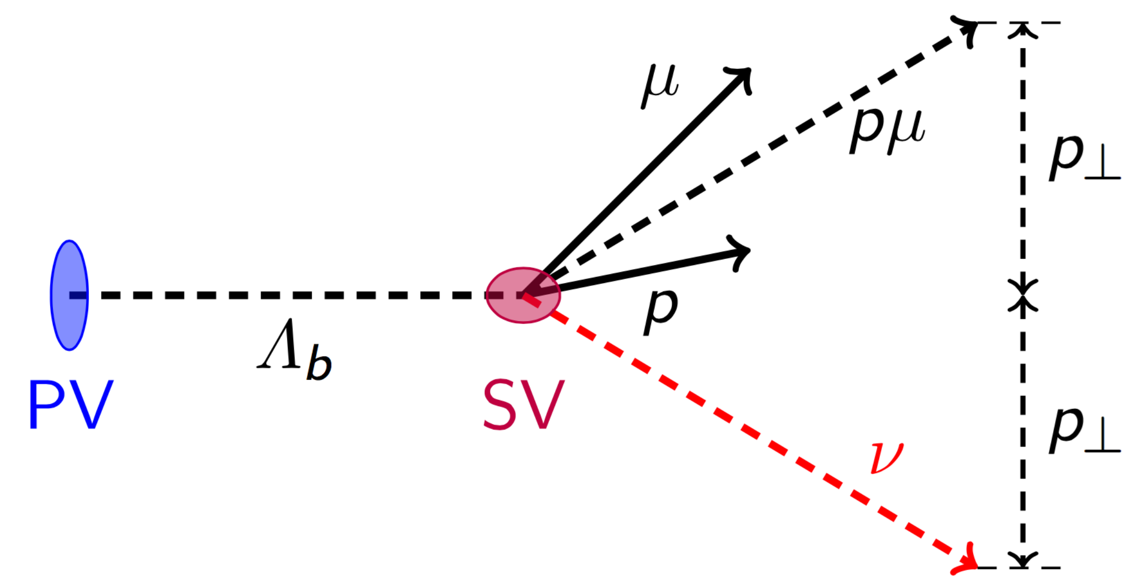
- Results consistent with SM at 2σ level
- Strong constraints on theories beyond SM

|Vub| measurement with $\Lambda_b^0 \to p\mu^-\bar{\nu}_\mu$

2fb[-1] data at 8 TeV - arXiv:1504.01568 - submitted to Nature

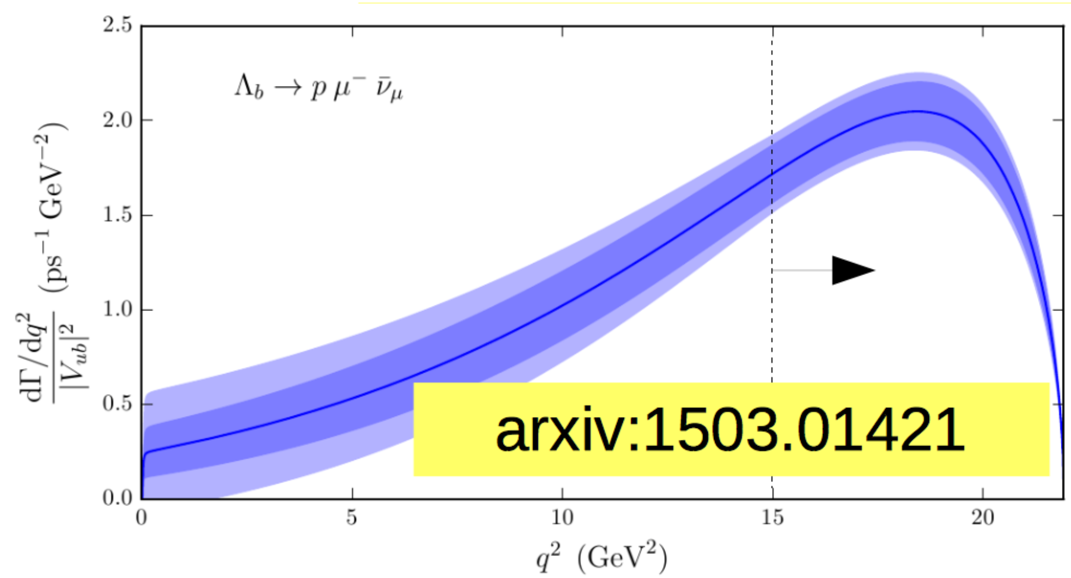
- Long standing discrepancy between inclusive and exclusive determination of CKM element $|V_{ub}|$
- Use of *b*-baryon decays provides a complementary approach to *B* mesons
- Exploit displaced vertex to reconstruct corrected mass

$$M_{corr} = \sqrt{p_\perp^2 + M_{p\mu}^2} + p_\perp$$

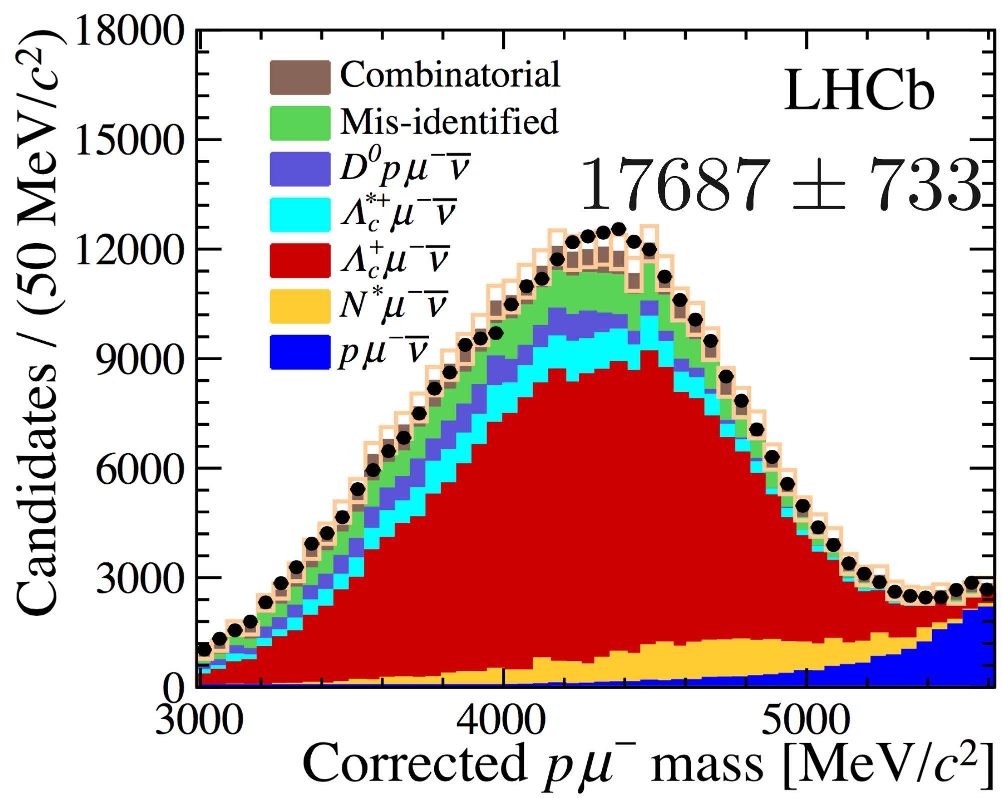


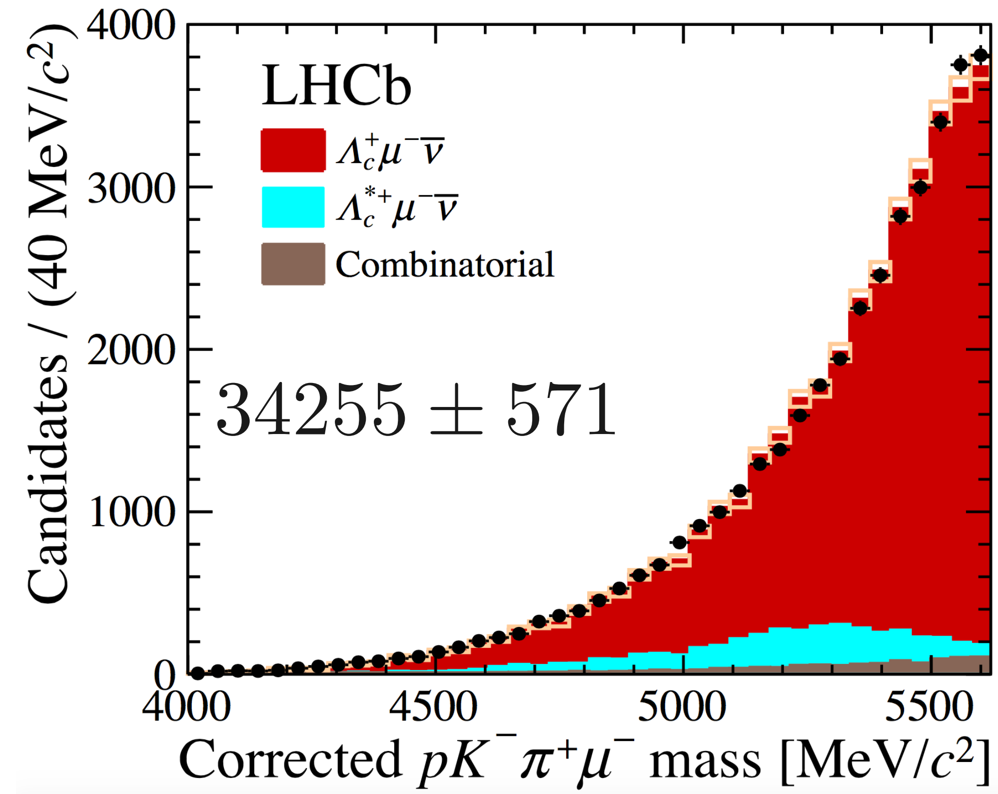
$|V_{ub}|$ measurement

- Reconstruct $q^2 = m(\mu\nu)^2$
  - Select events with $q^2 > 15$ GeV^2
  - Highest rate, best resolution & most reliable theory (lattice) predictions

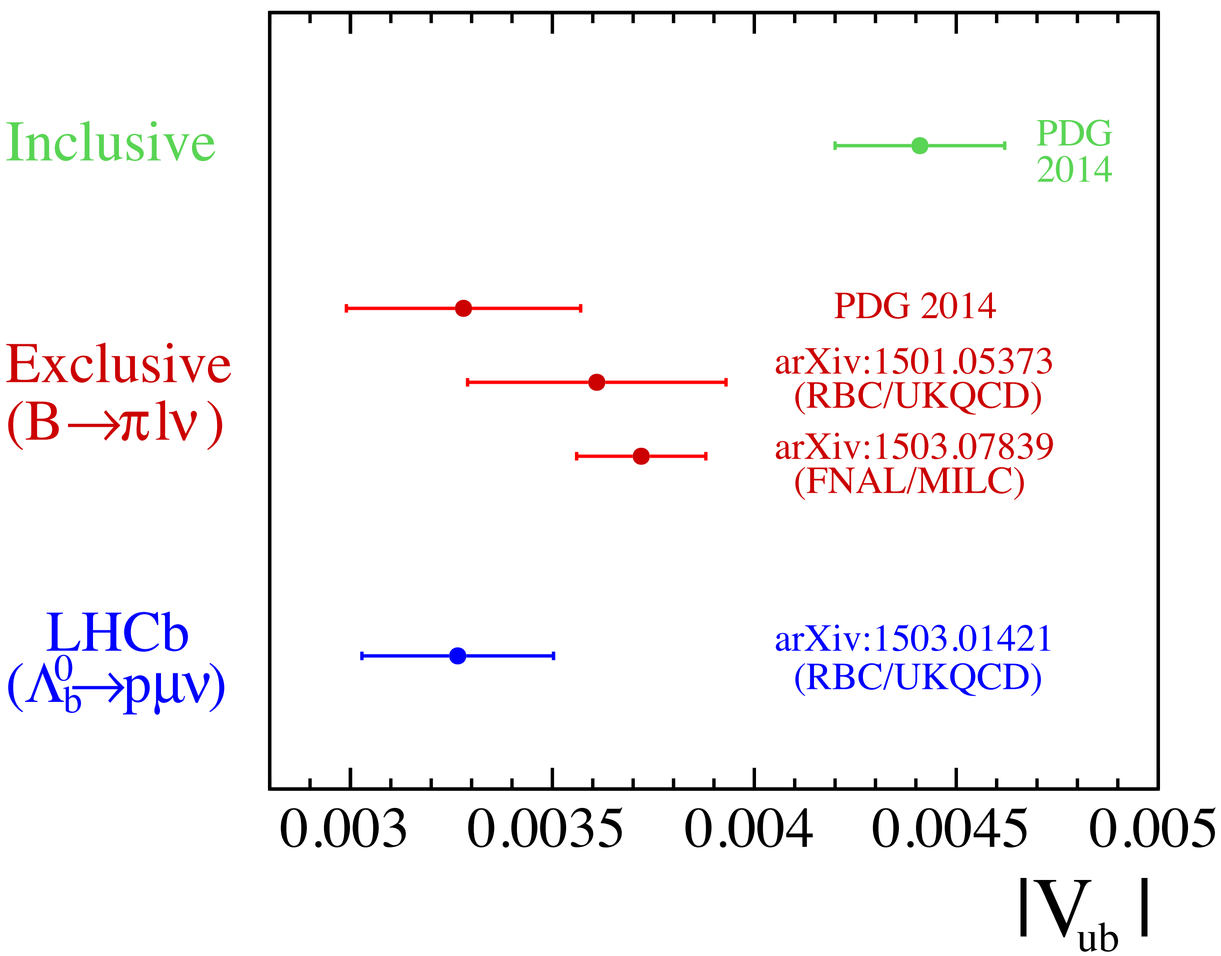


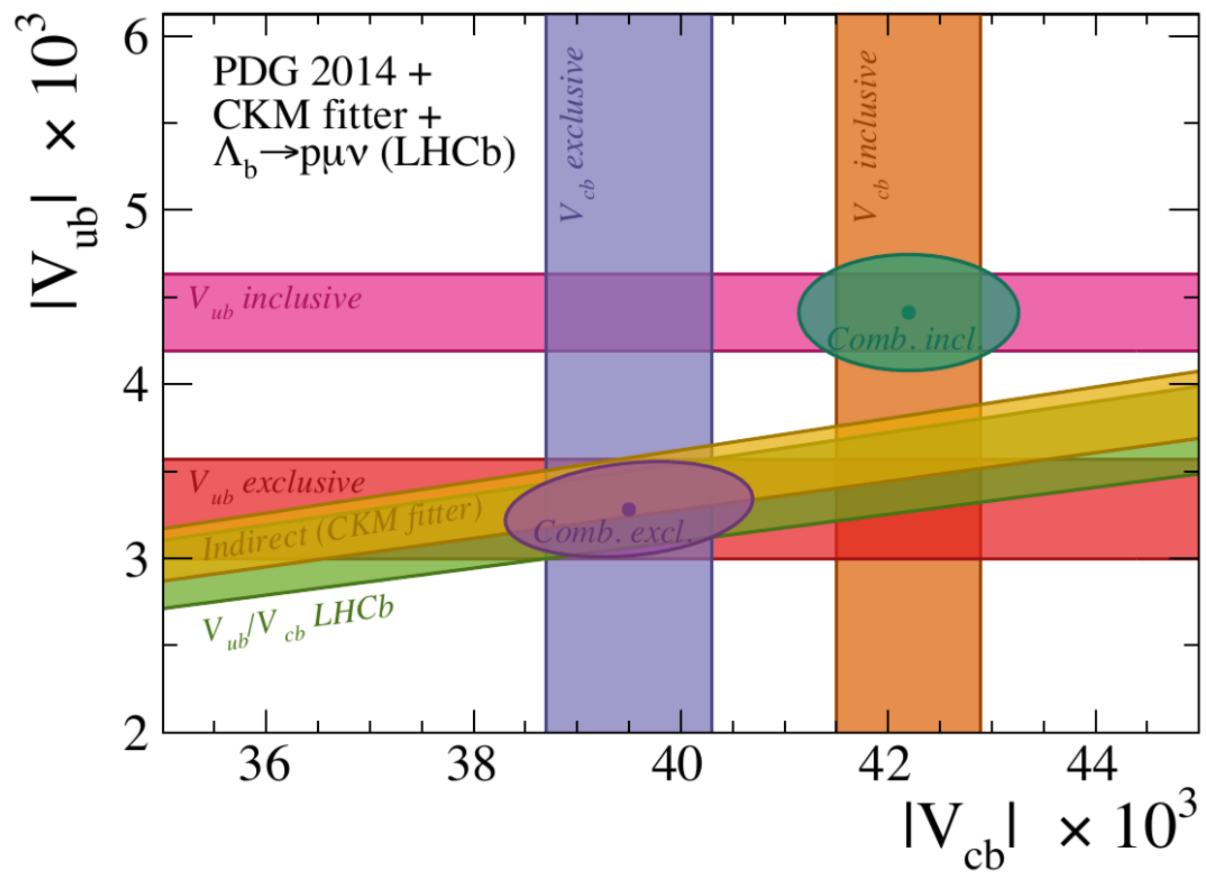
- Fit m_{corr} to extract the number of signal events





|Vub| puzzle





LHCb results do not support explanation based on right handed currents

$$|V_{ub}|^2 = |V_{cb}|^2 \frac{\mathcal{B}(\Lambda_b^0 \to p\mu^-\bar{\nu}_\mu)_{q^2>15\mathrm{GeV}^2}}{\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+\mu^-\bar{\nu}_\mu)_{q^2>7\mathrm{GeV}^2}} R_{FF}$$

world average	measured	LQCD [1]
$(39.5 \pm 0.8) \times 10^{-3}$	$(1.00 \pm 0.04 \pm 0.08) \times 10^{-2}$	0.68 ± 0.07

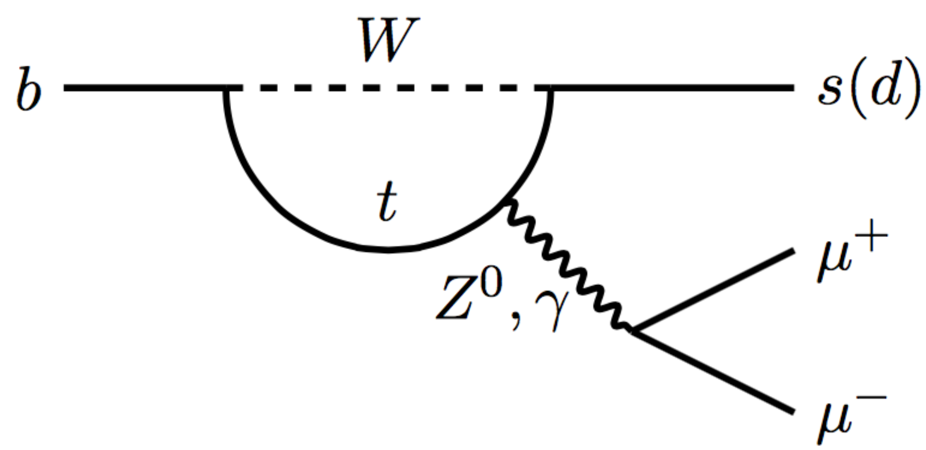
Most precise measurement

$$|V_{ub}| = (3.27 \pm 0.15 \pm 0.17 \pm 0.06) \times 10^{-3}$$

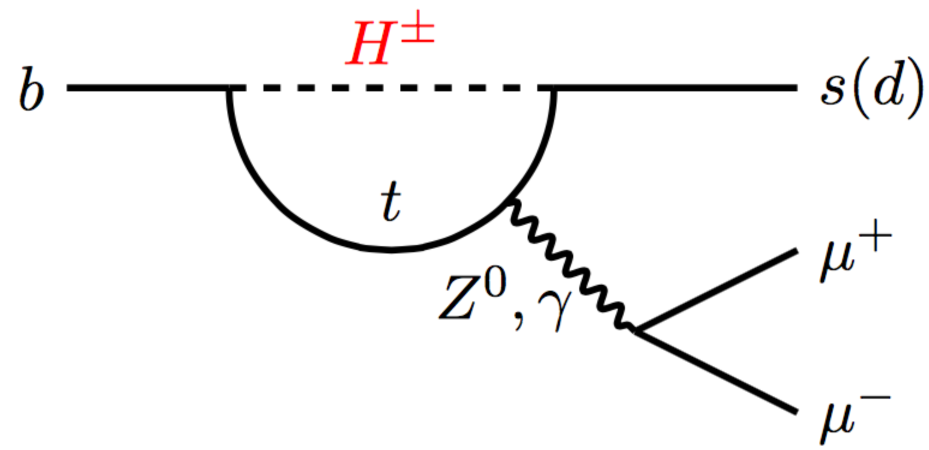
exp. LQCD |Vcb|

Rare decays as indirect probes for BSM physics

SM penguin diagram



NP penguin diagram



- Rare FCNC decays are loop-suppressed in the Standard Model (SM)
- New heavy particles in SM extensions can appear in competing diagrams can affect $\mathcal{B}$ and angular distributions

$$\mathcal{H}_{\text{eff}} = -\frac{4G_F}{\sqrt{2}} V_{\text{tb}} V_{\text{tq}}^* \sum_i \underbrace{\mathcal{C}_i \mathcal{O}_i}_{\text{Left handed}} + \underbrace{\mathcal{C}_i' \mathcal{O}_i'}_{\text{Right handed, } \frac{m_s}{m_b} \text{ suppressed}} + \sum \frac{c}{\Lambda_{\text{NP}}^2} \mathcal{O}_{\text{NP}}$$

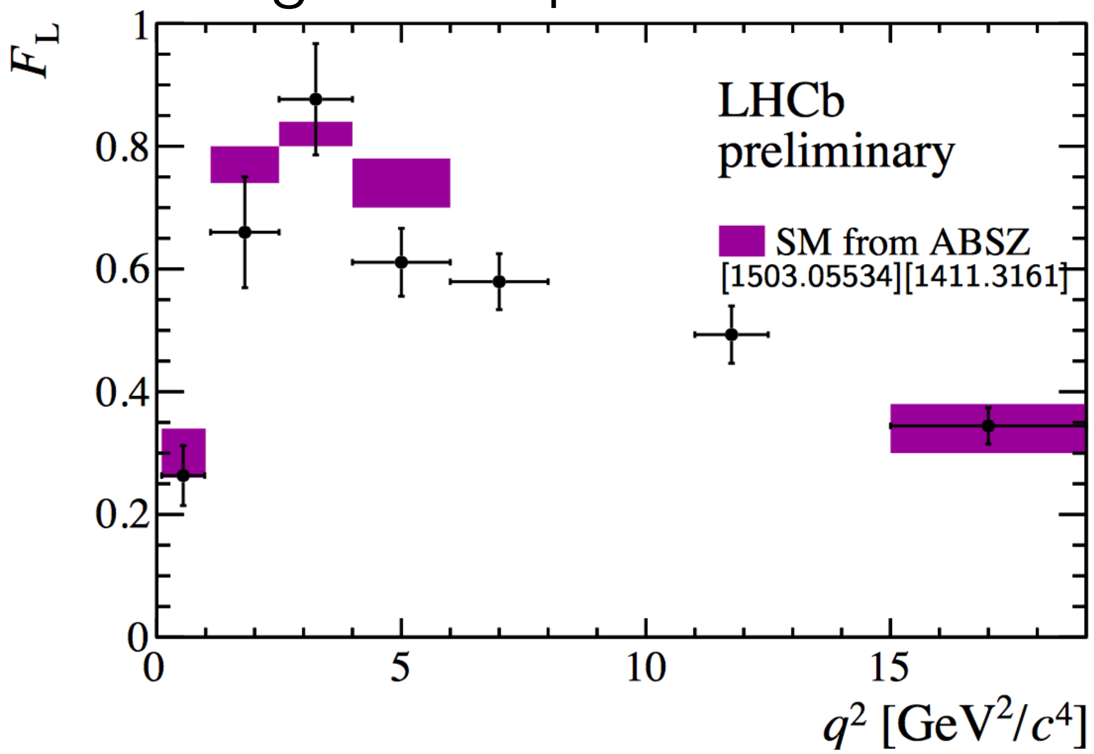
$i = 1, 2$	Tree
$i = 3 - 6, 8$	Gluon penguin
$i = 7$	Photon penguin
$i = 9, 10$	EW penguin
$i = S, P$	(Pseudo)scalar penguin

- Model independent description in effective field theory
- Wilson coeff. $\mathcal{C}_i^{(\prime)}$ encode short-distance physics, $\mathcal{O}_i^{(\prime)}$ corr. operators

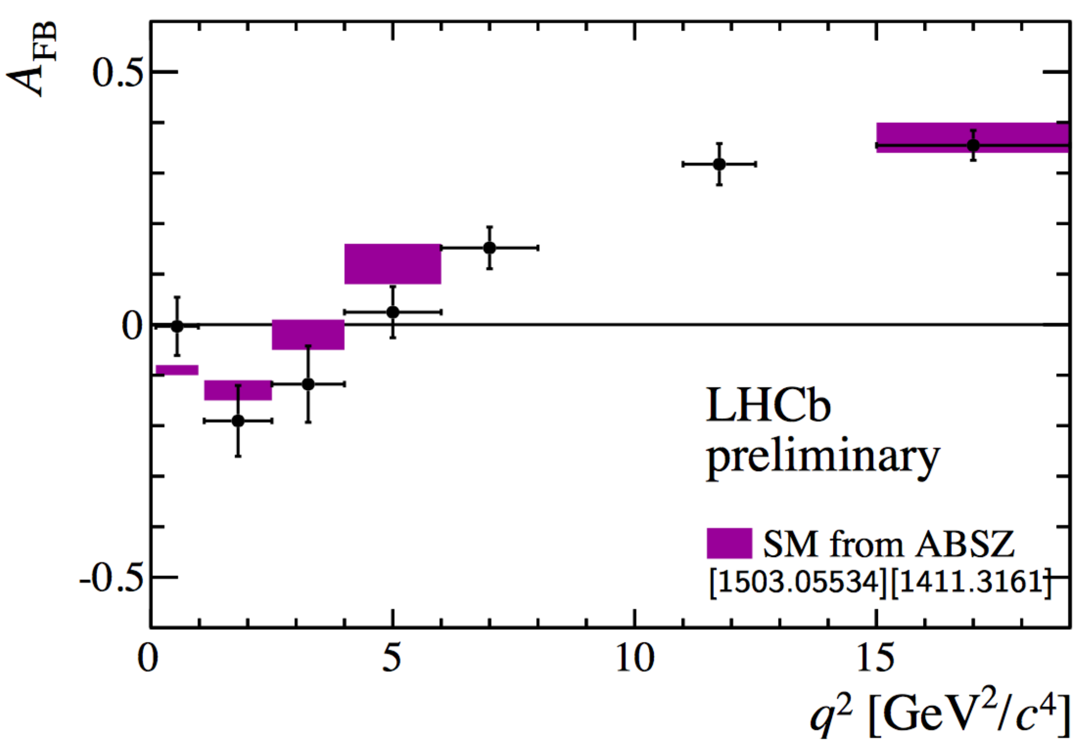
Full angular analysis of $B^0 \to K^{*0}\mu^+\mu^-$

- $B^0 \to K^{*0}\mu^+\mu^-$ provides superb laboratory to search for new physics in $b \to s l^+ l^-$ FCNC processes
  - rates, angular distributions and asymmetries sensitive to NP
  - experimentally clean signature
  - many kinematic variables ... with clean theoretical predictions
- Full set of observables measured: only a subset shown

F_L longitudinal polarisation fraction



Forward-Backward asymmetry

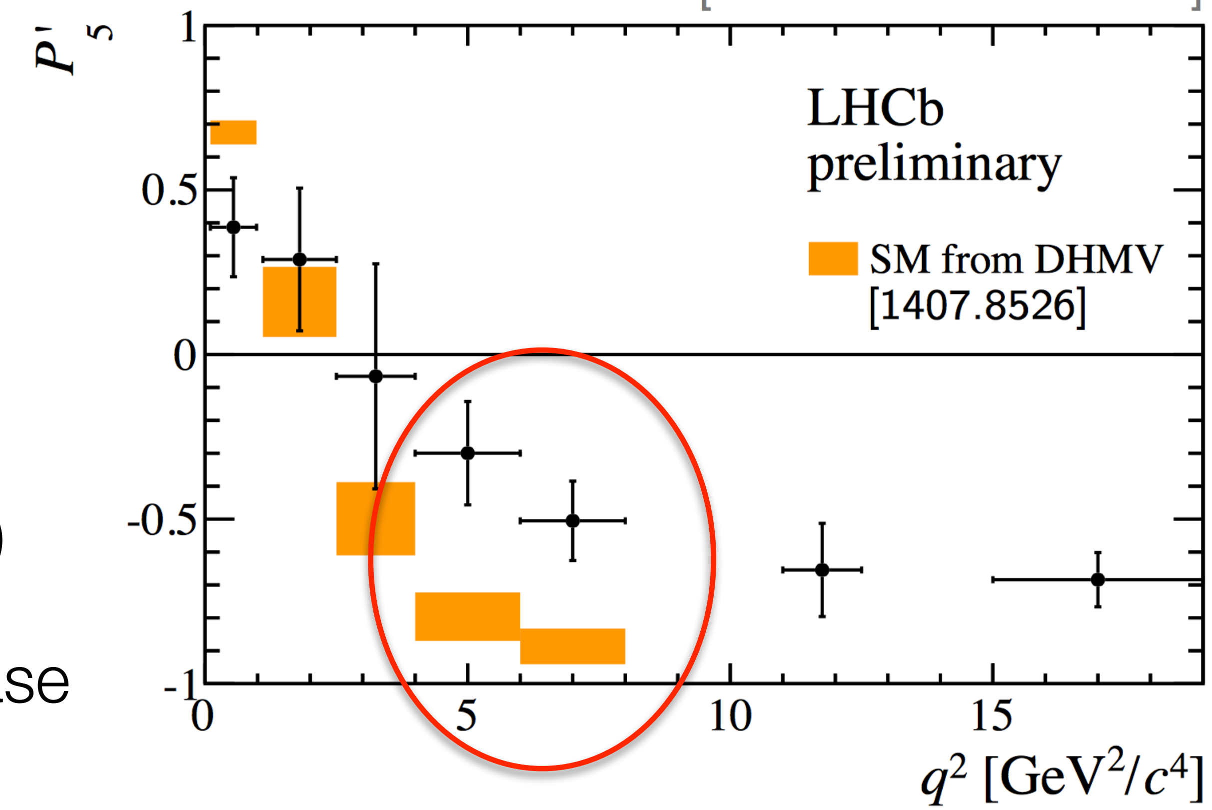


Tension in P_5' distribution

- Dimuon pair is predominantly spin-1
  - either vector (V) or axial-vector (A)
- There are 6 non-negligible amplitudes
  - 3 for VV and 3 for VA
  - expressed as $A^{L,R}_{0,\perp,\parallel}$ (transversity basis)
- P_5' related to difference between relative phase of longitudinal (0) and perpendicularly ($\perp$) polarised amplitudes for VV and VA
  - constructed so as to minimise form-factor uncertainties

$$P_5' = \sqrt{2}\frac{\mathrm{Re}\left(A_0^{\mathrm{L}}A_\perp^{\mathrm{L}*} - A_0^{\mathrm{R}}A_\perp^{\mathrm{R}*}\right)}{\sqrt{\left(|A_0^{\mathrm{L}}|^2 + |A_0^{\mathrm{R}}|^2\right)\left(|A_\parallel^{\mathrm{L}}|^2 + |A_\parallel^{\mathrm{R}}|^2 + |A_\perp^{\mathrm{L}}|^2 + |A_\perp^{\mathrm{R}}|^2\right)}}$$

[LHCb-CONF-2015-002]



Tension with SM at 3.7σ

Sensitive to NP in V or A couplings (Wilson coefficients $C_9^{(')}$ & $C_{10}^{(')}$)

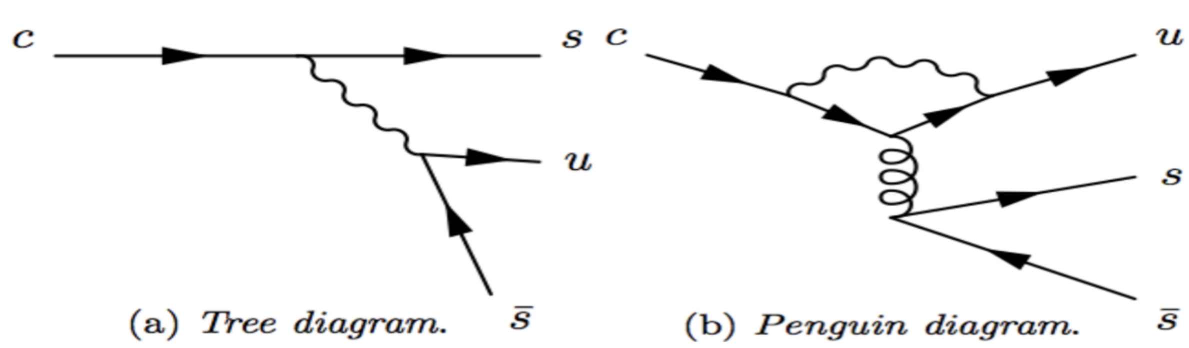
Analyses ongoing in Milano

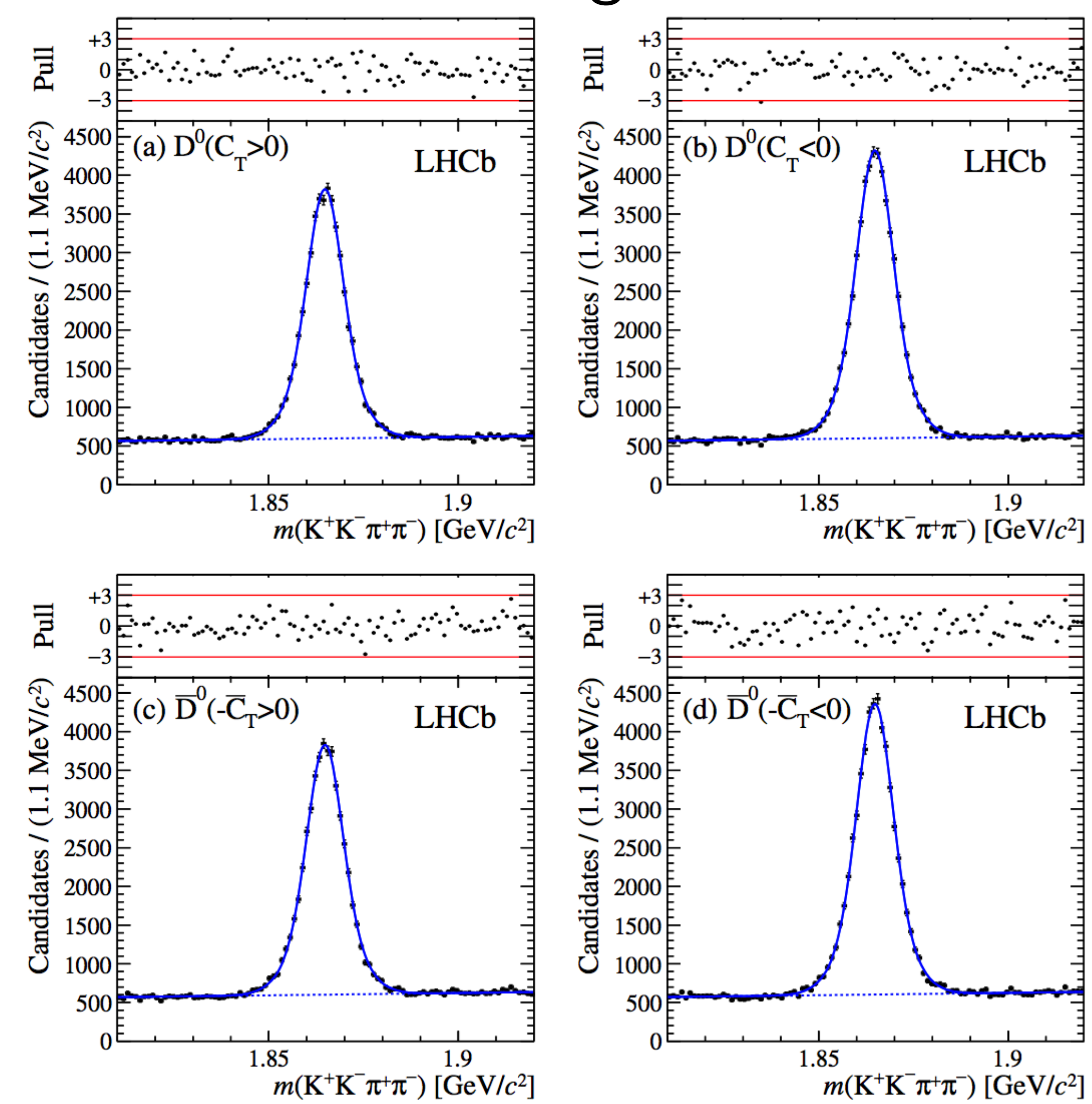
Search for CP violation in $D^0 \to K^+K^-\pi^+\pi^-$

J. Fu, N. Neri - JHEP10(2014)005

The study of *CPV* in SCS charm decays: uniquely sensitive to NP, in paticular to new contribution to $\Delta C = 1$ *QCD* penguin and chromomagnetic dipole operators.

171K Signal events

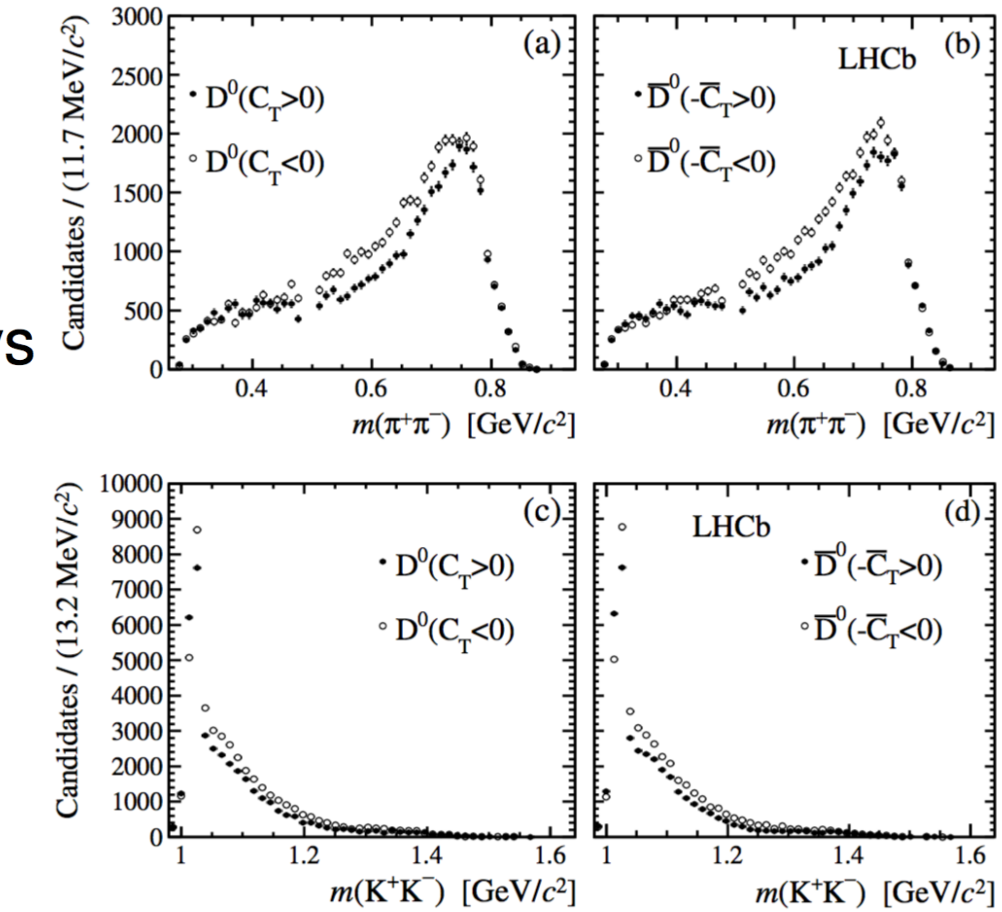




- Search for CPV using T-odd correlations:
  - Phase space integrated measurement
  - Measurements in different regions of the phase space
  - Measurements vs D^0 proper time

Interesting features and results

- T-odd triple products can be constructed in the $D^0(\bar{D}^0)$ rest frame:
  $C_T \equiv \vec{p}_{K^+} \cdot (\vec{p}_{\pi^+} \times \vec{p}_{\pi^-})$,
  $\bar{C}_T \equiv \vec{p}_{K^-} \cdot (\vec{p}_{\pi^-} \times \vec{p}_{\pi^+})$
- T-odd observable:
  $A_T \equiv \frac{\Gamma(C_T>0)-\Gamma(C_T<0)}{\Gamma(C_T>0)+\Gamma(C_T<0)}$, measured using D^0 *decays*;
  $\bar{A}_T \equiv \frac{\Gamma(-\bar{C}_T>0)-\Gamma(-\bar{C}_T<0)}{\Gamma(-\bar{C}_T>0)+\Gamma(-\bar{C}_T<0)}$, measured using $\bar{D}^0$ decays
- True *CP*-violating observable cancel FSI effects:
  $\mathcal{A}_T = \frac{1}{2}(A_T - \bar{A}_T)$



- Alternative approach for CP violation searches. Very low systematic errors
  - not sensitive to particle/antiparticle production asymmetries
  - not sensitive to charged particle reconstruction asymmetries

$$A_T = (-7.18 \pm 0.41(\text{stat}) \pm 0.13(\text{syst}))\%,$$
$$\bar{A}_T = (-7.55 \pm 0.41(\text{stat}) \pm 0.12(\text{syst}))\%,$$
$$a_{CP}^{T\text{-odd}} = (\ \ 0.18 \pm 0.29(\text{stat}) \pm 0.04(\text{syst}))\%,$$

JHEP10(2014)005

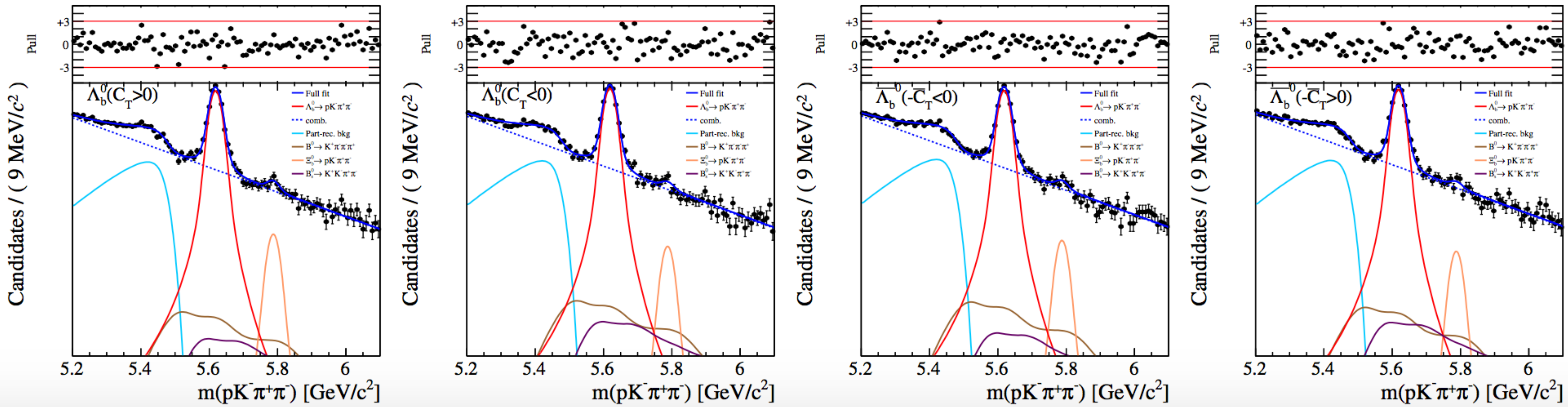
Search for CP violation in $\Lambda_b^0(\Xi_b^0) \to p h^- h^+ h^-$ (2)

J. Fu, A. Merli, N. Neri - Starting review process

- Statistical sensitivity of asymmetries from blind simultaneous fit.

Decay	A_T (%)	$\bar{A}_T$ (%)	$a_{CP}^{T\text{-odd}}$ (%)
$\Lambda_b^0 \to pK^-\pi^+\pi^-$	$x.x \pm 1.12$	$x.x \pm 1.18$	$x.x \pm 0.81$
$\Lambda_b^0 \to pK^-K^+K^-$	$x.x \pm 2.10$	$x.x \pm 2.14$	$x.x \pm 1.50$
$\Lambda_b^0 \to p\pi^-\pi^+\pi^-$	$x.x \pm 2.06$	$x.x \pm 2.05$	$x.x \pm 1.45$
$\Lambda_b^0 \to pK^+K^-\pi^-$	$x.x \pm 6.77$	$x.x \pm 6.09$	$x.x \pm 4.55$
$\Xi_b^0 \to pK^-K^-\pi^+$	$x.x \pm 7.42$	$x.x \pm 6.82$	$x.x \pm 5.04$

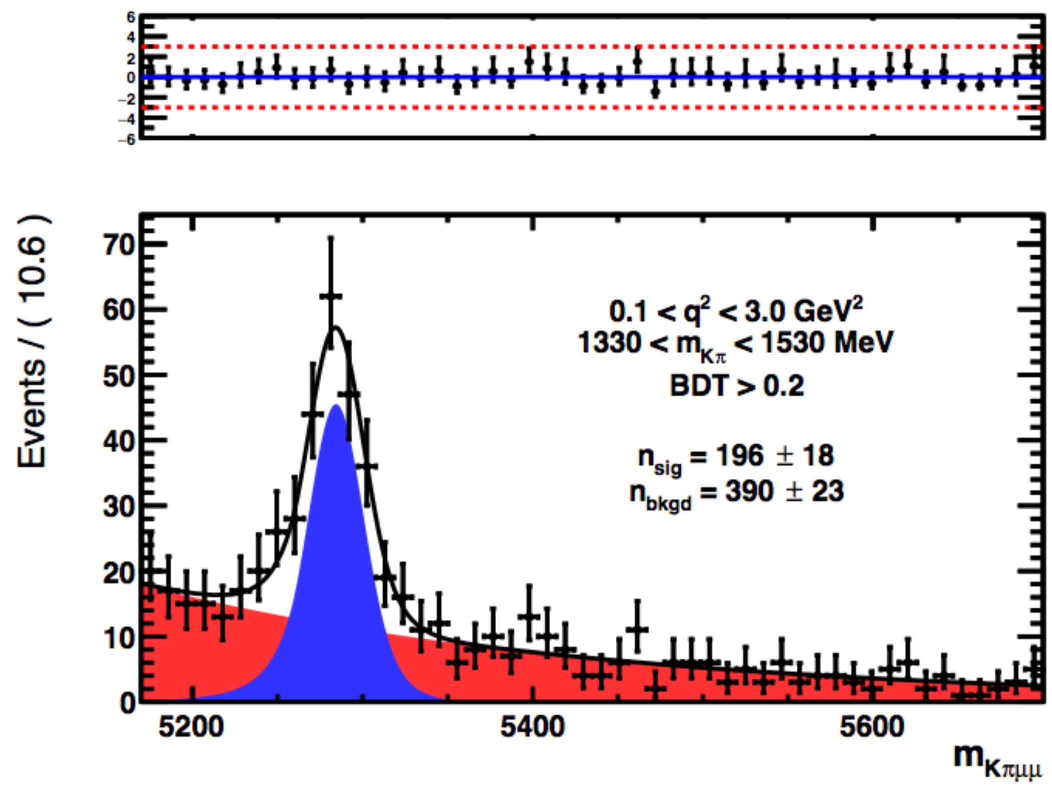
- Projection plots from simultaneous fit ($\Lambda_b^0 \to pK^-\pi^+\pi^-$).



The $b \to s\mu\mu$ portal

B. Dey, D. Marangotto, N. Neri

- The "B2KstarMuMu anomaly" (arXiv:1505.04160). Extend $\bar{B}^0 \to K^-\pi^+\mu^-\mu^+$ to wider $m(K\pi)$ window.
- Include SPD-waves (arXiv:1505.02873): many more observables to search for anomalies in.



- Similarly, $B_s \to KK\mu^-\mu^+$ and $\Lambda_b \to pK\mu^-\mu^+$, towards Run II.

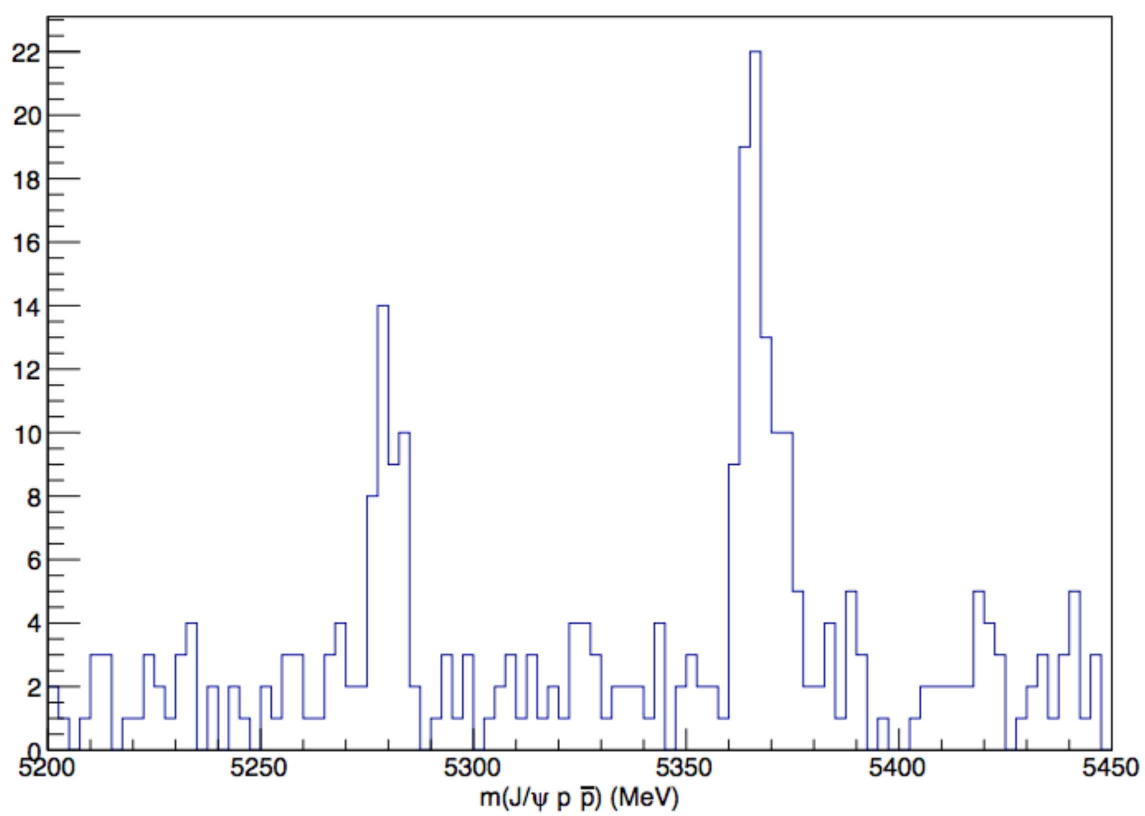
Related di-muon analyses

- $B_{d,s} \to c\bar{c}h_1h_2$, with $c\bar{c} \in \{J/\psi, \psi(2S)\}$ and $h_1h_2 \in \{K\pi, KK\}$. Same formalism as the electroweak penguins.

B. Dey

- In $\psi(2S) \to J/\psi\pi\pi$, D-wave component in dipion can break the 2-fold ambiguity in $\sin 2\beta_{(s)}$.

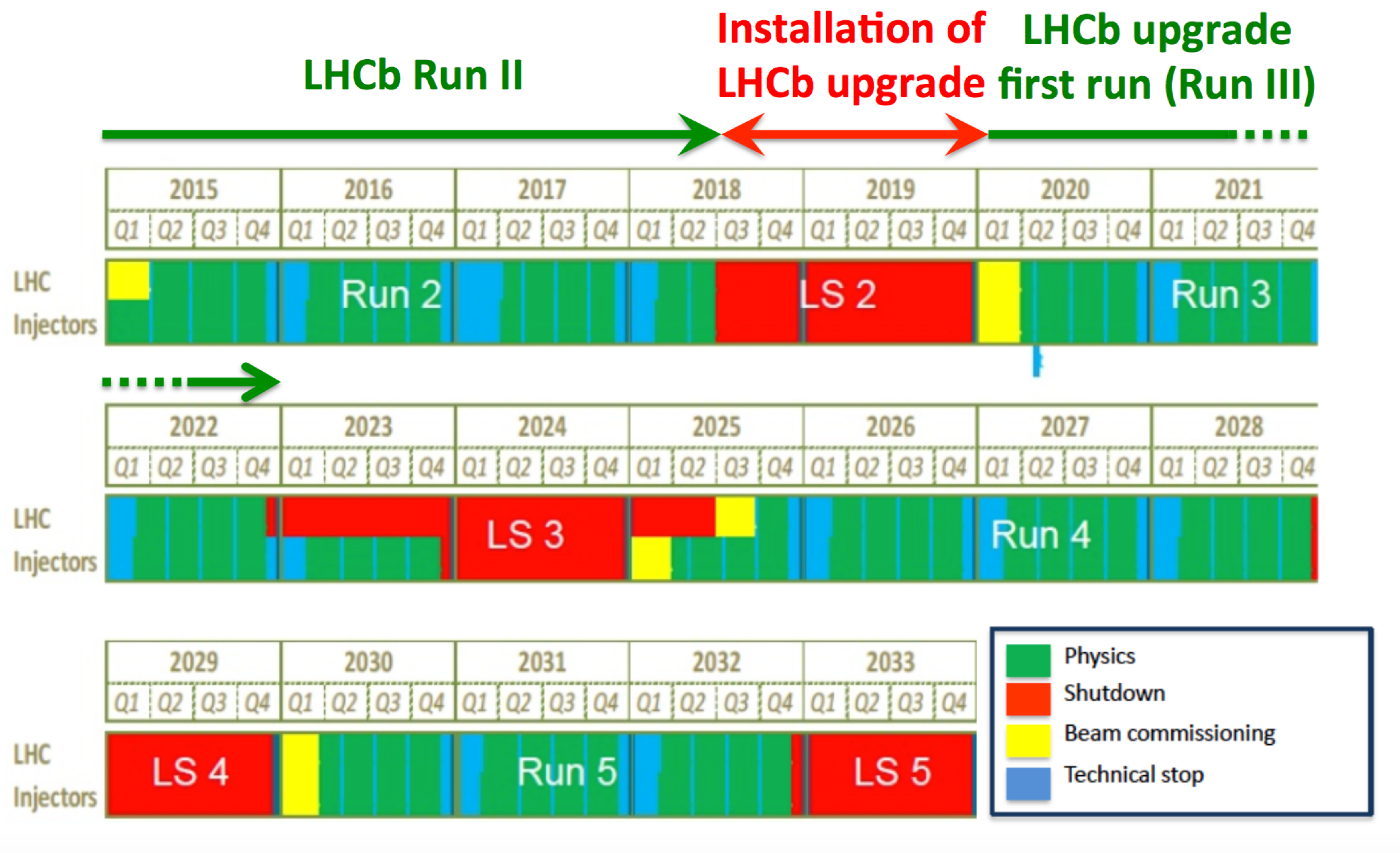
- First observation of $B_{d,s} \to J/\psi p\bar{p}$:



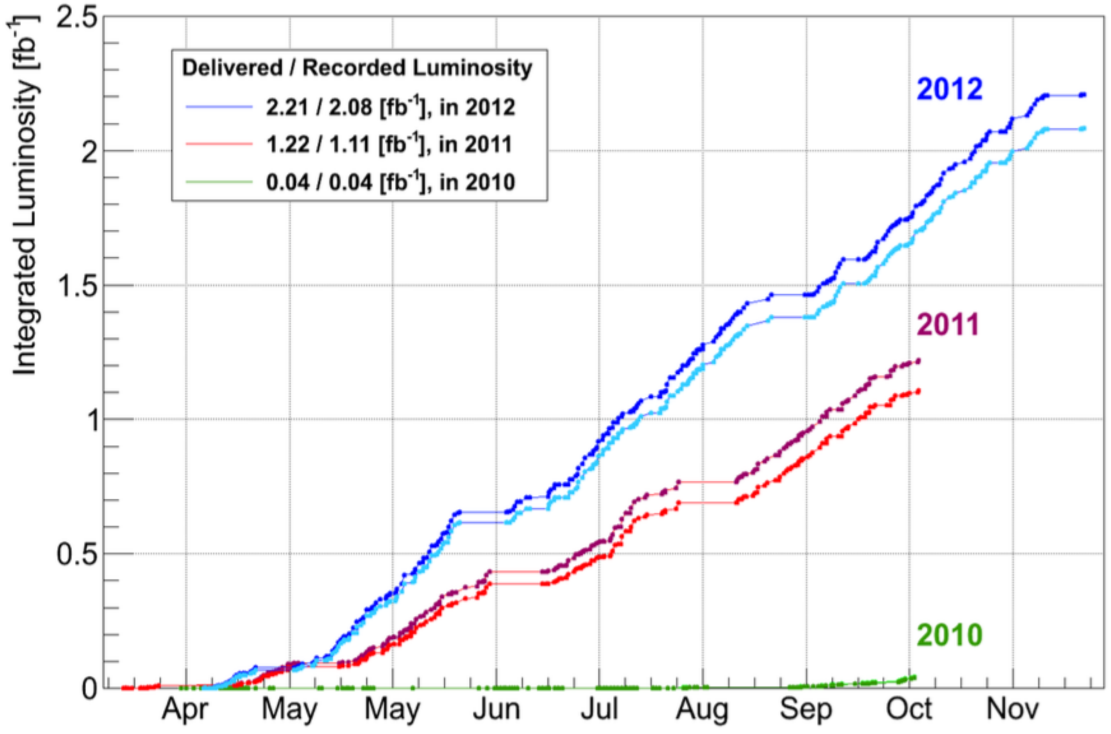
B. Dey, N. Neri

The LHCb upgrade Milano contributions

LHC schedule beyond LS1



LHCb luminosity prospects



During Run 1

- 7 and 8 TeV collisions
- luminosity levelled at $4 \cdot 10^{32}\ cm^{-2}s^{-1}$
- software trigger running at 1 MHz after hardware trigger, recording 3-5 kHz

Resuming now with Run 2

- 13 TeV collisions
- revised trigger strategy and output increased to 12.5 kHz

LHC era		HL-LHC era		
Run 1 (2010-12)	Run 2 (2015-18)	Run 3 (2020-22)	Run 4 (2025-28)	Run 5+ (2030+)
3 fb^{-1}	8 fb^{-1}	23 fb^{-1}	46 fb^{-1}	100 fb^{-1}

Note that beauty production cross section is almost doubled passing from 7 to 13 TeV *pp* collisions

LHCb upgrade

- running at $2 \cdot 10^{33}\ cm^{-2}s^{-1}$
- replace R/O, RICH photodetectors and tracking detectors
- full software trigger, running at 40 MHz and record 20 kHz

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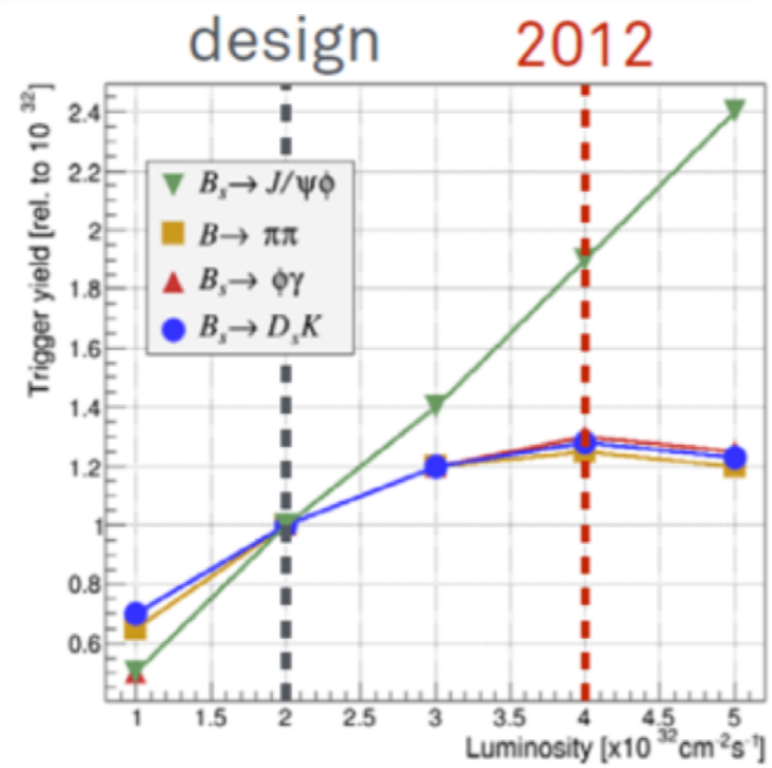
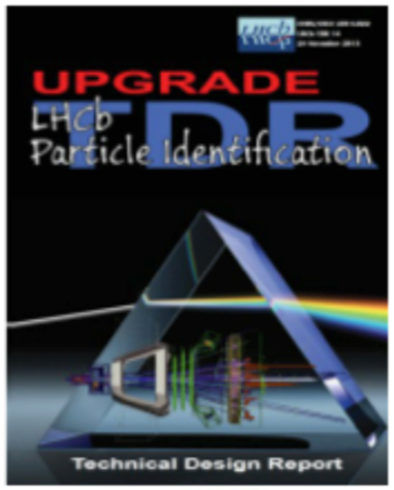
Motivations for the upgrade

- Main limitation that prevents exploiting higher luminosity with the present detector is the Level-0 (hardware) trigger
  - Level-0 output rate < 1 MHz (readout rate) requires raising thresholds
- This is particularly problematic for hadronic final states





- All TDRs approved
- Construction going to start soon

Latest sensitivity estimates

Type	Observable	LHC Run 1	LHCb 2018	LHCb upgrade	Theory
B_s^0 mixing	$\phi_s(B_s^0 \to J/\psi\,\phi)$ (rad)	0.049	0.025	**0.009**	~ 0.003
	$\phi_s(B_s^0 \to J/\psi\, f_0(980))$ (rad)	0.068	0.035	**0.012**	~ 0.01
	$A_{\rm sl}(B_s^0)$ (10^{-3})	2.8	1.4	**0.5**	0.03
Gluonic penguin	$\phi_s^{\rm eff}(B_s^0 \to \phi\phi)$ (rad)	0.15	0.10	**0.018**	0.02
	$\phi_s^{\rm eff}(B_s^0 \to K^{*0}\bar{K}^{*0})$ (rad)	0.19	0.13	**0.023**	< 0.02
	$2\beta^{\rm eff}(B^0 \to \phi K_S^0)$ (rad)	0.30	0.20	**0.036**	0.02
Right-handed currents	$\phi_s^{\rm eff}(B_s^0 \to \phi\gamma)$ (rad)	0.20	0.13	**0.025**	< 0.01
	$\tau^{\rm eff}(B_s^0 \to \phi\gamma)/\tau_{B_s^0}$	5%	3.2%	**0.6%**	0.2 %
Electroweak penguin	$S_3(B^0 \to K^{*0}\mu^+\mu^-; 1 < q^2 < 6\,{\rm GeV}^2/c^4)$	0.04	0.020	**0.007**	0.02
	$q_0^2\,A_{\rm FB}(B^0 \to K^{*0}\mu^+\mu^-)$	10%	5%	**1.9%**	$\sim 7\%$
	$A_{\rm I}(K\mu^+\mu^-; 1 < q^2 < 6\,{\rm GeV}^2/c^4)$	0.09	0.05	**0.017**	~ 0.02
	$\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)/\mathcal{B}(B^+ \to K^+\mu^+\mu^-)$	14%	7%	**2.4%**	$\sim 10\%$
Higgs penguin	$\mathcal{B}(B_s^0 \to \mu^+\mu^-)$ (10^{-9})	1.0	0.5	**0.19**	0.3
	$\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	220%	110%	**40%**	$\sim 5\%$
Unitarity triangle angles	$\gamma(B \to D^{(*)}K^{(*)})$	7°	4°	**0.9°**	negligible
	$\gamma(B_s^0 \to D_s^{\mp}K^{\pm})$	17°	11°	**2.0°**	negligible
	$\beta(B^0 \to J/\psi\,K_S^0)$	1.7°	0.8°	**0.31°**	negligible
Charm CP violation	$A_\Gamma(D^0 \to K^+K^-)$ (10^{-4})	3.4	2.2	**0.4**	–
	ΔA_{CP} (10^{-3})	0.8	0.5	**0.1**	–

- Before the upgrade (8 fb^{-1})
- After the upgrade (50 fb^{-1})
- Theory uncertainty (as far as we know today)

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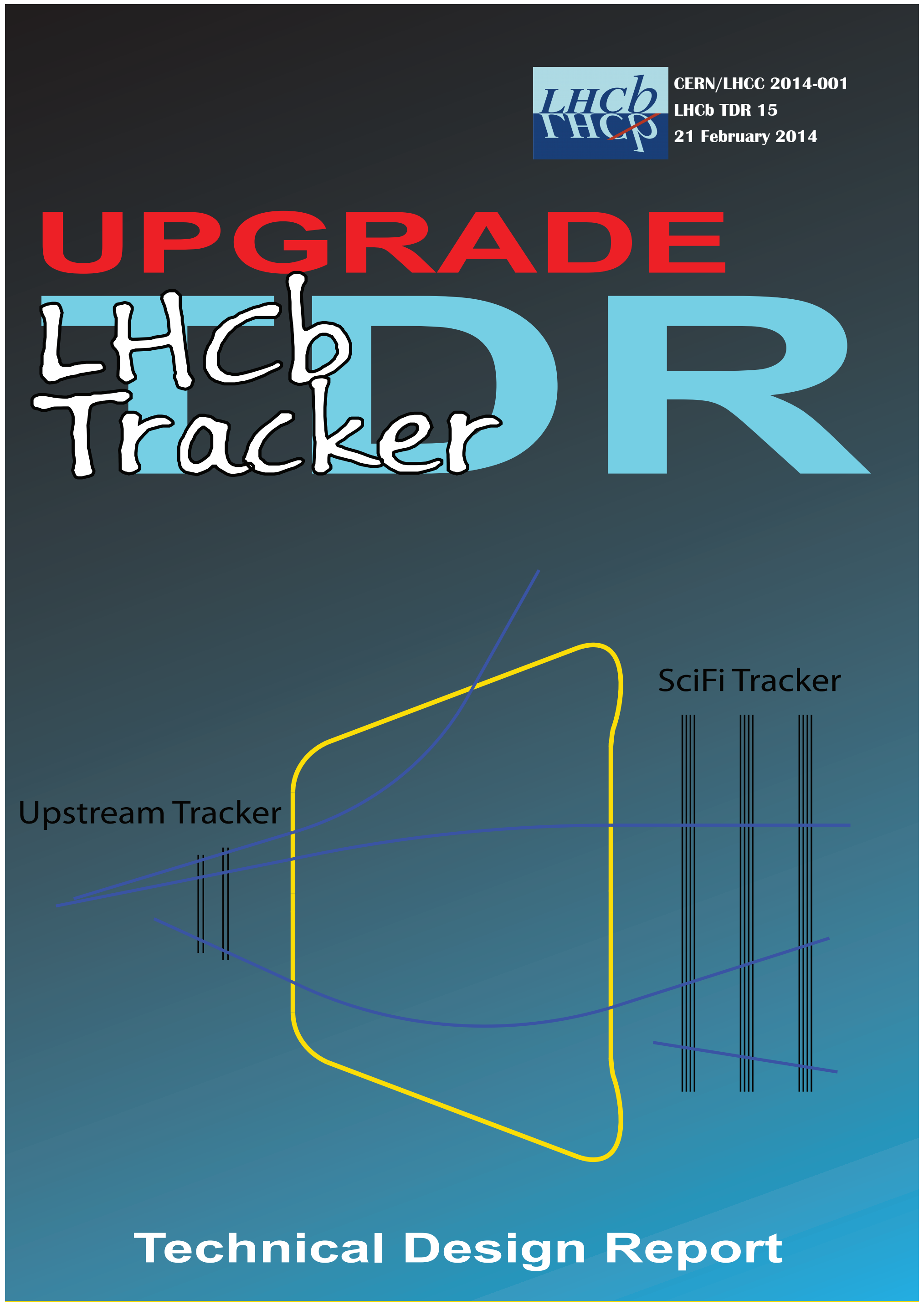
INFN Milano activities

- Upstream Tracker upgrade
  - Design and construction of flex cables and hybrid circuits for front-end electronics
  - Design and prototyping of the CO_2 cooling system
  - Thermal and mechanical simulations of the UT stave
  - Test and characterisation of prototype silicon strip sensors
  - Test beam: developed new DAQ board and software for reconstruction and analysis of the data

LHCb Tracker TDR



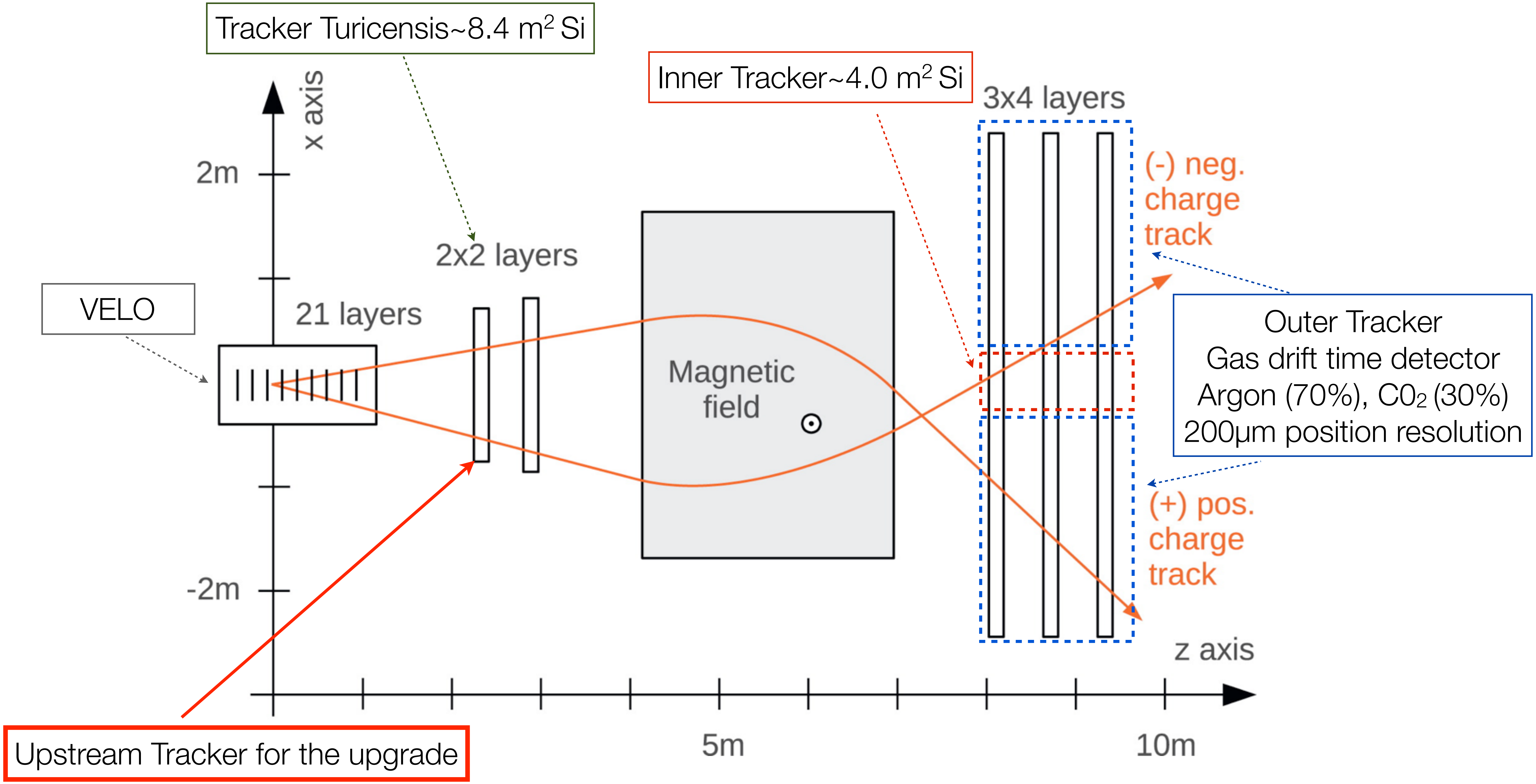
- Authors of Tracker TDR

A. Abba[u], F. Caponio[u], M. Citterio, S. Coelli, A. Cusimano[u], J. Fu, A. Geraci[u], M. Lazzaroni[t], M. Monti, N. Neri, F. Palombo[t]
[25] *Sezione INFN di Milano, Milano, Italy*

- Responsibilities for UT upgrade
  - Sensor and Hybrids WG (M. Citterio co-convener)
  - Mechanics and Cooling WG (N. Neri —> S. Coelli co-convener)
  - Editor of Tracking TDR (N. Neri "Mechanics and cooling" chapter)

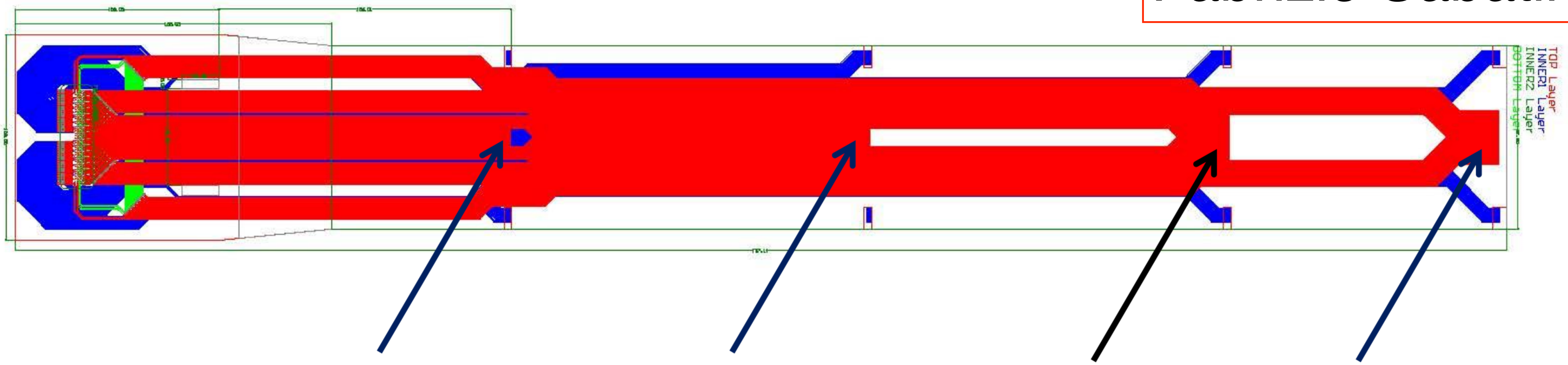
LHCb spectrometer

Silicon Tracker: 500µm thick, single sided Si strip detector, pitch~200µm, vertical and stereo angle strips arrangement (x-u-v-x)=(0°,-5°,+5°,0°)



Design of the flex cables

Mauro Citterio
Fabrizio Sabatini

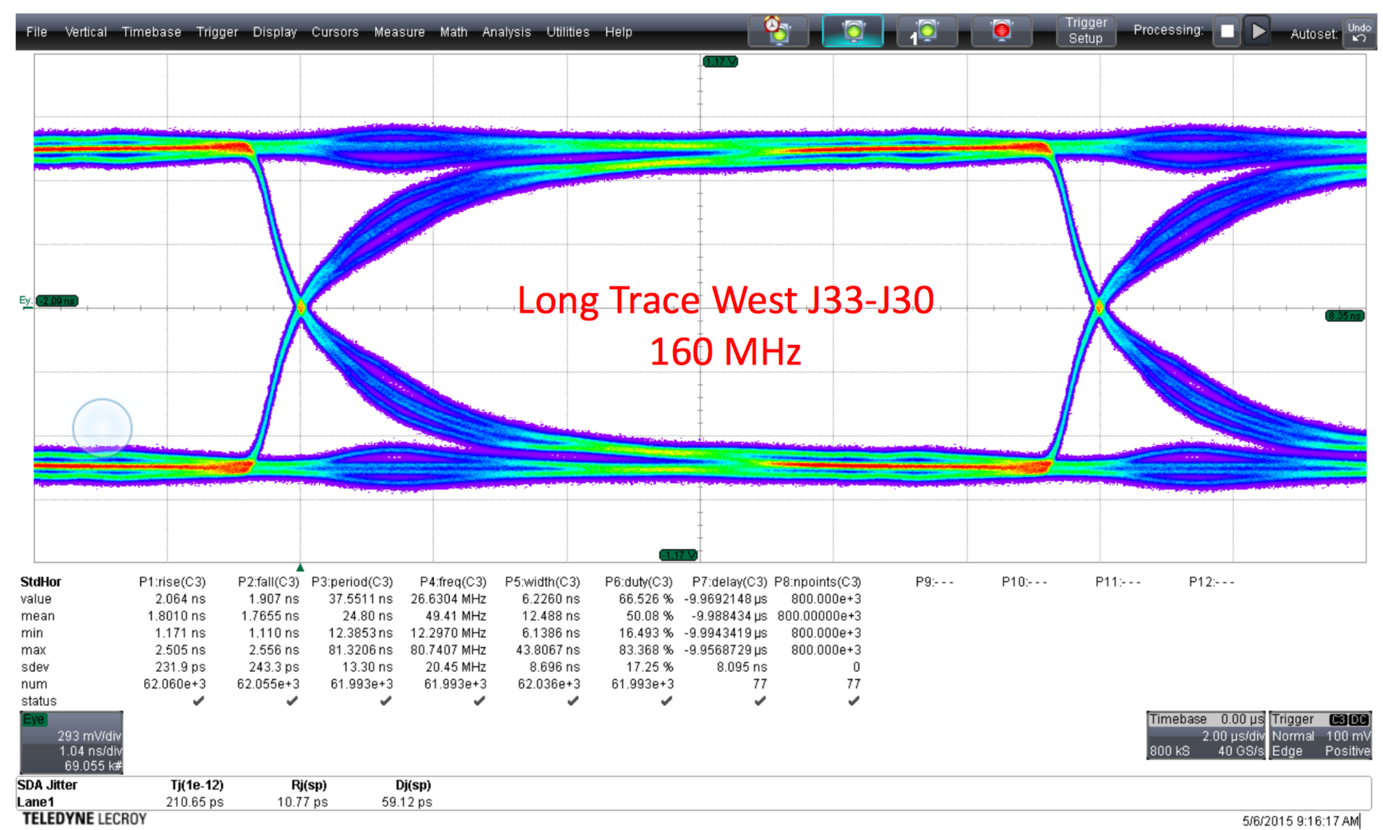


Traces are terminated with bonding pads (96+80+32+32), where hybrids will be mounted

- Cable for data and power lines, 80 cm long: Kapton + Cu (Al) traces.
- Low impedance, long traces, signal integrity: technological challenge
- First generation prototypes constructed and tested

First generation flex prototypes

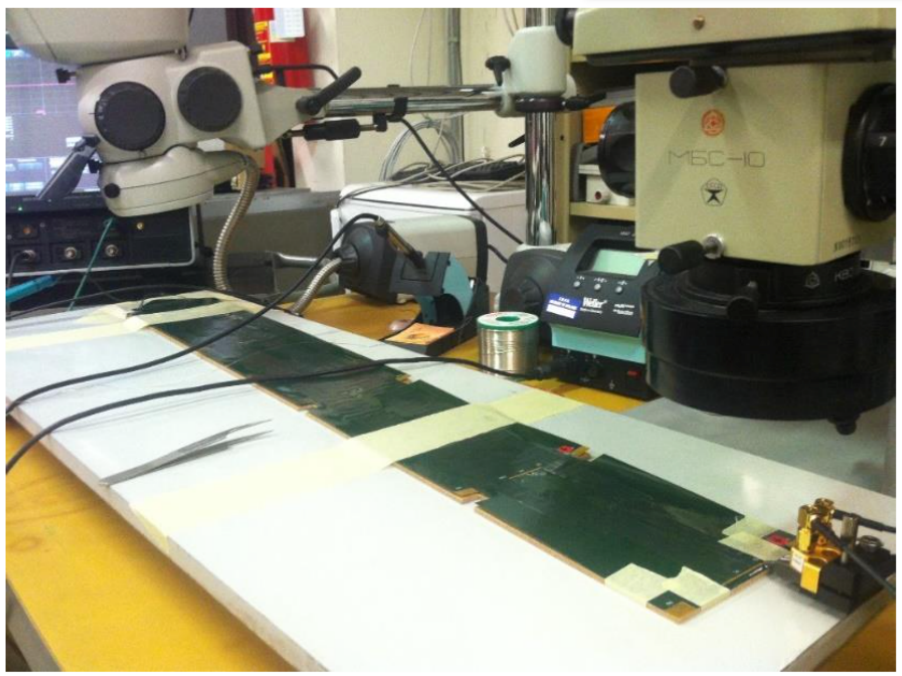
- First results very encouraging:
  - time domain reflectometry measurements for studying impedance vs position (time)
  - time domain transmission measurements
  - signal integrity, eye diagram
- Relatively low yield
  - try different manufacturer for II generation prototypes

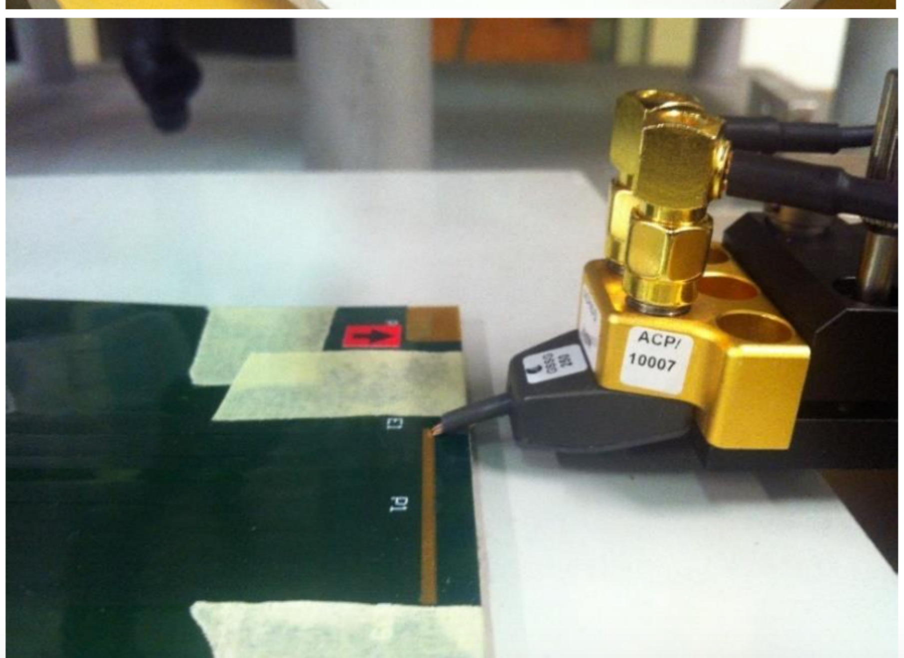


Flex cables testing

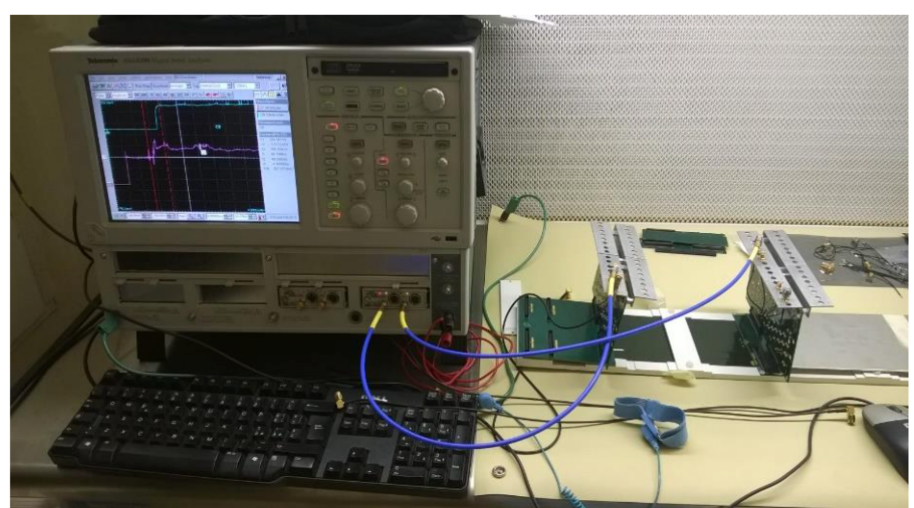
Mauro Citterio
Fabrizio Sabatini
Marco Petruzzo
Biplab Dey
Fabrizio Alberti
Ennio Viscione

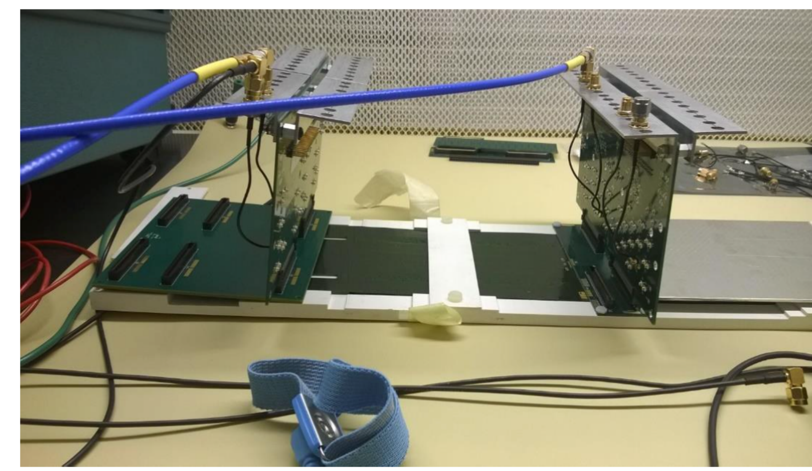
First manual tests with probes





Test setup using adapter cards





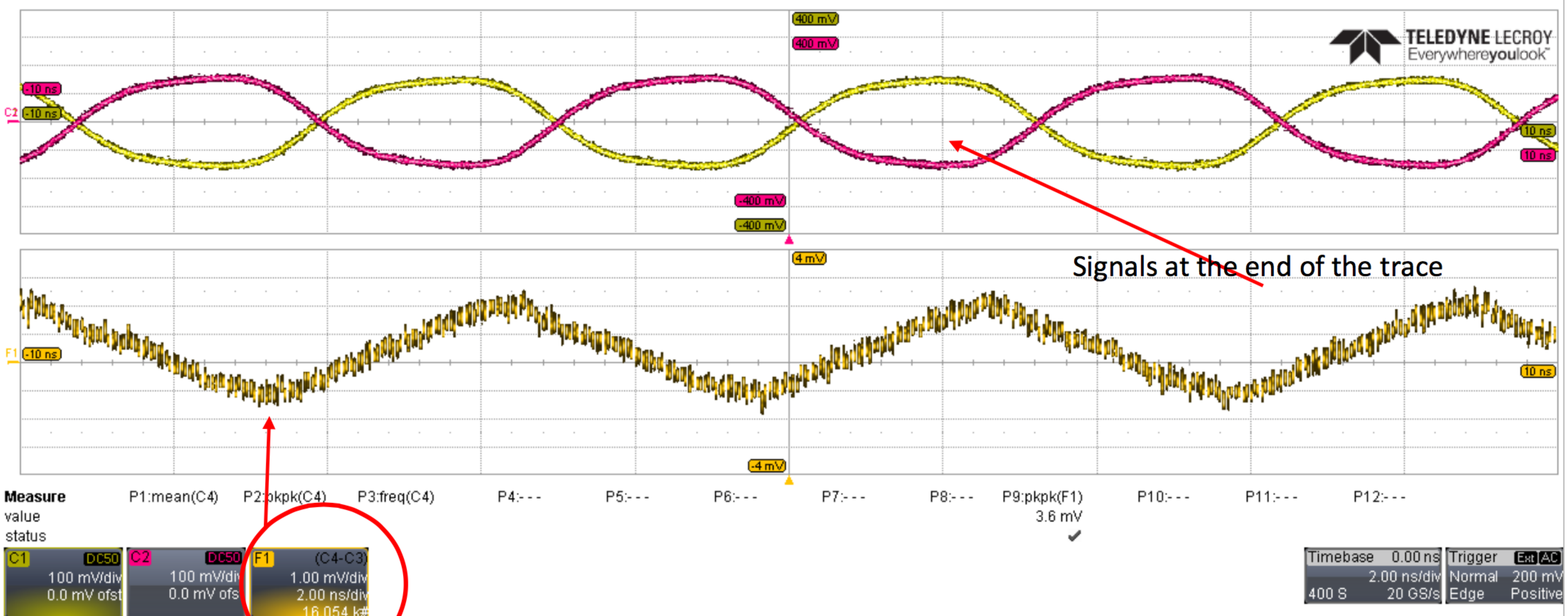
Cross-talk measurements

FEXT at 160 MHz on the longest traces:

- Diff-mode crosstalk shown
- Shape of crosstalk is "smoothed" by reflections.
- Vout= 350 mV due to attenuation, VFEXT(peak-peak) ~ 3.6 mV
- ESTIMATED worst case < 3 … 5 %

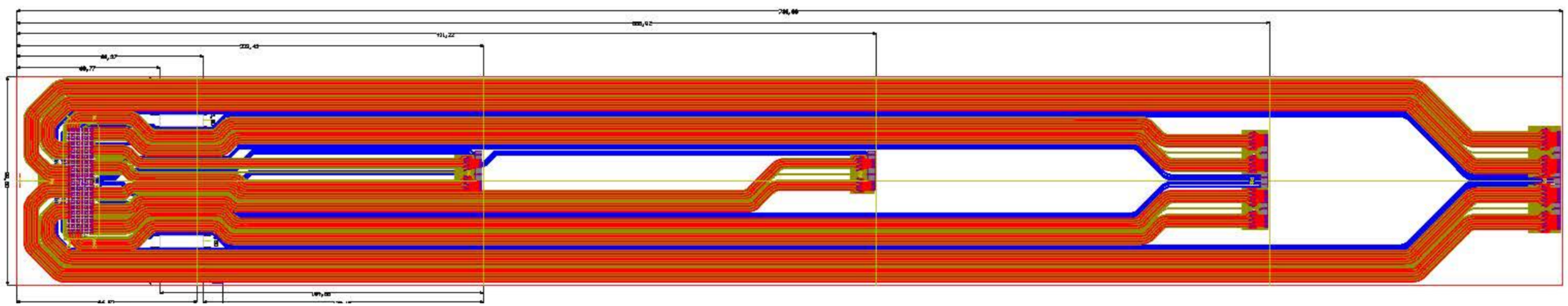
Low cross-talk

→ **NO ISSUE for the data transmission**



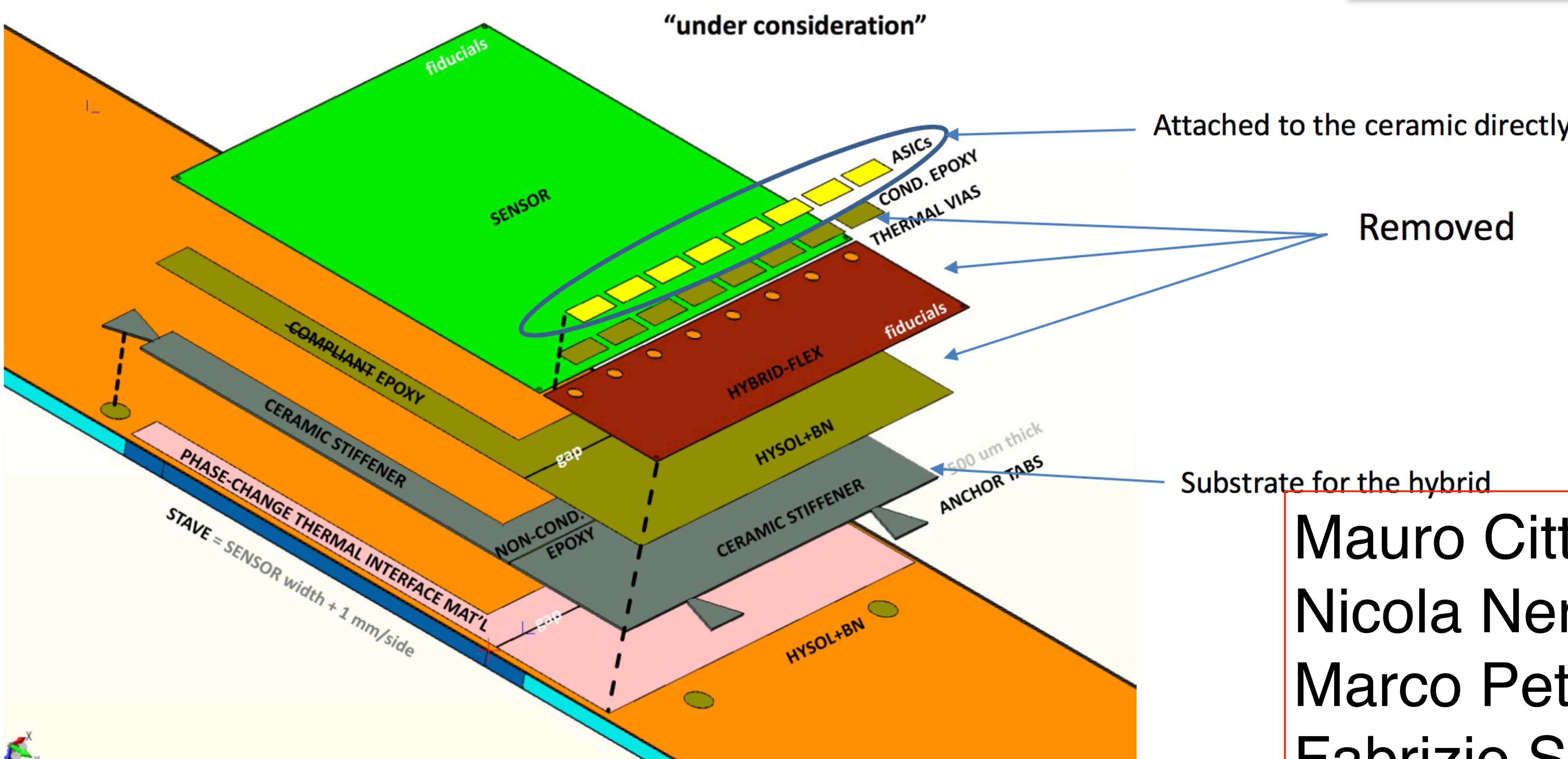
Diff-mode crosstalk

Second generation flex prototypes



- Improved design:
  - better trace shape and control of trace width
  - improve Z matching
  - additional ground sense lines
  - HV traces and pads for sensor bias
- Production at CERN workshop is now the baseline solution
  - expected delivery of 10 prototypes on July 10th
  - production in stages based on CERN board per month capabilities

Alternative hybrid solution



Mauro Citterio
Nicola Neri
Marco Petruzzo
Fabrizio Sabatini

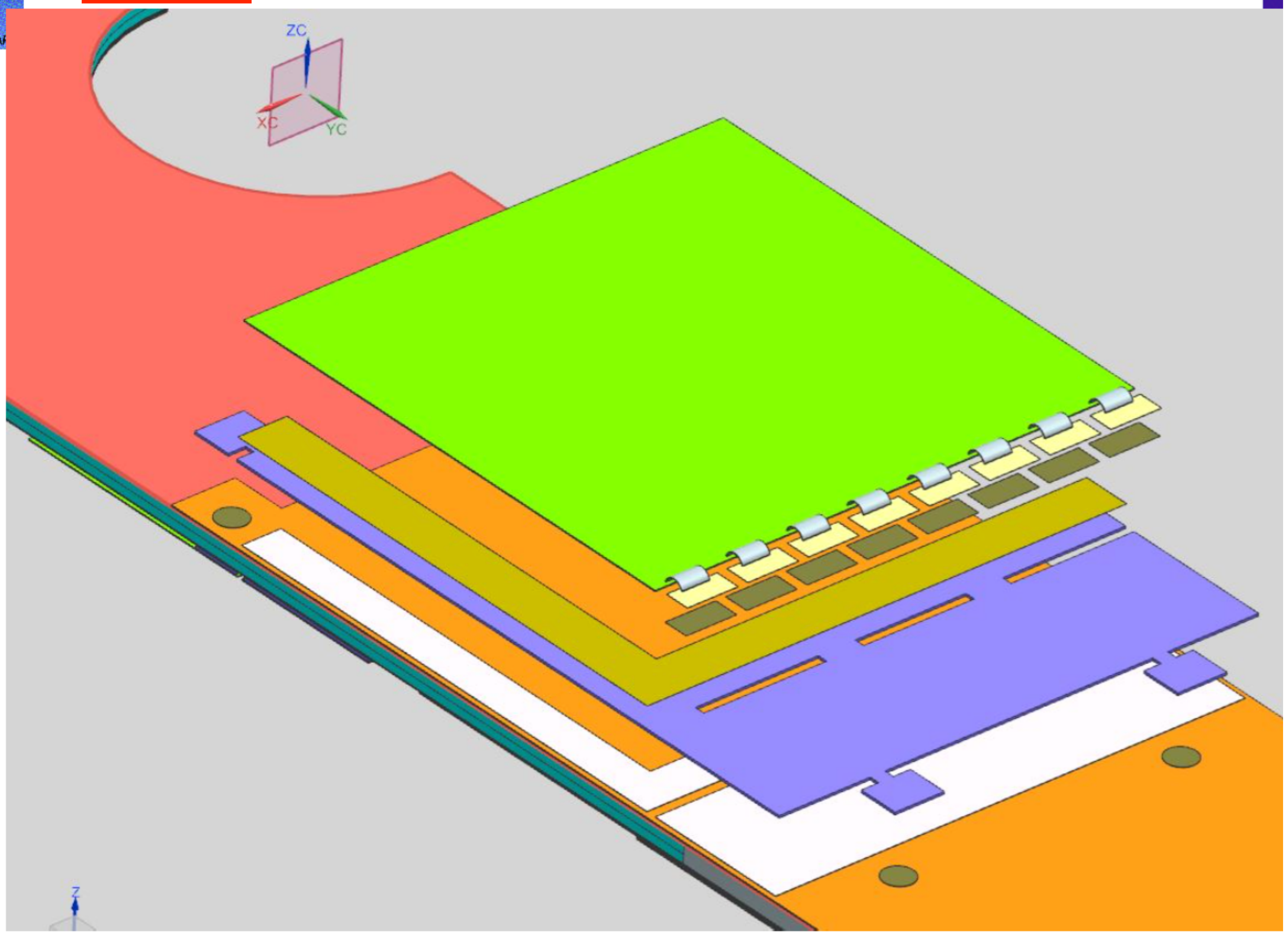
PROPOSAL: the hybrid is a ceramic AlN thick-film hybrid who satisfy both the thermal and electrical requirements of the system.

X0 does not increase → AlN X0 is 8.4 cm, thickness 250 um

Mechanical requirement could also be satisfied by the hybrid itself

Milano proposal for sensor hybrid

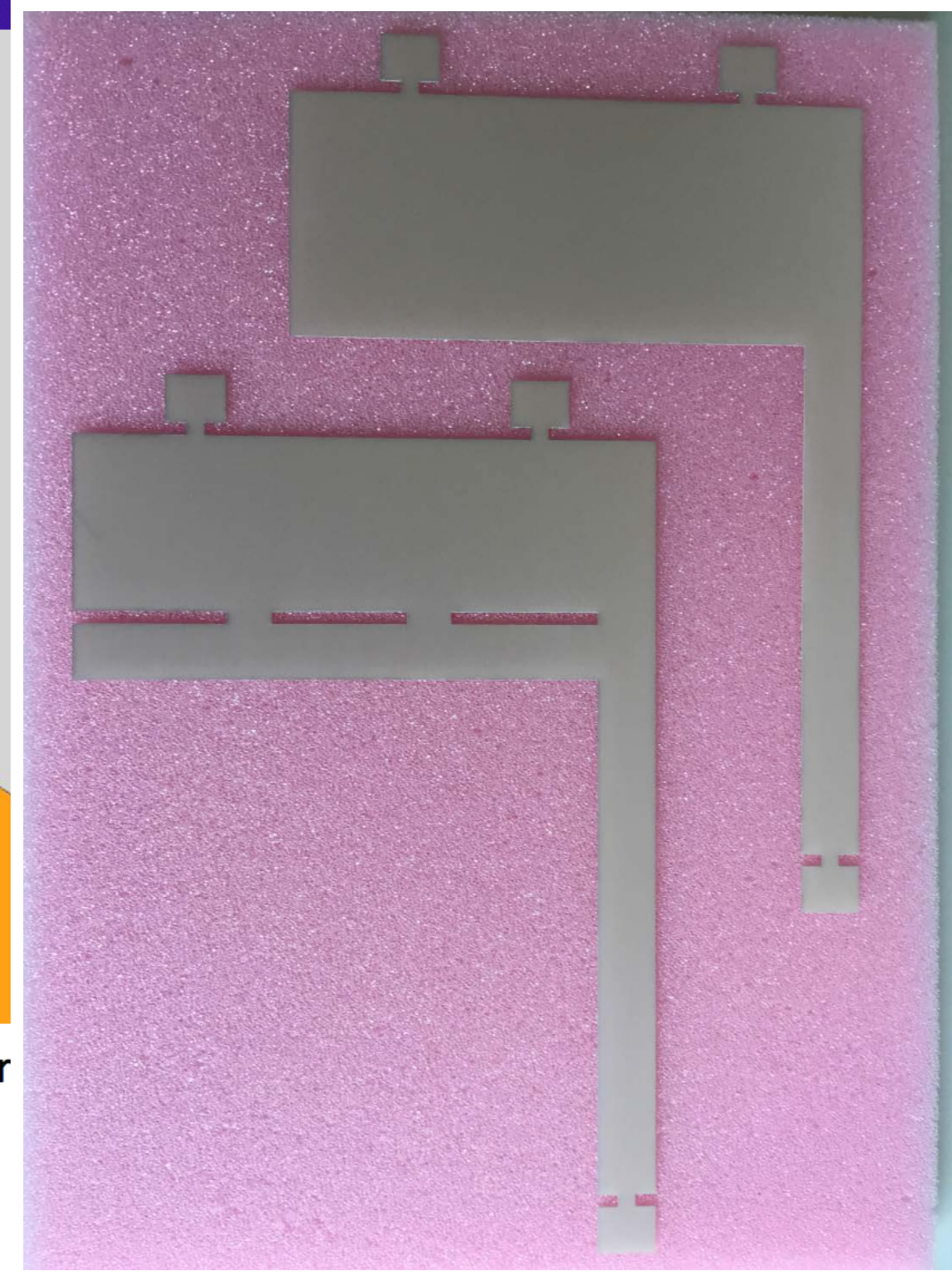
New Ceramic Hybrid Design



With respect to v5 hybrid solution: no thermal vias, no hybrid flex, no epoxy layer
Pro: improved thermal conductivity and cooling efficiency
Simplified construction and mounting of the stave

8/05/2015 Mauro Citterio - UT Workshop May 2015

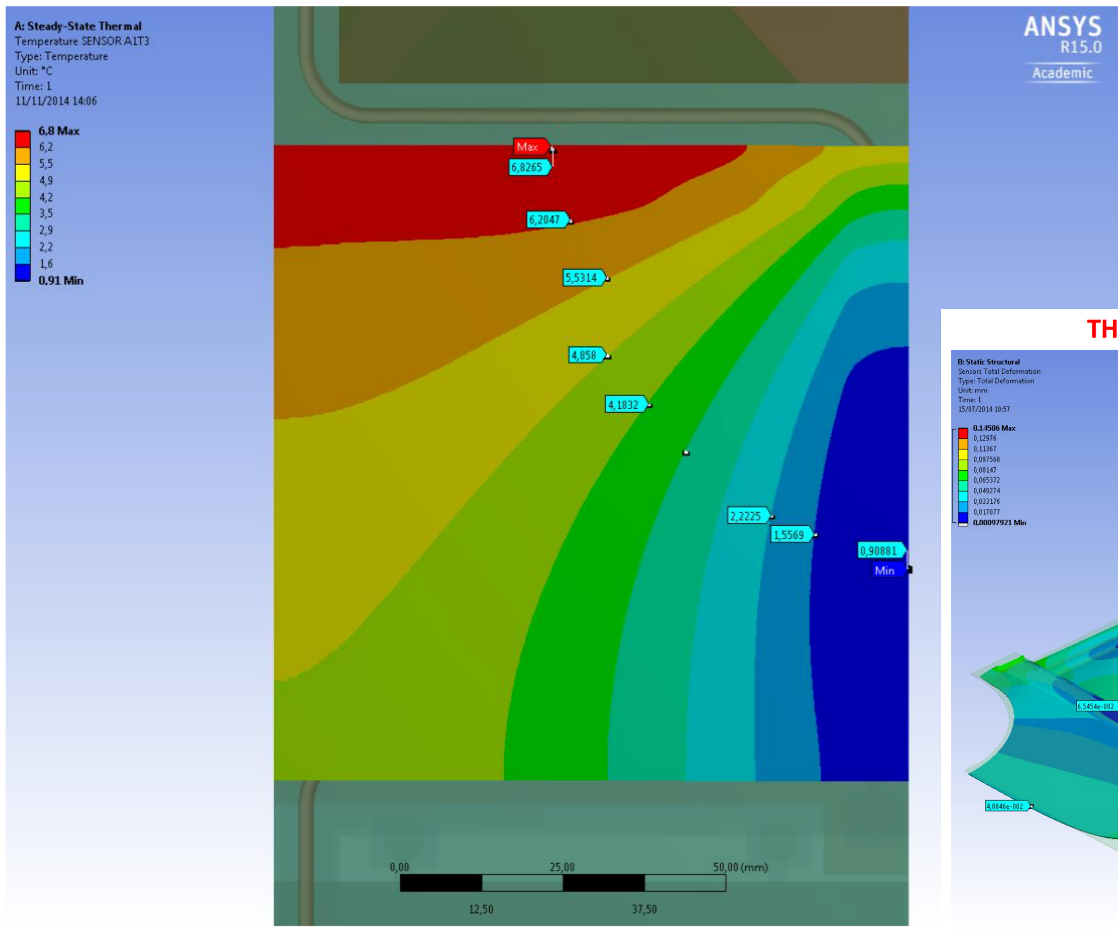
Mechanical prototypes

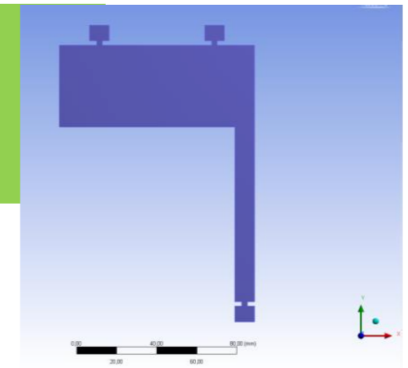


Thermal & Mechanical simulations

Simone Coelli
Mauro Monti

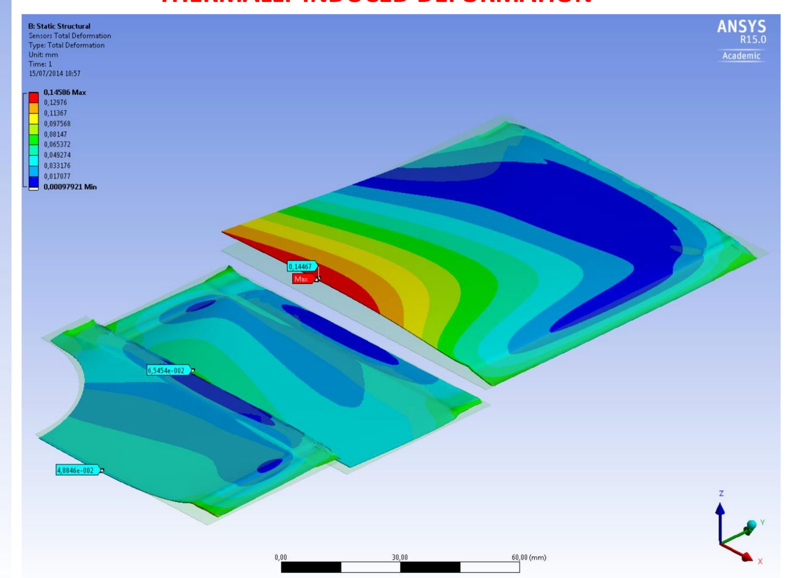
Material AlN (Aluminum Nitride)
thermal conductivity k = 180/180/180;
ceramic thickness = 0.250 mm





SENSOR A1.T3
MAX DELTA T = 5.9 °C

THERMALLY INDUCED DEFORMATION



MAX DISPLACEMENT IN THE SENSOR A1.T3: 150 μm
almost all in the vertical direction Z axis, out of sensor plane

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Coolant T=0 °C
Max T = 6.8 °C
Max ΔT_{sensor}= 5.9 °C

LHCb	LHCb UT DETECTOR UPGRADE EDR June 2015		
Document: EDMS 517621 v.1		Created: 2015.06.09 Modified:	Page: 1 of 25 Rev. No.: 1

LHCb UT DETECTOR UPGRADE

SUMMARY OF THE THERMAL AND MECHANICAL FINITE ELEMENT ANALYSIS (F.E.A.) FOR THE DESIGN AND THE OPTIMIZATION OF THE DETECTOR STAVE

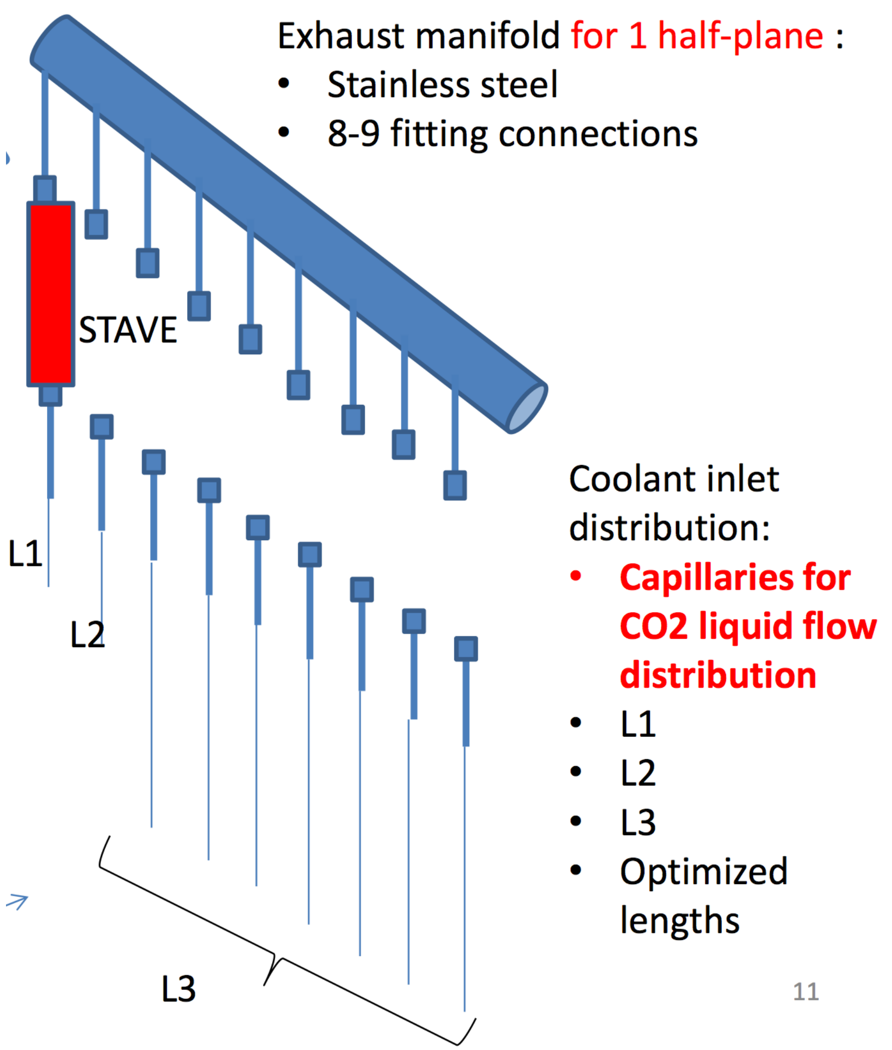
This document contains background information for the EDR in June 2015 regarding the ANSYS FEM analysis made and the work in progress for the LHCb UT detector local supports, called "staves", toward an optimized design.

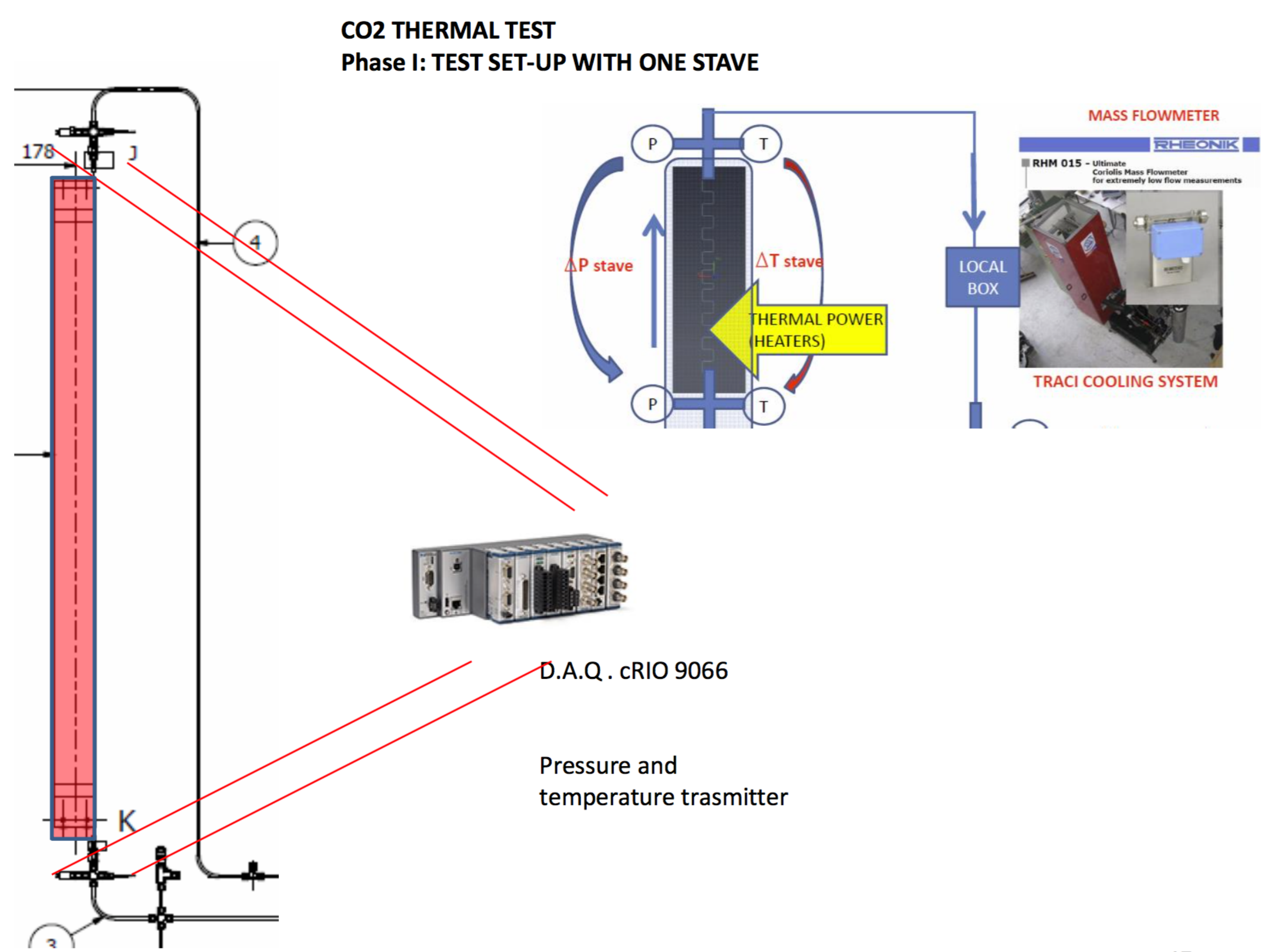
Simone Coelli – I.N.F.N. MILANO
Mauro Monti – I.N.F.N. MILANO

Design of the CO_2 cooling system

Simone Coelli
Carlo Gesmundo

- Participation to the development of TRACI cooling system in collaboration with CERN
- Crucial contribution for the design and test of the UT CO_2 cooling system





CO_2 cooling test setup in Milano

Opened cold box

TRACI v 2-Phase Accumulator Controlled Loop system from CERN.

Measurement of CO_2 mass flow

Simone Coelli
Andrea Capsoni
Carlo Gesmundo
Andrea Merli
Ennio Viscione

Dummy stave with temperature sensors

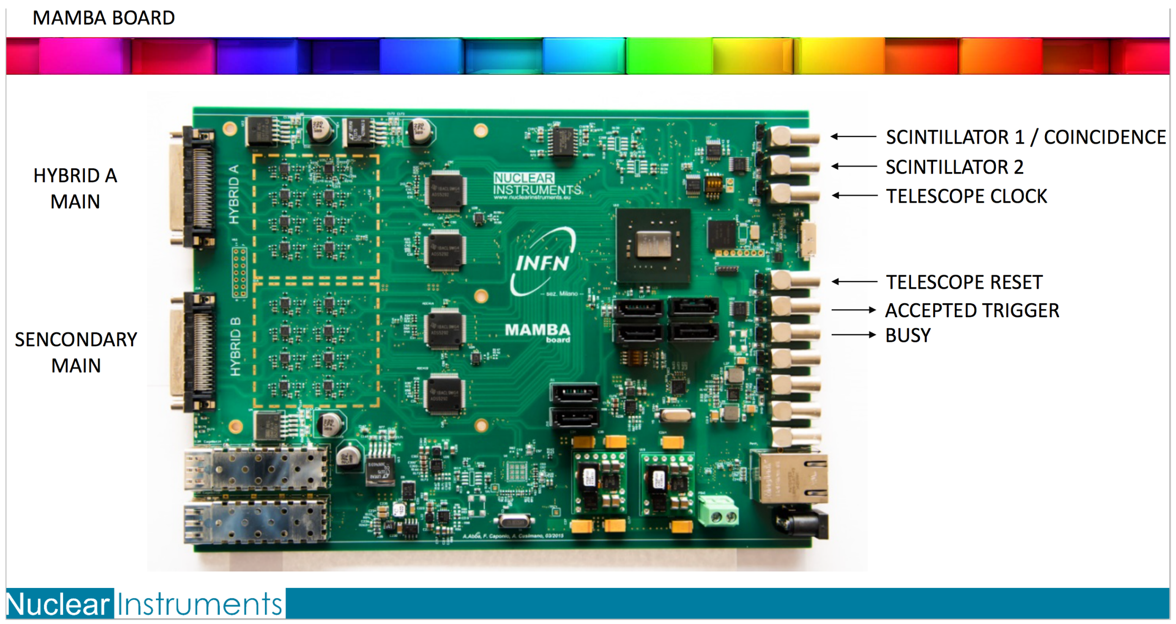
Mock-up stave with titanium cooling tubes in snake pipe configuration

Cooling system measurement of T, P of CO_2 fluid

Just started with first measurements

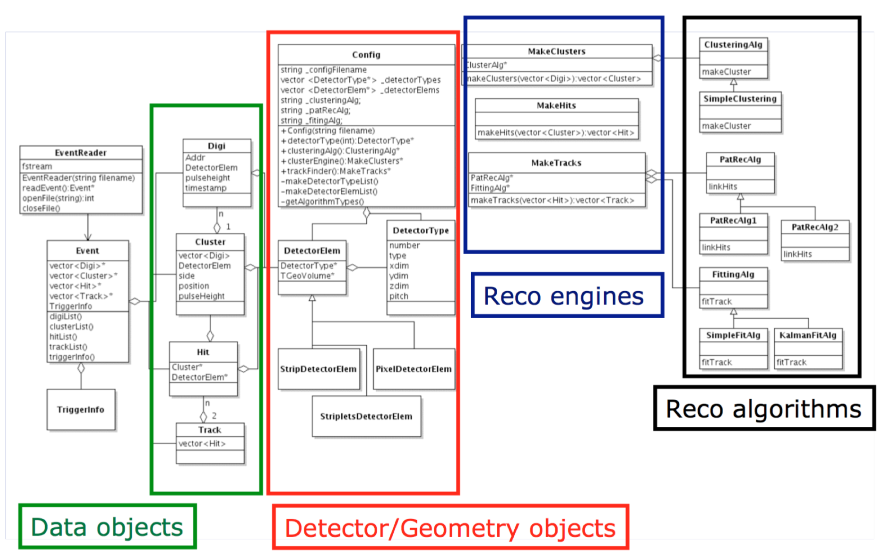
Prototype sensor testing

- Designed a DAQ board for detector prototypes. Signal digitalisation and zero suppression (Beetle chip)



Andrea Abba,
Francesco Caponio

- Developed a software package (Sbt) for track reconstruction and analysis of testbeam data



Nicola Neri
Marco Petruzzo
Jinlin Fu

LHCb-PUB-2015-015
May 30, 2015

Testbeam studies of pre-prototype silicon strip sensors for the LHCb UT upgrade project

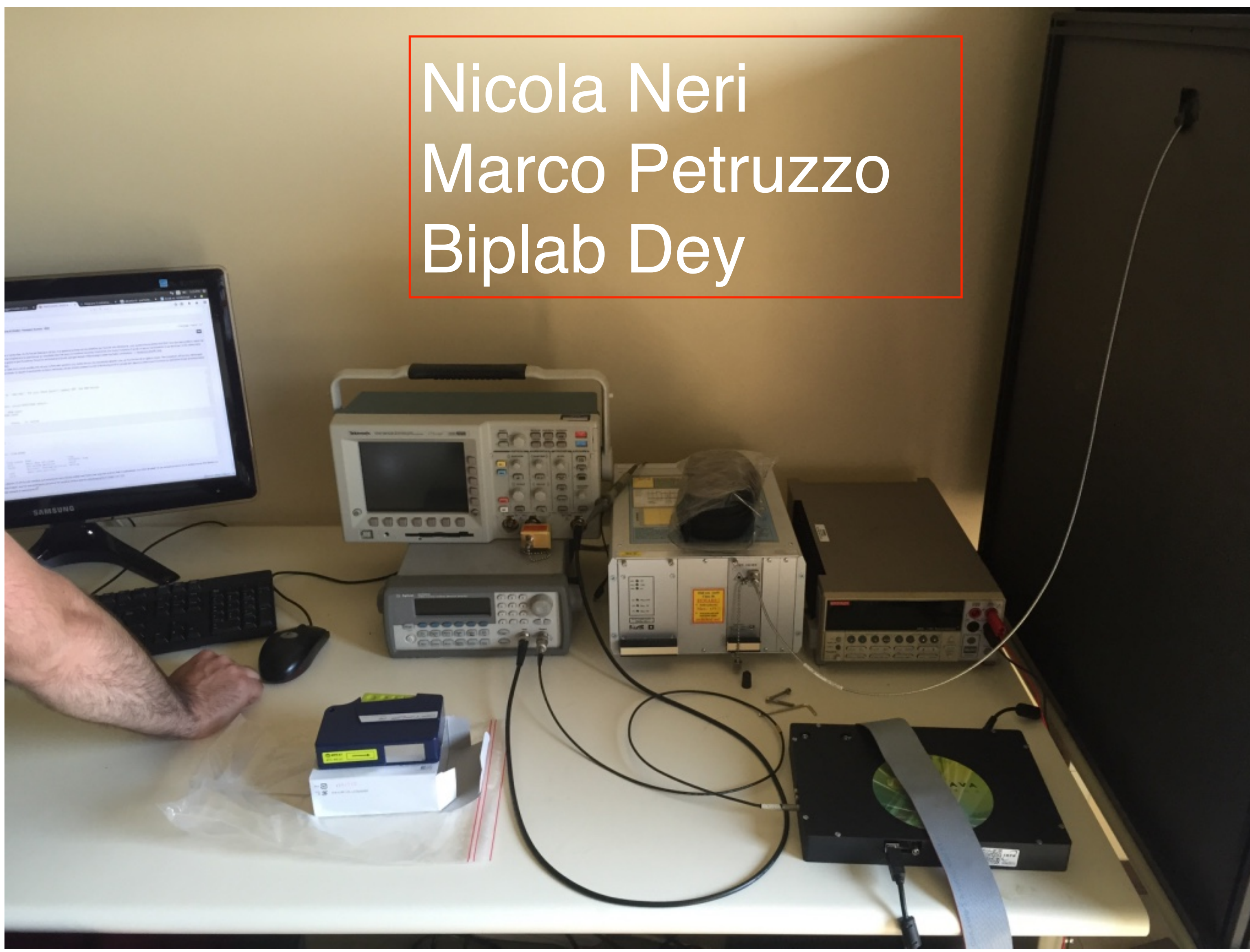
A. Abba[1], M. Artuso[2], S. Blusk[2,6], T. Britton [2], A. Davis[3], A. Dendek[4], B. Dey[5], S. Ely[2], T. Evans[7], J. Fu[1], P. Gandini[2], F. Lionetto[5], P. Manning[2], B. Meadows[3], R. Mountain[2], N. Neri[1], M. Petruzzo[1], M. Pikies[4], T. Skwarnicki[2], T. Szumlak[4], J. C. Wang[2]

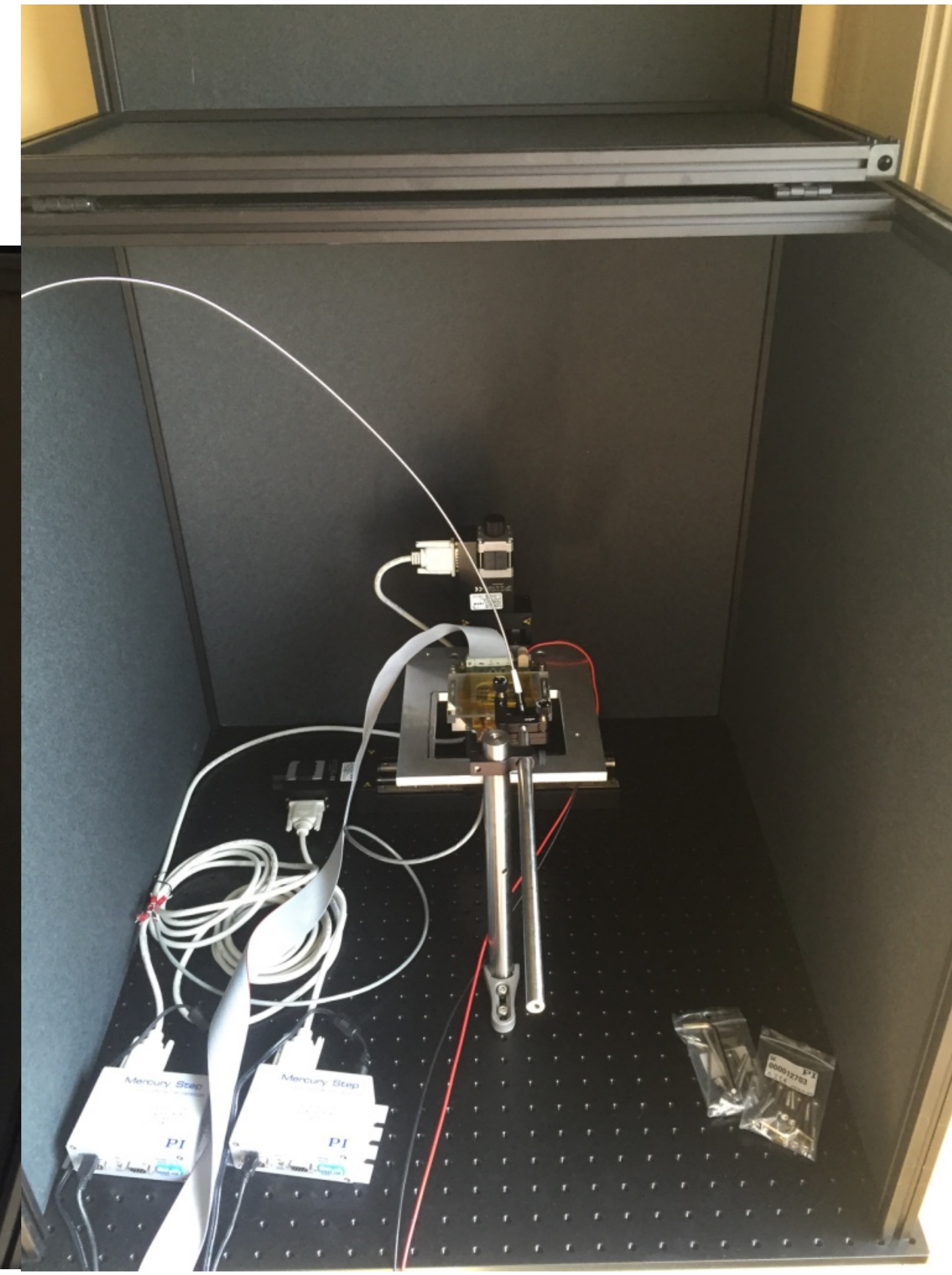
[1]*Instituto Nazionale di Fisica Nucleare - Sezione di Milano, Italy*
[2]*Syracuse University, Syracuse, NY USA*

Prototype sensor testing

- Test detector modules using 1064 nm laser with 10 μm spot size and radioactive sources
- The setup is ready and will be used as soon as safety procedures will be implemented

Dark Box with automatic positioning system

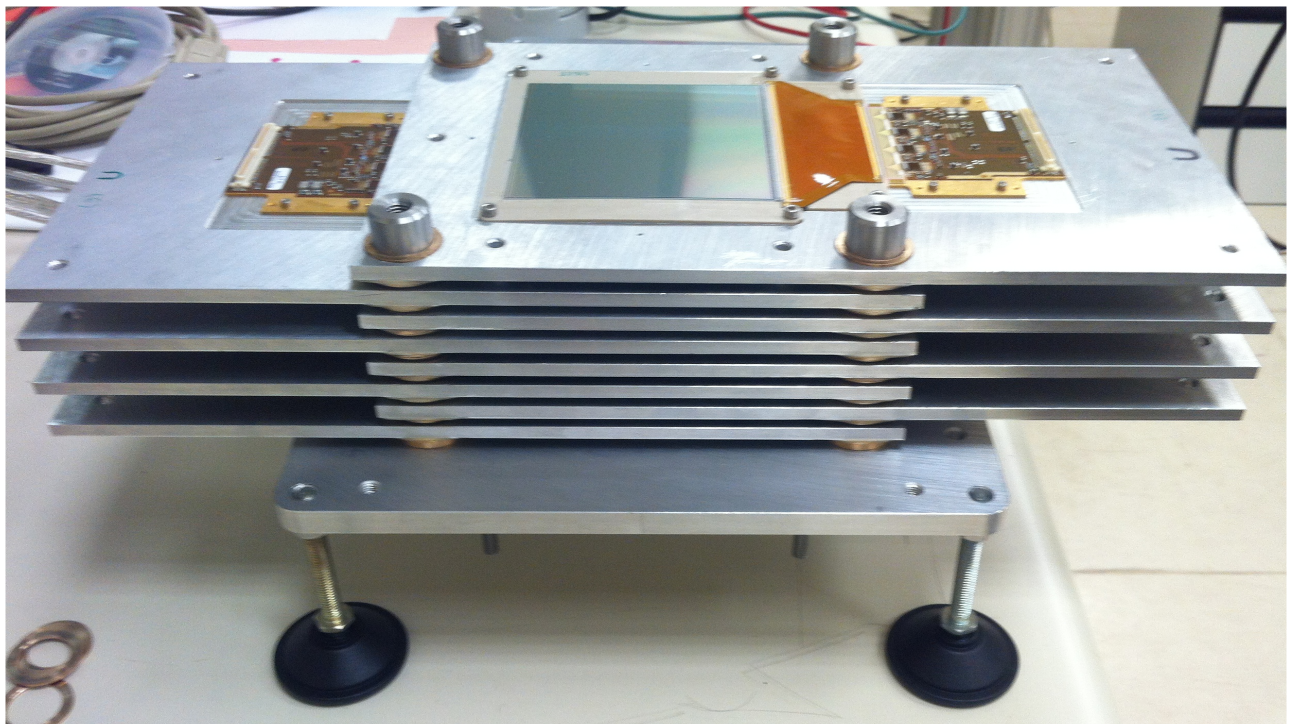


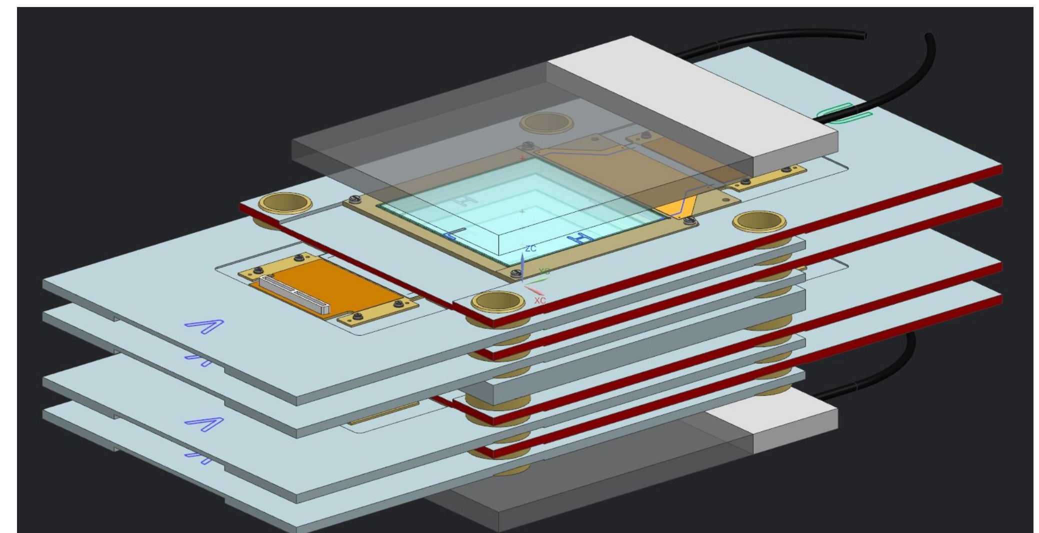


Silicon sensor telescope

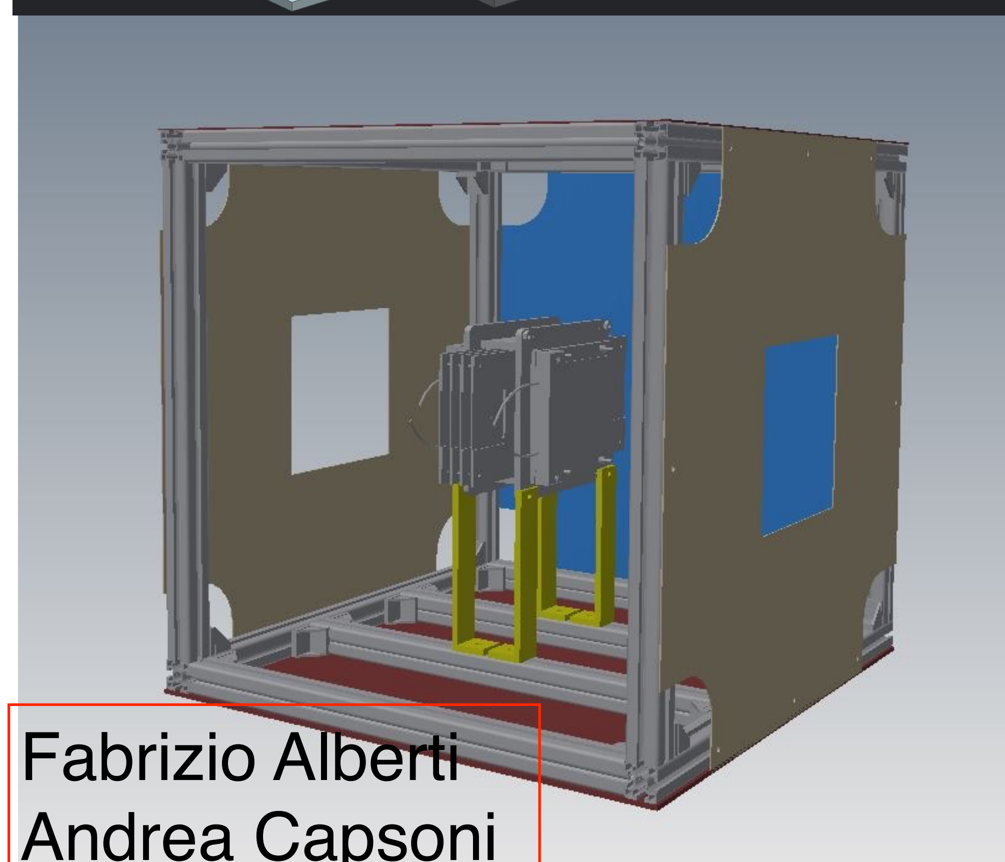
Nicola Neri (System design, simulations)
Marco Petruzzo

Simone Coelli (Mechanics)
Mauro Monti





- Built in Milano a prototype for “artificial retina” for fast track finding. CSN5 experiment
- Test on beam at CERN



Fabrizio Alberti
Andrea Capsoni

Tesi di laurea

- M. Petruzzo, “First Prototype of a Tracking System with Artificial Retina for Fast Track Finding”, October 2014 - PhD student Unimi
- E. Spadaro Norella, “Analisi dei dati del test su fascio di prototipi di rivelatori al silicio a strip per l’ upgrade dell’ esperimento LHCb”, March 2015 (laurea triennale)
- A. Merli, “Search for CP violation using T-odd correlations in $\Lambda^0_b \to ph^-h^+h^-$ and $\Xi_b{}^0 \to ph^-h^+h^-$ decays ($h = K, \pi$)”, April 2015 - borsista neolaureato INFN
- D. Marangotto, Study of $\Lambda^0_b \to ph^-\mu^+\mu^-$ decays”, ongoing

Contributions at conferences

- N. Neri, “First Prototype of a Tracking System with Artificial Retina for Fast Track Finding”, IEEE Nuclear Science Symposium, Seattle, USA (November 2014)
- N. Neri, “First prototype of a silicon tracker with artificial retina”, TREDI 2015, Trento (February 2015)
- N.Neri, “First results of the silicon telescope using an artificial retina for fast track finding”, ANIMMA2015, Lisboa, Portugal (April 2015)
- J. Fu, “Ricerca di violazione di CP attraverso osservabili T-dispari in decadimenti di mesoni con charm”, IFAE 2015, Roma (April 2015)
- N. Neri, “Production and decay of heavy flavour baryons”, FPCP2015, Nagoya, Japan (May 2015)
- M. Petruzzo, “Real time tracking with a silicon telescope prototype using the “artificial retina” algorithm”, Pisa Meeting 2015 (May 2015)
- B. Dey, “Recent Results from LHCb”, SSI 2015, SLAC, (August 2015)

Richieste 2016 - Milano

Anagrafica

People	Position	LHCb 2015	LHCb 2016
B. Dey	PostDoc	0,75	1,0
J. Fu	PostDoc	0,8	0,7
A. Merli	Borsista	0	0,6
N. Neri	PhD Staff	0,7	0,7
F. Palombo	Faculty	0	0
M. Petruzzo	PhD student	0	1,0
M. Citterio	Applied Physicist Staff	0,3	0,2
S. Coelli	Mechanical Engineer Staff	0,4	0,4
M. Lazzaroni	Electronic Engineer Staff	0,3	0,3
Others		2,2	0
FTE		5,45	4,9

- Missioni e metabolismo
  - MI: 5 kEuro
  - ME: 55+19 (respons.) = 74 kEuro
  - Consumo 8 kEuro
- Upgrade UT:
  - preproduzione data-flex (10%) 30 kEuro
  - produzione data-flex (40%) SJ a PRR 120 kEuro
  - costruzione prototipi ibridi 10 kEuro
  - meccanica e cooling (da stabilire)
- MOF Silicon Tracker
  - 6kEuro

Richieste per servizi in Sezione

- Servizio officina meccanica e progettazione: 24 mesi uomo
- Servizio elettronica: 24 mesi uomo

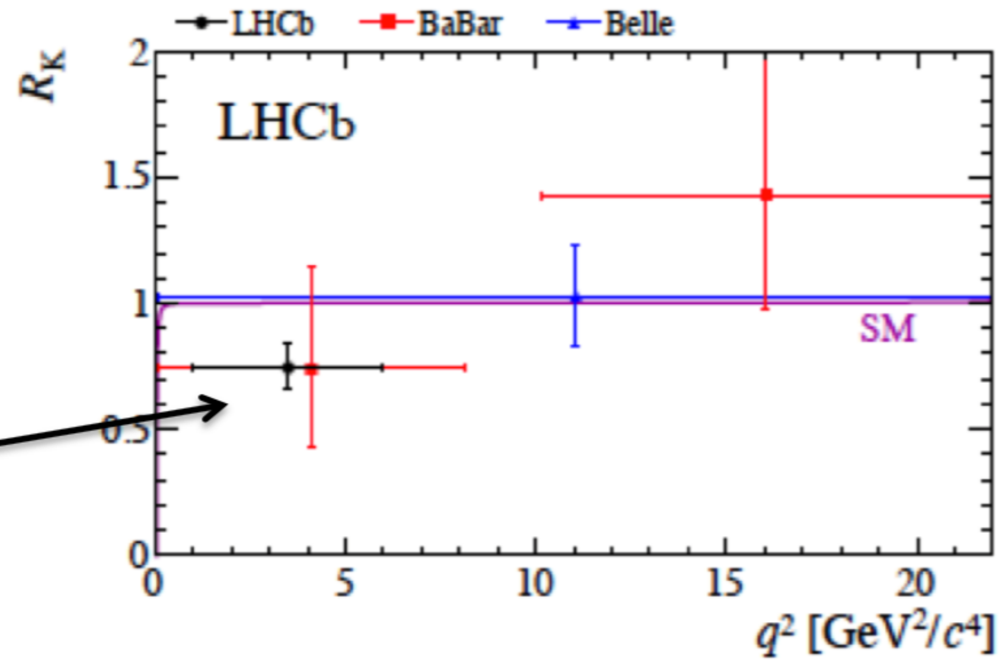
Backup

$B^+ \to K^+ \ell^+ \ell^-$: R_K anomaly

- $R_K = \mathfrak{B}(B^+ \to K^+ \mu^+ \mu^-) / \mathfrak{B}(B^+ \to K^+ e^+ e^-)$
  - expected in the SM to be 1 with great accuracy
  - test of lepton universality
- Hint of a possible discrepancy with SM measured by LHCb with 3 fb^{-1}

$$0.745^{+0.090}_{-0.074}(\text{stat}) \pm 0.036(\text{syst})$$

$$1 < q^2 < 6\ \text{GeV}^2/c^4$$



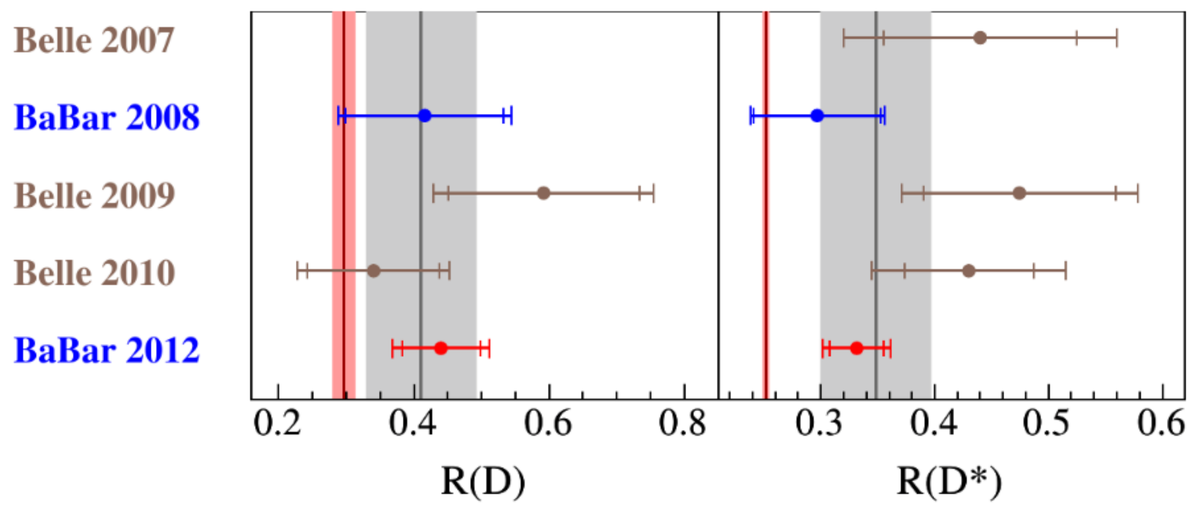
LHCb, PRL 113 (2014) 151601
Belle, PRL 103 (2009) 171801
Babar, PRD 86 (2012) 032012

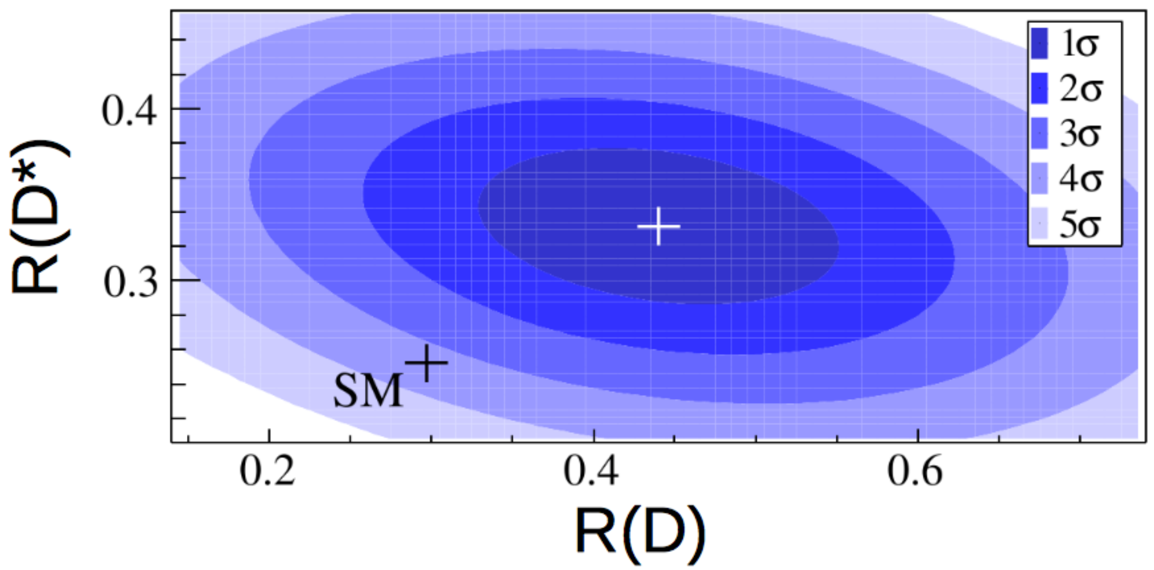
- Compatible with SM at 2.6σ at low di-lepton invariant mass

$B \to D^{(*)}\tau\nu$

- Powerful channel to test lepton universality
- ratios $R(D^{(*)}) = \mathcal{B}(B \to D^{(*)}\tau\nu)/\mathcal{B}(B \to D^{(*)}\mu\nu)$ could deviate from SM values, e.g. in models with charged Higgs
- Heightened interest in this area
  - anomalous results from BaBar
  - other hints of lepton universality violation, e.g. R_K , $H \to \tau\mu$

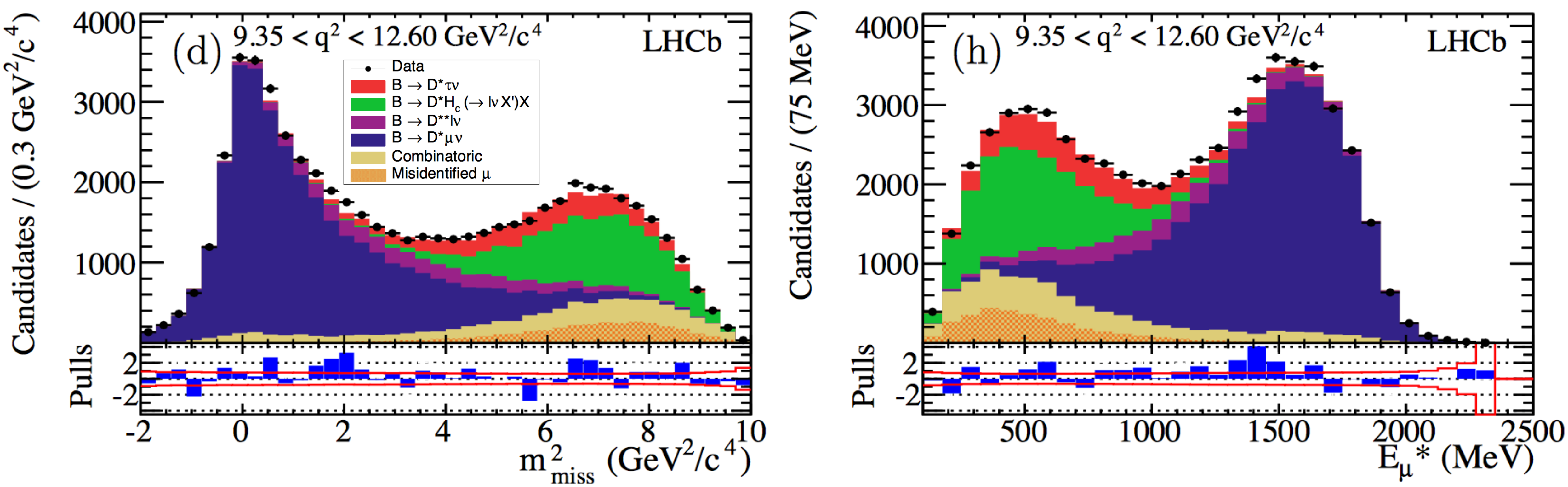
PRL 109 (2012) 101802
& PRD 88 (2013) 072012





$B \to D^{*}\tau\nu$ at LHCb

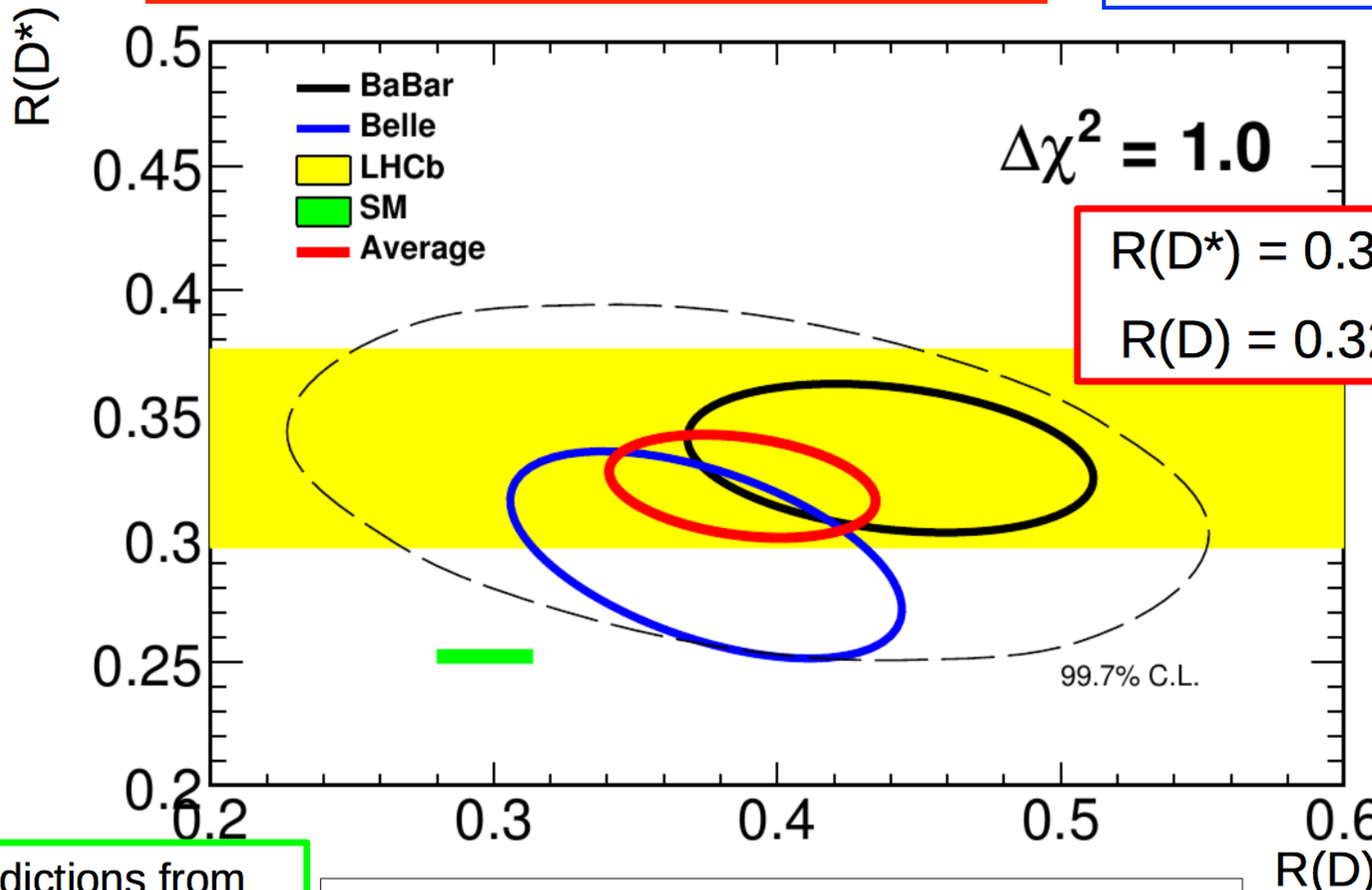
- Identify $B \to D^{*}\tau\nu$, $D^{*} \to D\pi$, $D \to K\pi$, $\tau \to \mu\nu\nu$
  - Similar kinematic reconstruction to $\Lambda_b \to p\mu\nu$
  - Assume $p_{B,z} = (p_{D^*} + p_\mu)_z$ to calculate $M_{miss}^2 = (p_B - p_{D^*} - p_\mu)^2$
  - Require significant B, D, τ flight distances & use isolation MVA
- Separate signal from background by fitting in M_{miss}^2, q^2 and E_μ
  - Shown below high q^2 region only (best signal sensitivity)



$B \to D^{(*)}\tau\nu$ results vs SM

Tension with SM seems to persist

Very preliminary & unofficial average



R(D*) = 0.390 ± 0.047

R(D) = 0.322 ± 0.021

SM predictions from PRD 85 (2012) 094025

Careful averaging needed to account for statistical and systematic correlations

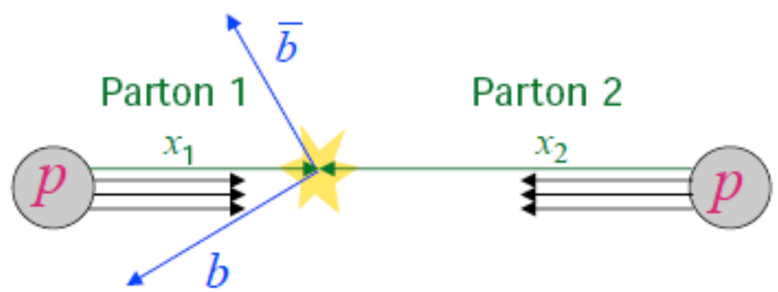
from T. Gershon

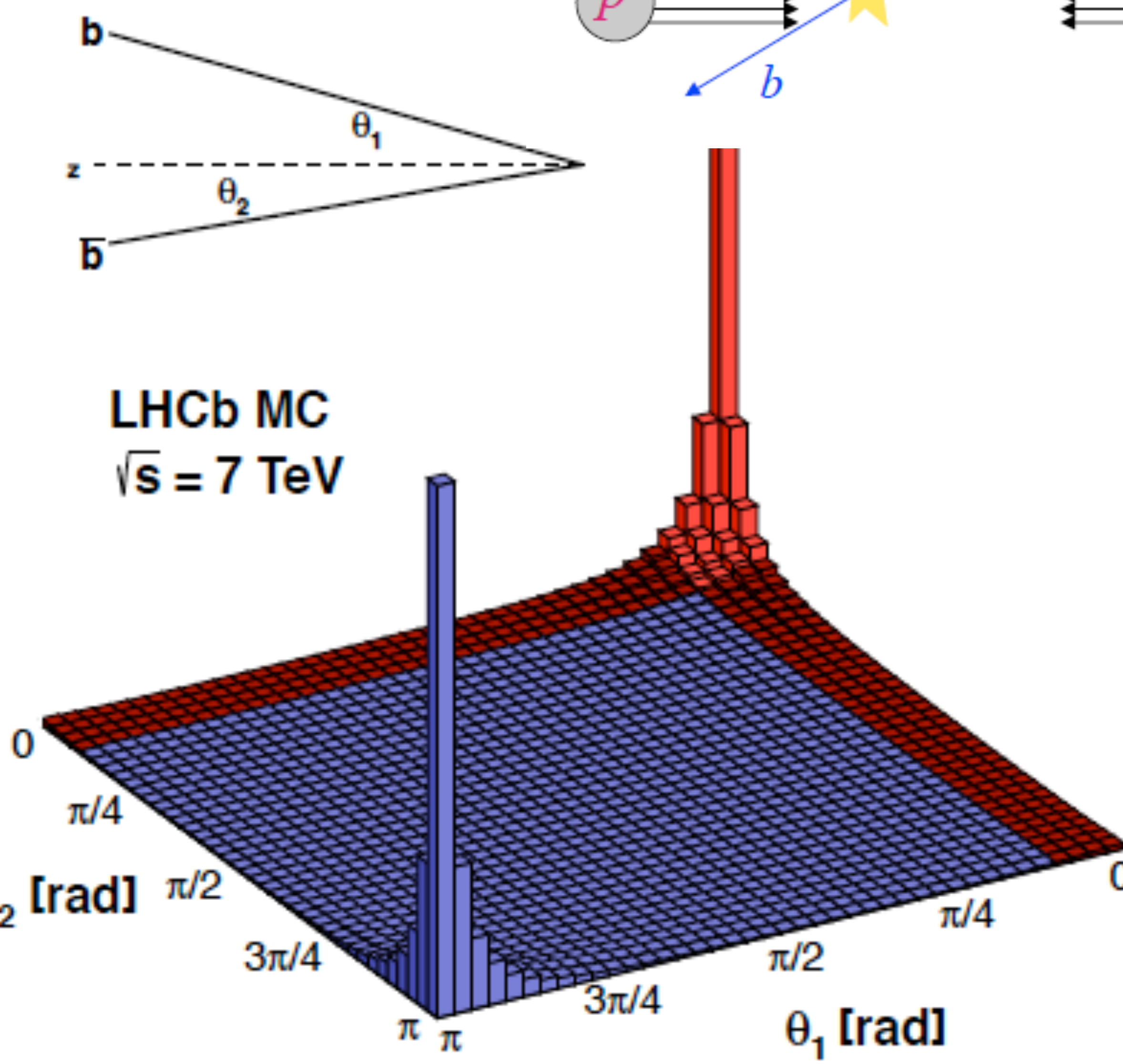
24

Thanks to M. Rotondo

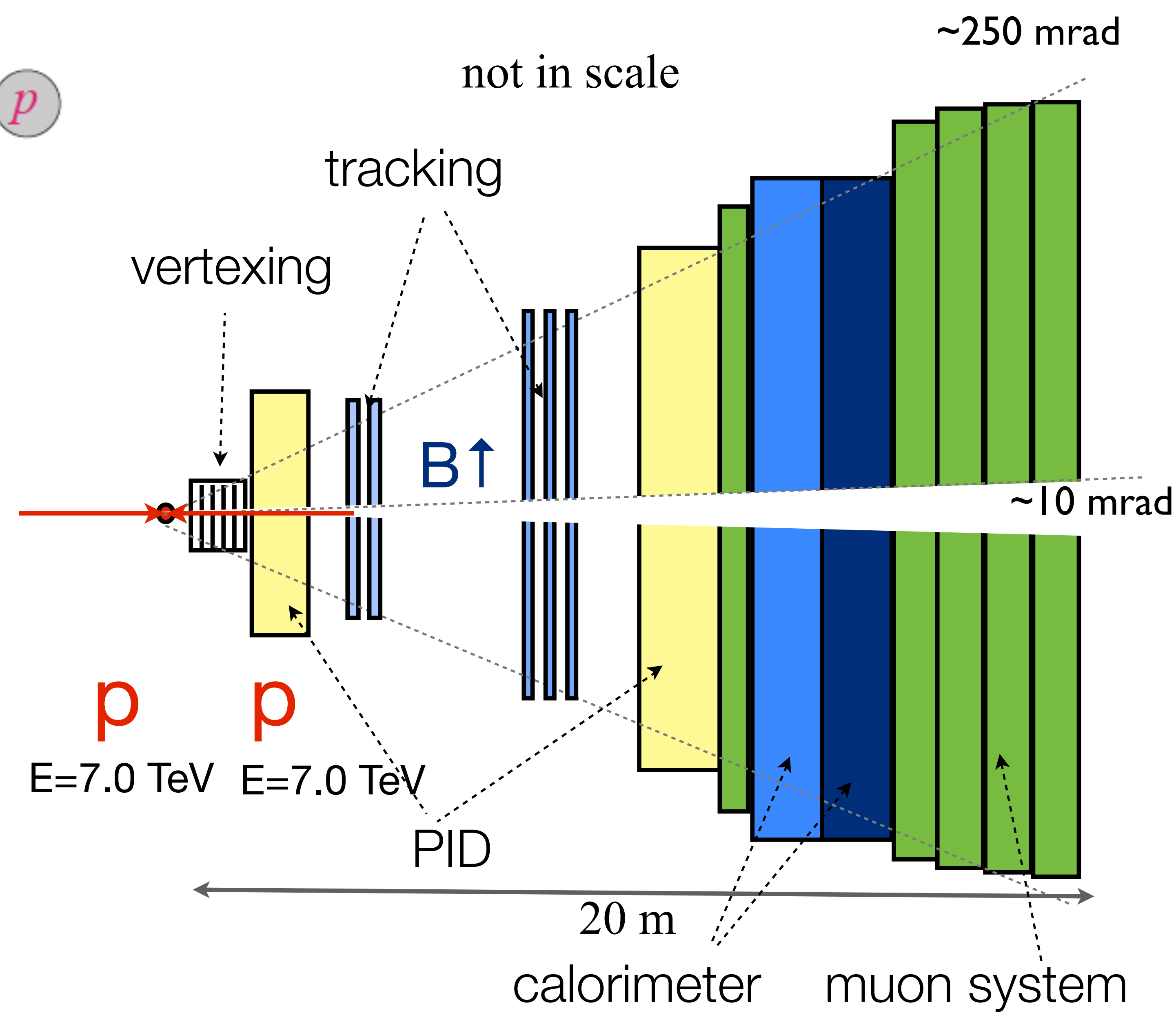
Detector geometry

In high energy pp collisions $b\bar{b}$ events are produced in the forward and backward directions

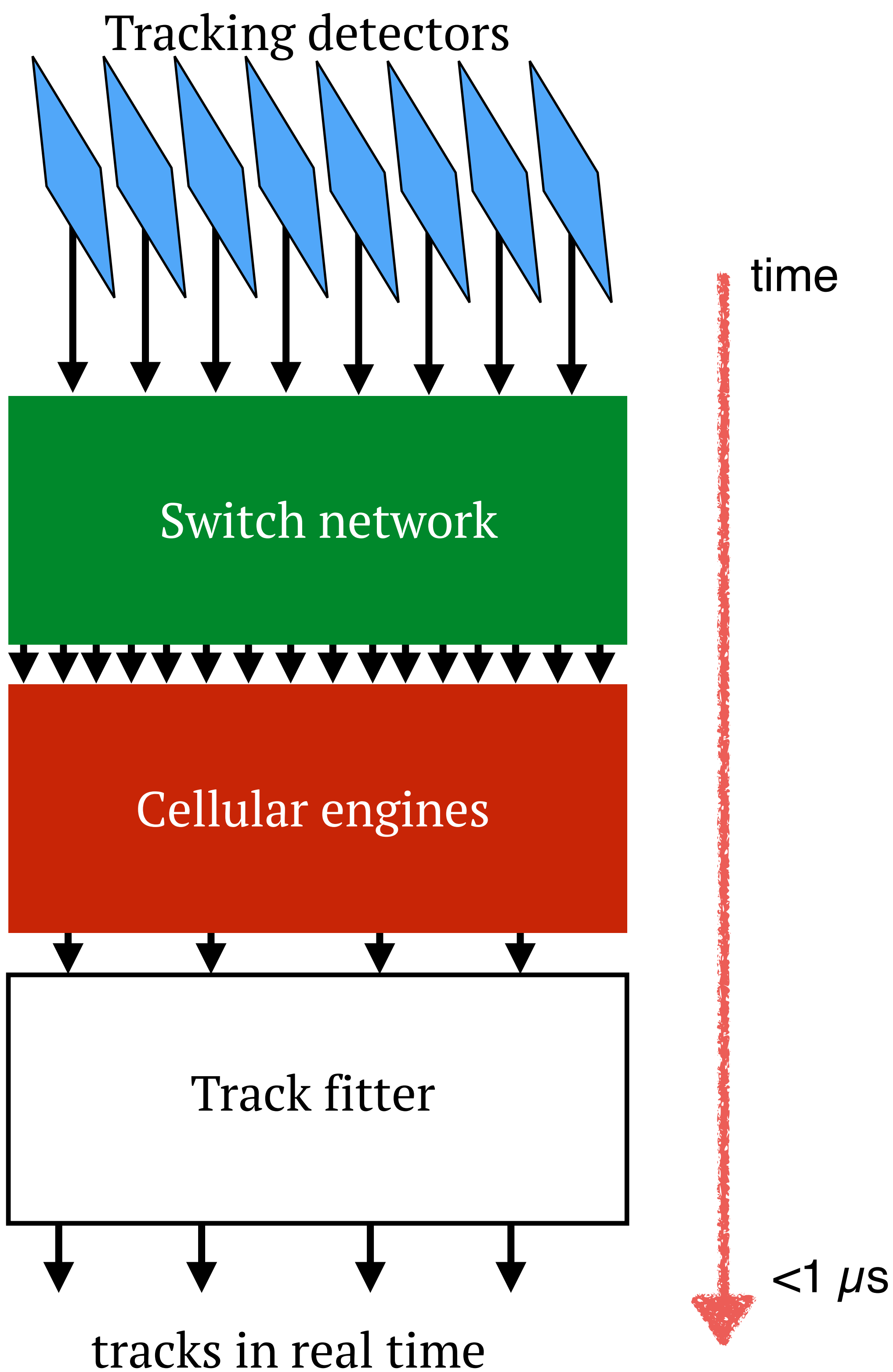




LHCb single arm magnetic spectrometer.
Dipole magnetic field ∫B·dl=3.73 T·m, perpendicular to beam axis



Artificial retina for fast track finding



- The *"artificial retina"* algorithm for fast track finding was originally proposed by *Luciano Ristori* in *NIM A 453 (2000) 425-429.* It takes inspiration from neurobiology and applies to positions sensitive detectors (*e.g.* pixel, strip detectors).
- The algorithm allows massive parallelisation of the calculations for pattern recognition and track parameter determination
- The tracking performance are comparable with offline results with a latency of the response < 1μs.
- Capable to operate 40 MHz, LHC bunch crossing rate, and take L0 trigger decisions
- R&D for LHCb upgrade. Now proposed R&D experiment in CSN5