CMS report

Riunione Gruppo 1 Padova

Alberto Zucchetta on behalf of the CMS Padova group

3 Marzo 2020

CMS Padova group

Many activities ongoing:

- Detector upgrade
- Software development
- Physics analysis and results

Only a brief summary reported today, definitely non-exhaustive!

PADOVA

	Responsabilità Subsystem	Cognome	Nome	Livello	Descrizione Responsabilità
	GOD	carlin	roberto	LV0	SP
	DT	ventura	sandro	LV2	DT Upgrade coordinator
	MU	ventura	sandro	LV2	Electronics coordinator
	DT	bellato	marco	LV2	DT Electronics coordinator
	TK	bacchetta	nicola	LV2	Tracker technical coord
	DT	rossin	roberto	LV2	DT DPG deputy coord
	DT	meneguzzo	anna	LV3	Longevity task force coordinator
	TSG	passaseo	marina	LV2	FOG coordinator
	FIS	tosi	mia	LV2	Tracking POG convener
	TSG	ronchese	paolo	LV3	BPH Software coordination
	FIS	margoni	martino	LV2	BPH PAG Convener (fino a 31/8/2019)
	FIS	margoni	martino		BPH Conference Contact (dal 1/9/2019)
	FIS	zucchetta	alberto	LV3	B2G Diboson convener

CMS preparations for Run 3 and HL-LHC

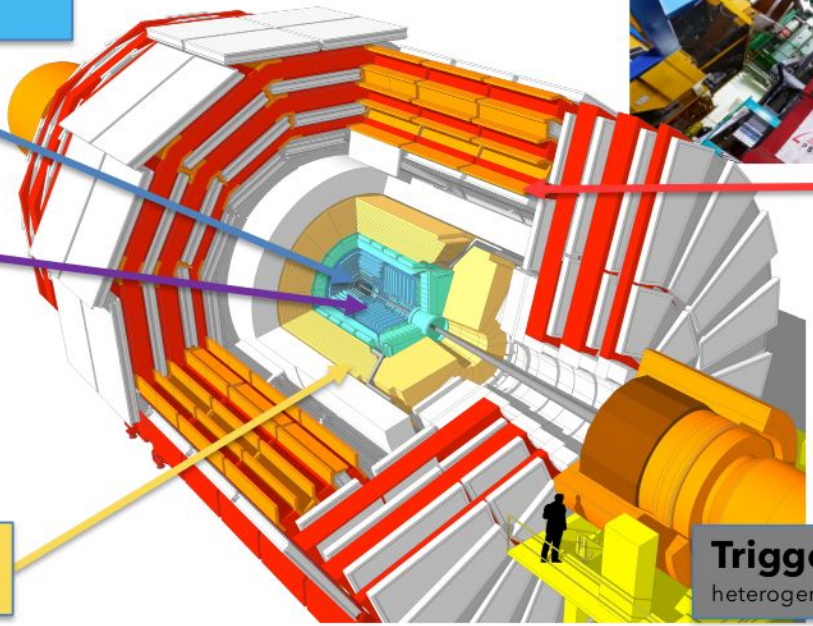
N. Bacchetta

Silicon Tracker
- Pixel
  replace layer1 [250 fb^{-1}] and all DCDC converters
- Microstrips
  running colder -20°C (2018) → -25°C (Run3)

Muon Detectors
shielding against neutron background
- Drift tubes
  upgrade front-end electronics
- Resistive Plate Chambers
  leak repair
- Cathode strip chambers
  upgrade front-end electronics
- GEM
  installed GE1/1 chambers

for phase2

new beampipe
for phase2

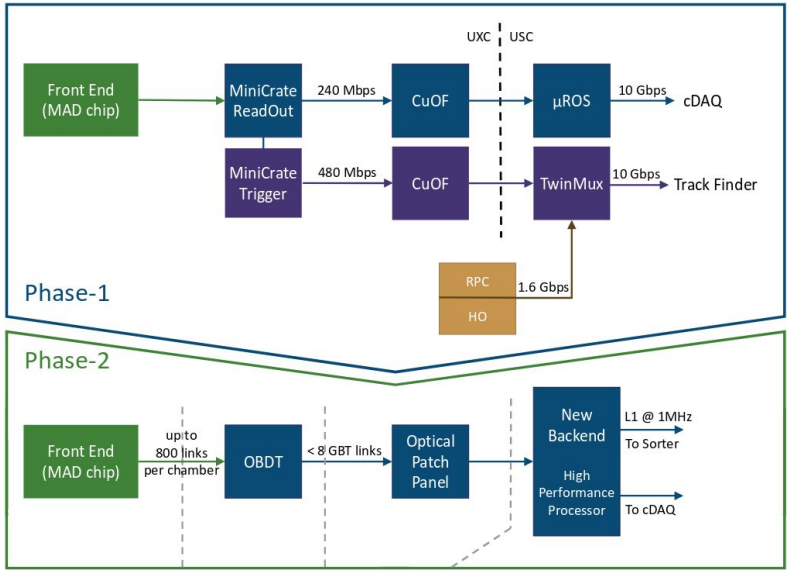


Hadron Calorimeter
install new SiPM+QIE11-based 5Gbps readout

M. Tosi

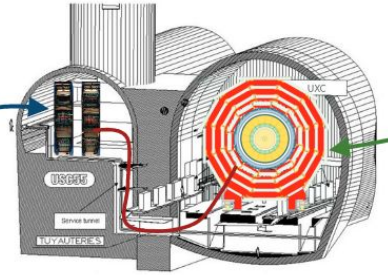
Trigger System
heterogenous HLT farm (CPU+GPU) -decision in 2020

Drift Tubes electronics upgrade for Phase-2



New On-Detector Electronics

- Get a simple (fewer parts) and robust (much less dissipation) system
- Limit the Minicrate to temporal digitization in the experimental cavern and optical transmission
- Move the intelligence and complexity of the trigger generation in an environment without radiation



New Back-End Electronics

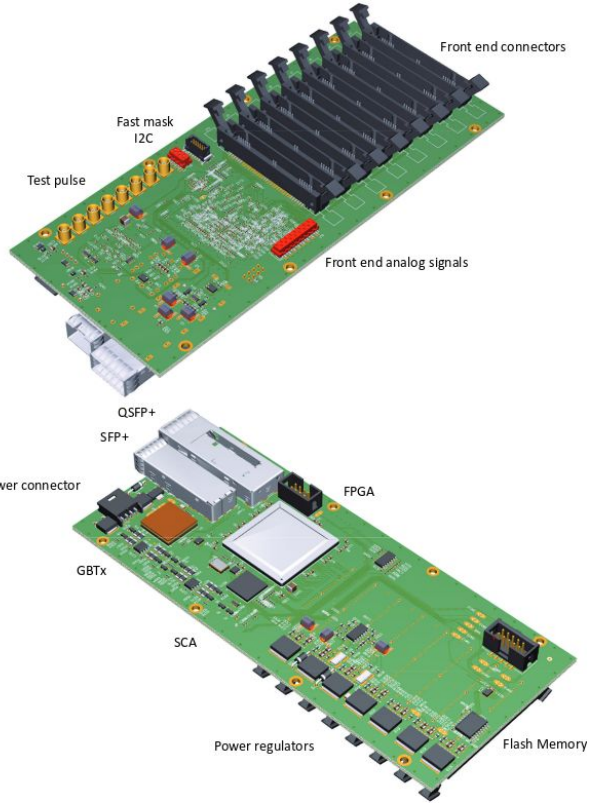
- FPGA-based processors in service room will generate trigger primitives and perform readout functionalities
- Expected performance improvements:
  - Better time resolution for the trigger
  - Better spatial resolution in theta view

Upgrade motivations:

- L1 trigger limited to 300 kHz (need at least 500 kHz for HL-LHC)
- Designed for radiation levels corresponding to 500 fb^{-1}, sensitive devices
- Buried in iron yoke ➜ difficult and scarce maintenance
- Not fully robust against single-hit inefficiency
- Due to trigger primitives generated locally, its generation requires at least 3 layers out of 4.
- Aging of DTs could lead to significant chamber trigger inefficiency

S. Ventura, M.Bellato, R. Rossin, Officina Elettronica, Officina Meccanica, e molti altri....

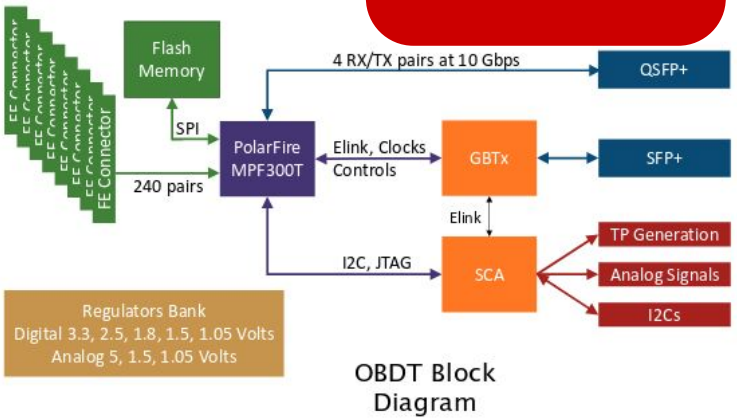
The OBDT board development



- Phase 2 electronics will contain the same basic functionality but in a simpler and better organized way
- On detector electronics will act as a simple bridge containing only the TDCs while most functionalities will be moved outside of the experimental cavern
- This will allow more flexibility and larger bandwidth
- Reduce electronics exposed to radiation

- The OBDT (On-Board electronics for Drift Tubes) module is a board based on a FPGA (PolarFire) implementing the Time-to-Digital-Converters (1 ns resolution)
- High-throughput with 10Gbps optical link to send data to the back-end in service cavern
- The OBDT module will perform slow control (FE access, monitoring, test pulse, RPC connection)
- Radiation-tolerant (up to 20 krad

S. Ventura, M.Bellato, F. Gonella, Officina Elettronica, Officina Meccanica, e molti altri....

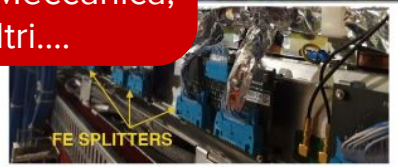


OBDT Block Diagram

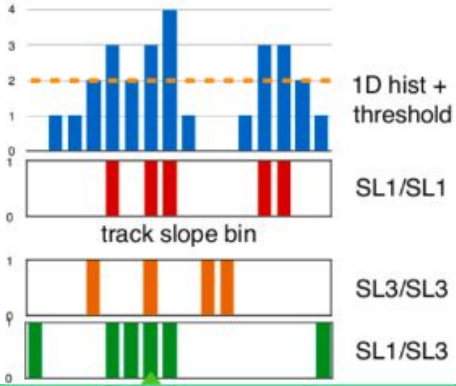
Slice test at CERN & plans

- One sector of CMS is equipped with signal splitters to commission the new electronics alongside the legacy system during Run 3
- Results of the 2019 tests published (TWEPP19). Good time resolution and linearity confirmed
- Remaining clock and synchronization issue being investigated before next prototype production
- Splitting OBDT for phi (**PADOVA**) and theta (CIEMAT): different firmware and board motivated by different connectors
- A new prototype is planned for Q2 2020, with new lpGBT instead of GBTx, PolarFire with larger number of input channel, remote FPGA programming
- Radiation test of current OBDT in Trento in 2020

S. Ventura, M.Bellato, F. Gonella, Officina Elettronica, Officina Meccanica, e molti altri....

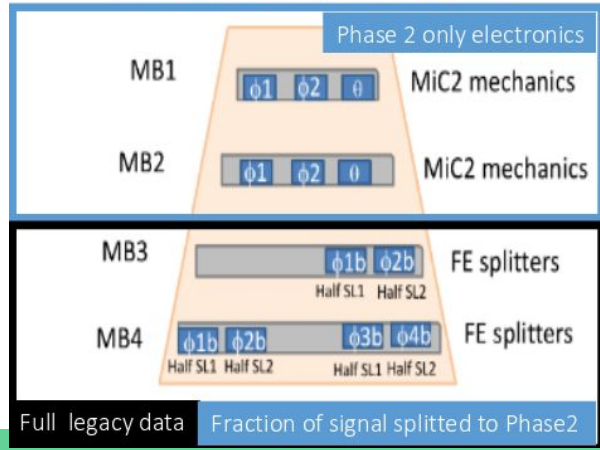


HL-LHC trigger studies



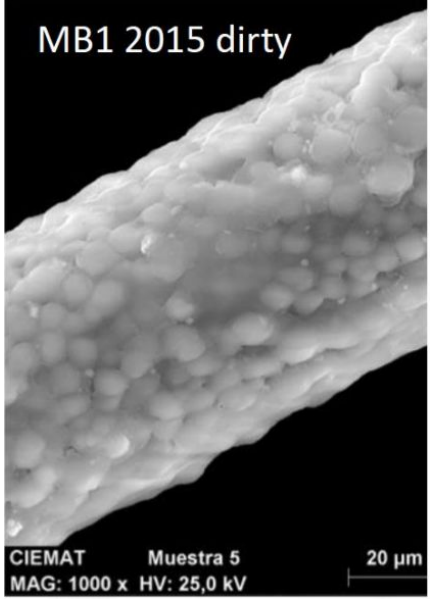
- Developing new algorithms to extract the **trigger primitives** (backend)
- To be implemented in a FPGA
- Based on a Compact Hough Transform, it provides good theta-phi resolution and excellent robustness against noise (crucial in HL-LHC)

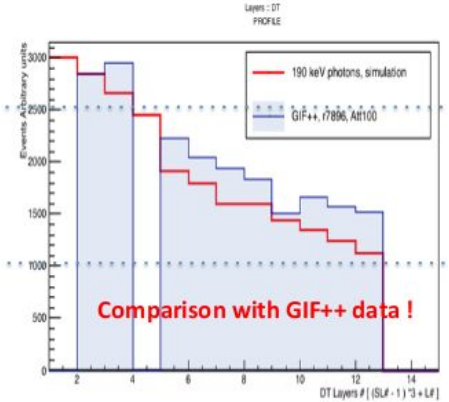
N. Pozzobon, P. Zotto, F. Montecassiano



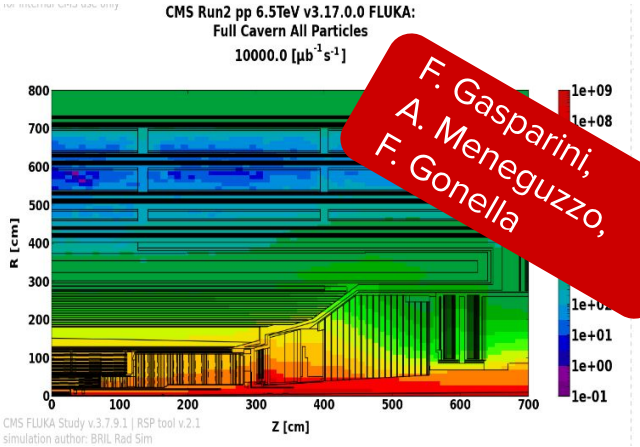
DT longevity studies and simulations

- 2 DT chambers irradiated at the CERN GIF facility with a dose equivalent to 3x the dose expected at HL-LHC
- A loss of wire gain of the 70-80% and a loss of efficiency of 30-40% at HL particle rate were observed
- Suspect is that the chamber was contaminated presumably by the outgassing of some material present in the DT gas volume
- Electronic microscope observation and EDS spectral analysis of some extracted wires showed they were covered by a coating (few μm thick) of a compound containing molecules of Silicon, Oxygen and Carbon
- Many experts involved in the department (Fisica dello Stato Solido), PD university (Dip. di Chimica), Laboratori di Legnaro, and external laboratories



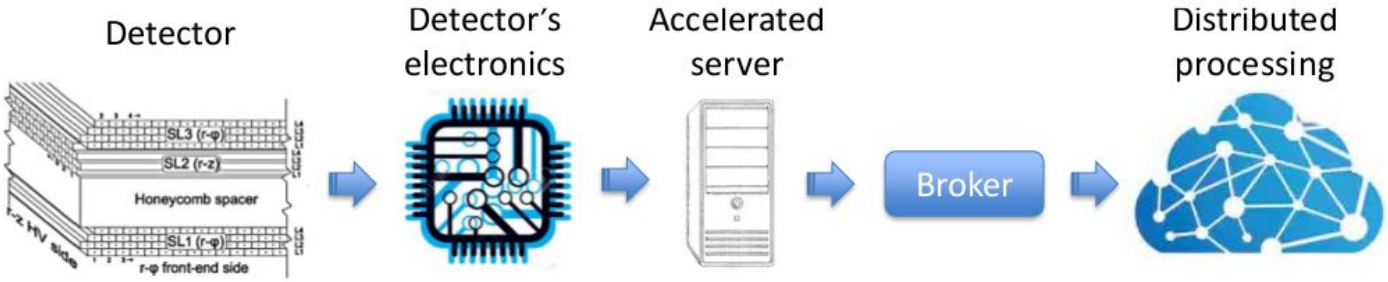


- Simultaneously, reproduce GIF results with simulation of the detector based on Fluka
- Particularly low-level and CPU-intensive
- Fluka simulation reproduces reasonably well the GIF data (in the plot, the number of photons in each layer is shown)



F. Gasparini, A. Meneguzzo, F. Gonella

40 MHz scouting at Padova and Legnaro



CMS Drift Tubes muon chambers

HL-LHC prototype electronics

Xilinix KCU PCIe FPGA

INFN CloudVeneto data-center

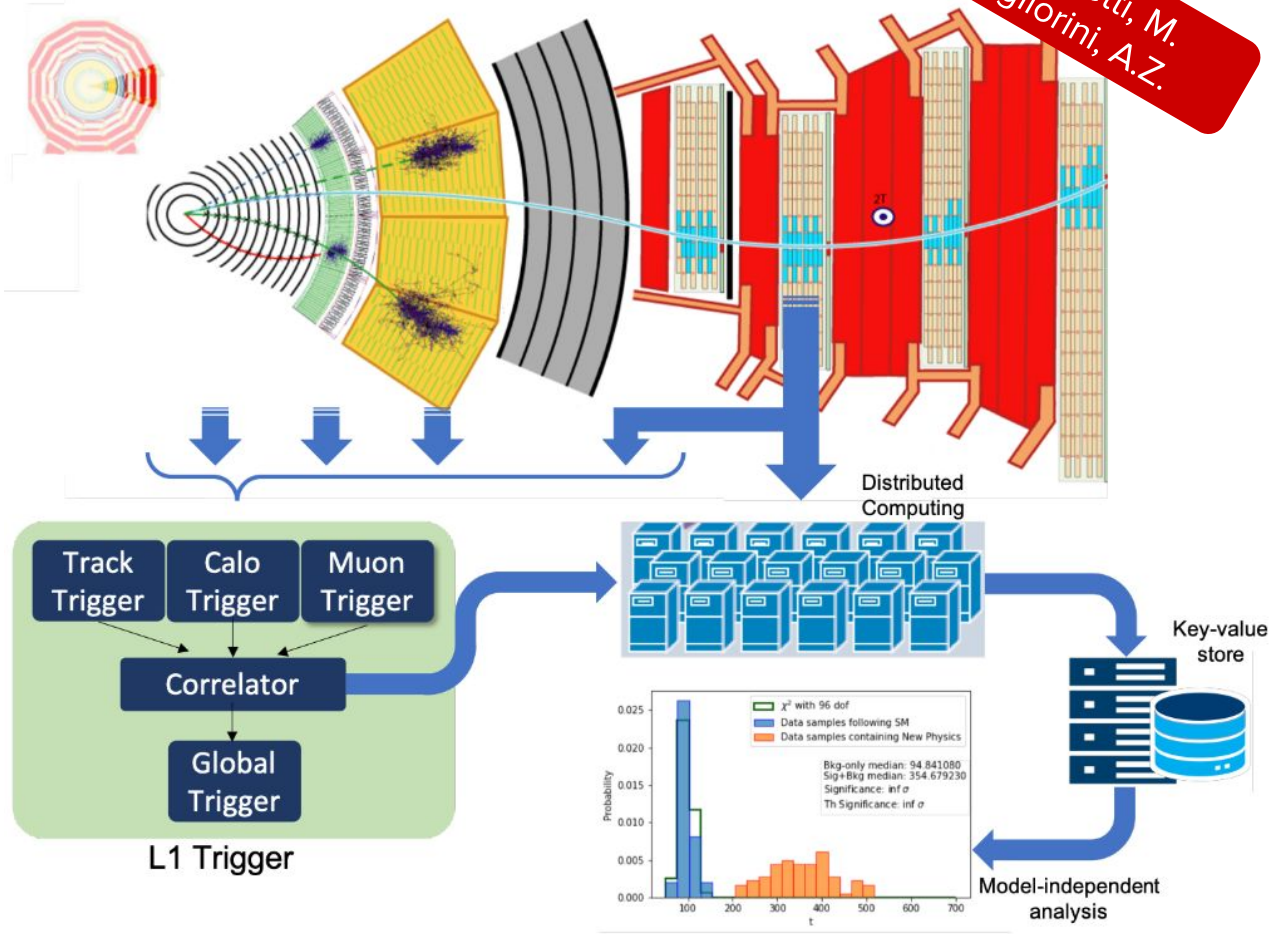
- Working setup to read a scaled-down version of a detector (the muon DT chambers) with a trigger-less system (aka **40 MHz readout**)
- Data stored and analyzed in real time through distributed-computing techniques
- DataFrame objects allow manipulation of large quantities of data with minimal CPU occupancy
- Scales well with CPU availability
- Plan to replicate the setup at CERN to read the **Slice test OBDTs** with a very similar setup

M. Zanetti, M. Migliorini, A.Z.

40 MHz scouting at CMS

M. Zanetti, M. Migliorini, A.Z.

- 40 MHz scouting is being currently considered at CMS for HL-LHC
- Read trigger primitives before L1 trigger decision ensures no bias is introduced by trigger algorithms
- This is possible for some subdetectors (muons and calorimeters primarily)
- Data is stored at high rate and in a compressed format for fast analysis
- Opens up a whole new set of NP searches: long-lived particles, magnetic monopoles, and many others....



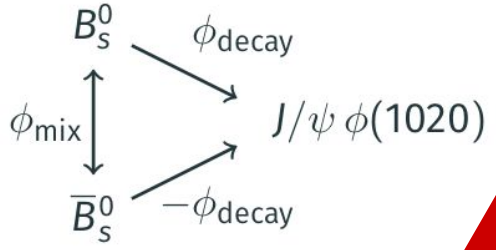
Physics Analyses

CP violation with $B_s \to J/\psi\,\phi(1020)$: motivations

- ϕ_s: CPV phase arising from the **interference** between direct B_s decays into a CP final state and decays through $B_s - \overline{B}_s$ mixing
- **SM prediction**:

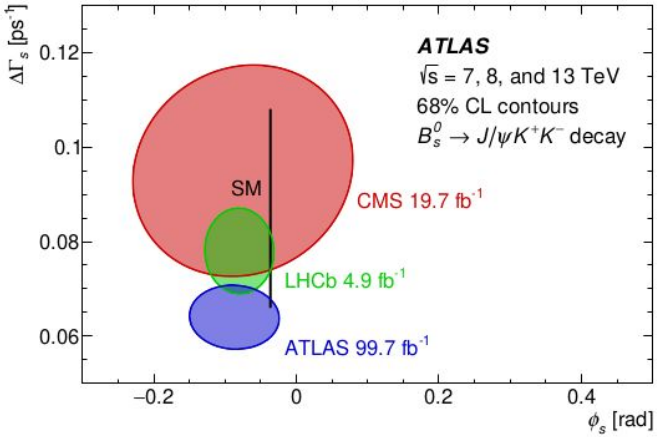
$$\phi_s \simeq -2\arg\left(-\frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*}\right) = -36 \pm 1\ \text{mrad}$$

- **New physics** can contribute in the $B_s - \overline{B}_s$ mixing, changing ϕ_s.
- **State-of-the-art:** agreement with SM, but exp. sensitivity $\sim 25\times$theory
- **Current 13 TeV results**:
  - LHCb (Eur.Phys.J.C(2019)79:706)
  - ATLAS (arXiv:2001.07115)
- **Some tensions between experiments**, CMS results highly anticipated



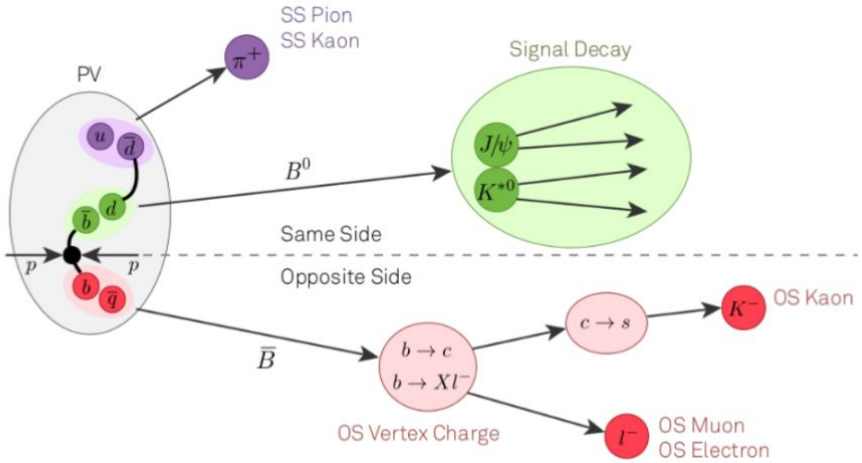
$$\phi_s = \phi_{mix} - 2\phi_{decay}$$

A. Bragagnolo, E. Lusiani, H. Yarar, M. Margoni, P. Ronchese, F. Simonetto



CP violation with $B_s \rightarrow J/\psi\,\phi(1020)$: flavour tagging

- **Process of identifying the flavour of a given particle (B_s^0 vs $\overline{B}_s^0$)**
- **Tagger for this analysis:** opposite side muon tagger
  - Exploit $b \rightarrow \mu^- X$ decays of the **other** b in the events (assuming $b\bar{b}$ prod.)
- **Per-event mistag probability directly evaluated with a DNN**
  - Requires (almost) no calibration to be deployed in Data

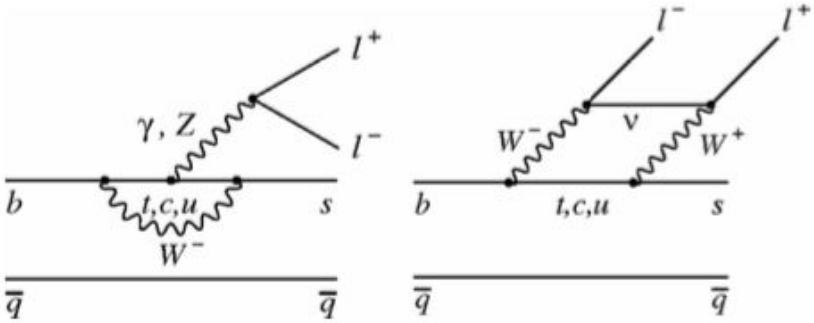


A. Bragagnolo, E. Lusiani, H. Yarar, M. Margoni, P. Ronchese, F. Simonetto

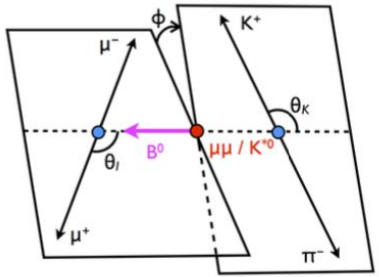
Outlook

- **Very advanced statem targeting Moriond EW 2020**
- **Planned cross-experiment combination** with ATLAS and LHCb
  - First 13 TeV combination for ϕ_s and $\Delta\Gamma_s$
- **Full Run 2 measurement to start in Spring**
  - Works already in advanced state, waiting for Ultra Legacy
  - ETA $\sim$ Fall 2020

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

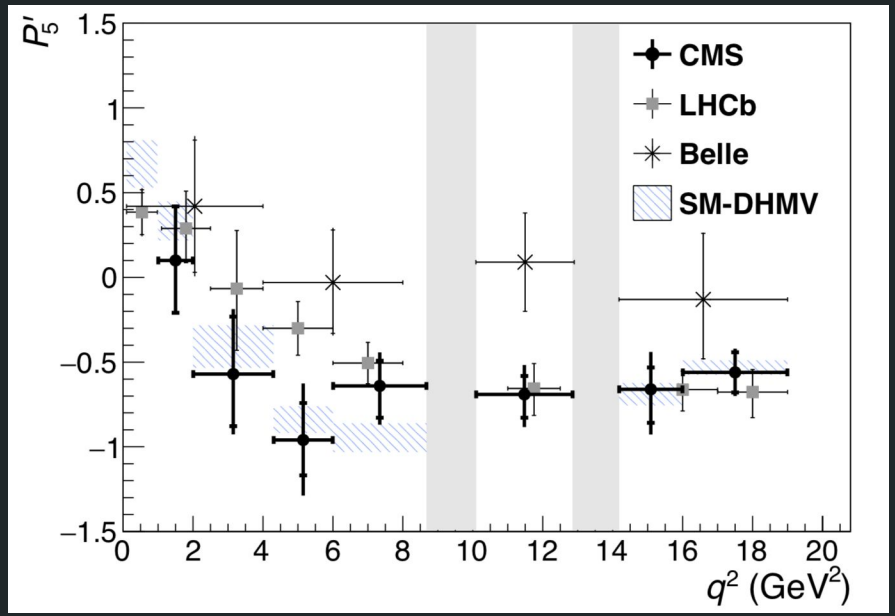


Decay fully described by three angles measured in terms of dimuon invariant mass (q^2)



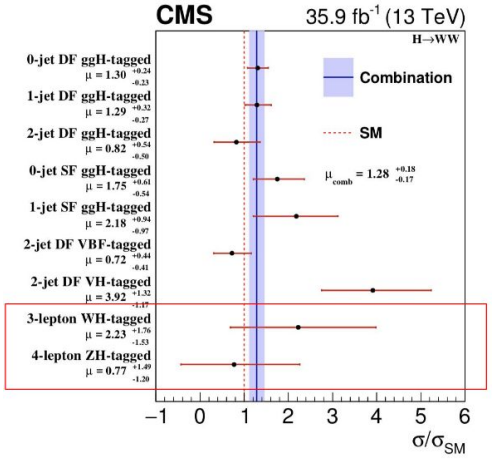
A. Boletti,
S. Lacaprara,
M. Margoni,
P. Ronchese,
F. Simonetto

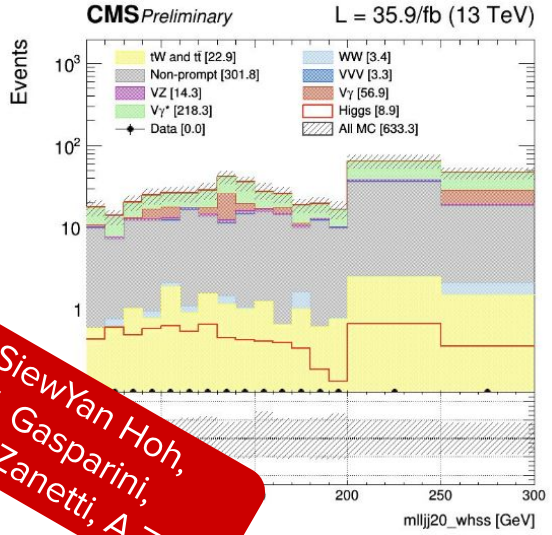
- Flavor-changing neutral current decays b → sll doubly suppressed in the SM, good probe for new physics
- Clean SM calculation of several angular parameters P_i
- Tension found in low q^2 region
- Being updated with full Run 2 data

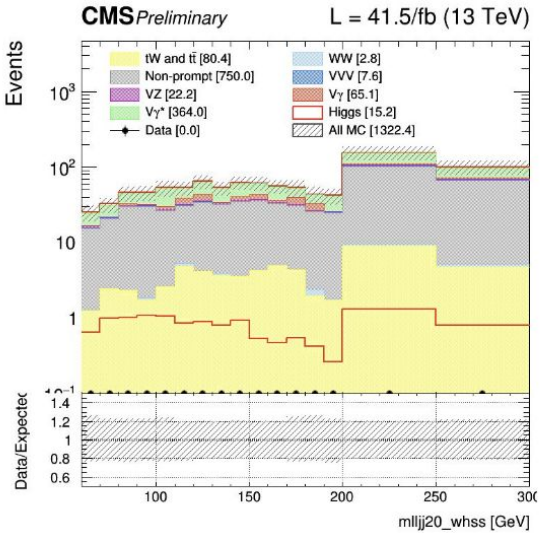


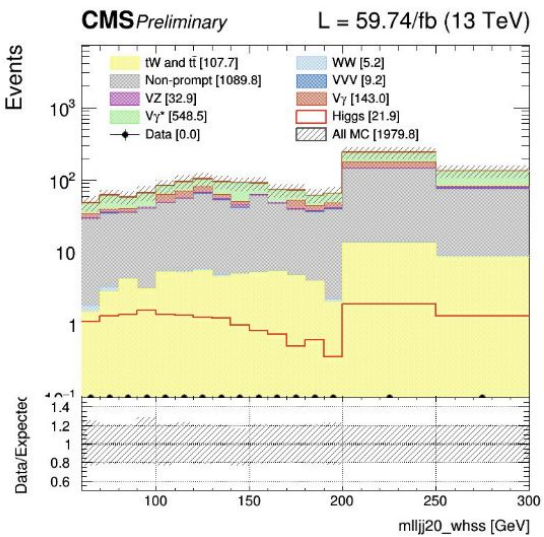
SM Higgs ➔ WW

- Participating to the SM Higgs measurements in the WW channel
- Focus on the vector-boson associated production (ZH, WH) in multilepton final states, and particularly in the WH➔2 same-sign leptons + jets
  - very clean final state, low statistics➔may be visible with full Run 2
  - low SM backgrounds: “**fake” leptons from W+jets**, tt, VZ, DY, Vg, Vg*, VVV
  - charge selection is a crucial selection, especially for electrons
  - the presence of neutrinos means that the H is not directly reconstructible



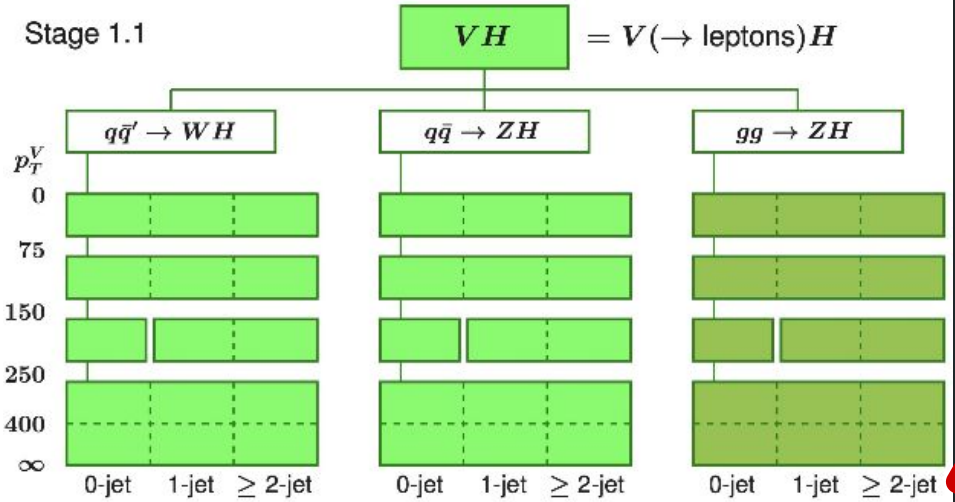


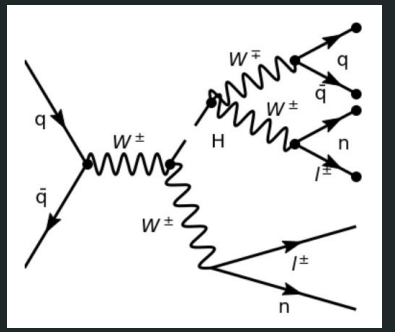




SiewYan Hoh,
U. Gasparini,
M. Zanetti, A.Z.

SM Higgs ➔ WW: between theory and experiment





The **STXS** framework:

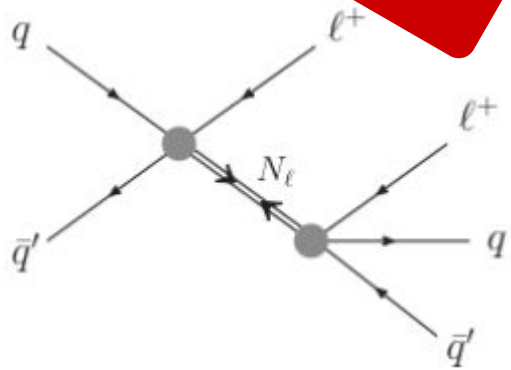
- Common framework between LHC experiments and theorists
- Measure the Higgs (multi)-differential cross sections in bins of kinematic variables (H p_T, number of jets, ...)
  - Not always easy: how do you estimate the Higgs p_T in the WH➔ WWW➔ lvlvqq?
- Reduce model dependence
- Easier interpretations in new physics scenarios
- Updated results on HWW searches, including the **STXS for the first time**, are expected for the Moriond conference

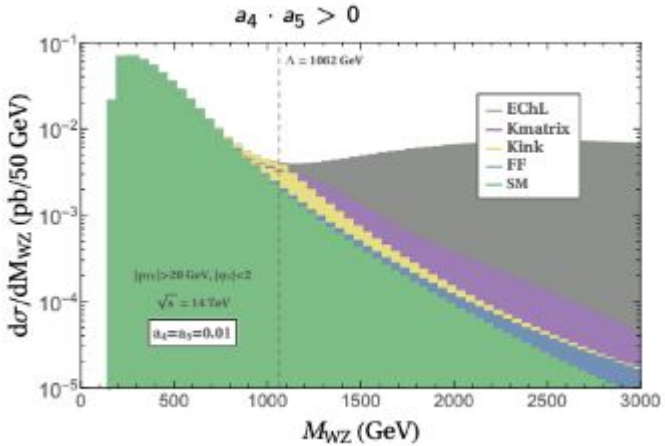
SiewYan Hoh

Heavy Composite neutrino searches

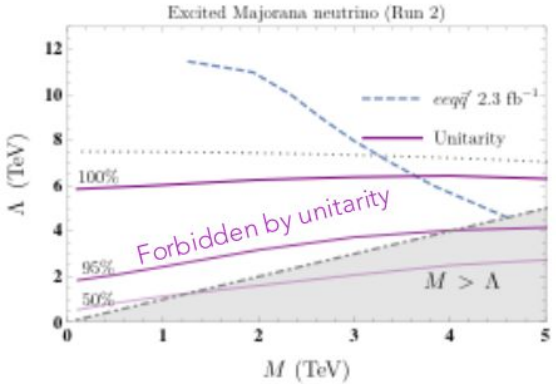
M. Presilla, P. Azzi

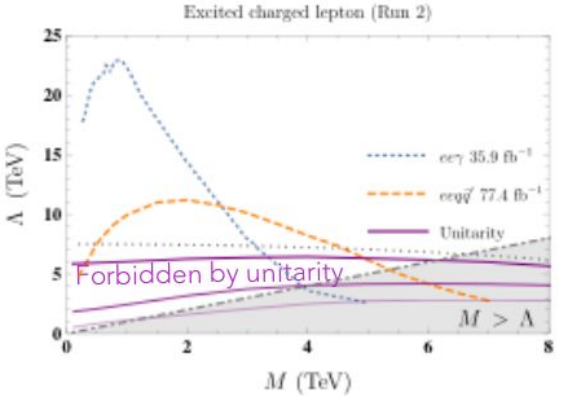
- "Search for **heavy composite Majorana neutrinos** with full Run2 datased" in the lljj boosted final state (ArXiv. 1510.07988, 1707.00844, 1810.00374, 1903.12285)
- Search for heavy resonances that decay to in 2l+2j (l=e, mu)
- Plan to publish legacy measurement with full Run2 statistics by Summer
- Common final state with non-resonant **Anomalous Quartic Gauge Couplings (AQGCs)**
- Important to consider unitarity consideration in the anomalous QGC signal modelling and its effects on the experimental sensitivity (kinematic distributions)





- Consideration of **UNITARITY CONSTRAINTS** on heavy composite particles at the LHC have become relevant for several analyses, both SM and BSM.
- Unitarity bound restriction of the allowed parameter space of the model (M, Λ):

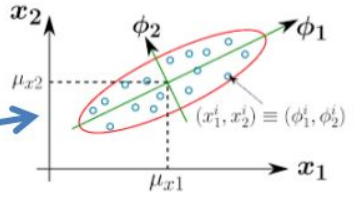


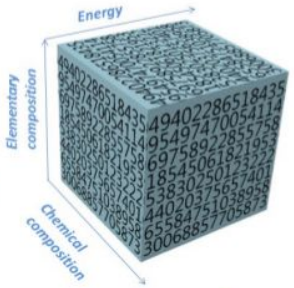


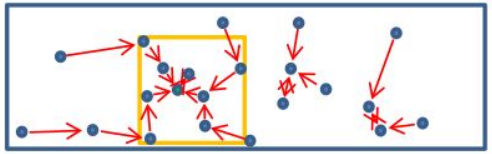
RanBox: Anomaly Detection for NP searches at the LHC

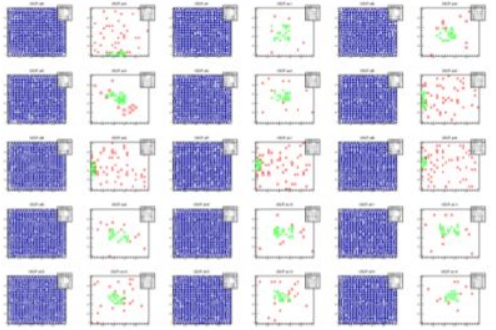
Developed a novel, fully unsupervised search for anomalies suitable for LHC data

- Standardize features with PCA, reduce dimensionality to principal components
- Apply integral transform to all components, "flattening" all marginals → all information remains in the **copula space**, data is now a unit box in N-Dim space, overdensities are now only due to internal interdependencies
- Select random M<N subspace of features (10 typical)
  - Via hierarchical clustering, find high-density seed in M-dim space; define box in space.
  - Via gradient descent, move box around and find most significant overdensity
- Repeat selection, iterate and find most significant region in overall space
- Transform back into original feature space, examine distributions







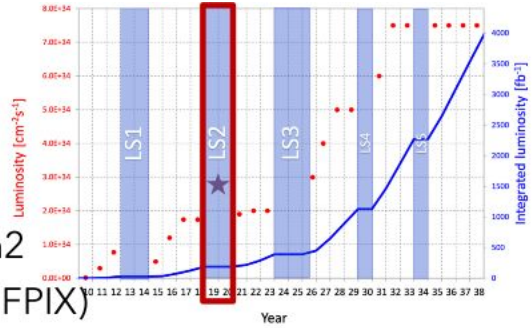


Above: scatterplots of features in copula space; in blue all data; in green highest density ranbox region; in red data outside box in features not shown

T. Dorigo

Backup slides

Tracker LS2 upgrade

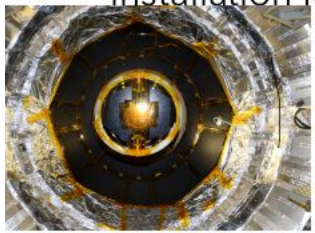


- as already foreseen in the Phase I Pixel TDR,
  the main objectives will be the **replacement** of **BPIX L1**
  → BPIX L1 will be equipped w/ the new FE PROC600V4,
  which will overcome some of the shortcomings encountered during run2
- in addition, **replacement** of **all DCDC converter boards** (for both BPIX and FPIX)
  using the new FEAST2.3 chip
- plan would be to <u>last until LS3 w/o further interventions on the detector</u>

- many other consolidation work ongoing in preparation for Run3
  and, mostly, Phase2 detectors and conditions:

minimize activation
(steel → aluminum)

→ a complete **new beam pipe** and **supports** for CMS
designed <u>compatible w/ the present and Phase2 detector</u> configuration
installation foreseen for 2020



→ **run at $-25°\ C$** (instead of the current $-20°\ C$)
- ❑ dedicated test is planned at the beginning of 2020
  - ➢ no major problems expected
    thanks to the vapour-sealing and insulation of the cooling stations
    improvement already done in LS1

CP violation with $B_s \rightarrow J/\psi\,\phi(1020)$: analysis strategy

1. **Tagging dedicated trigger**: $J/\psi \rightarrow \mu^+\mu^-$ candidate plus an additional muon for flavour tagging
   - Very high tagging efficiency
   - Allows to go cut at lower lifetime values
2. **Innovative DNN based flavour tagger**
   - More stable and performing
   - Negligible related systematic uncertainty
3. **First CMS attempt to measure** the B_s mass difference Δm_s and the direct CP observable $|\lambda|$
   - Δm_s requires very high tagging efficiency and excellent time (vertex) resolution

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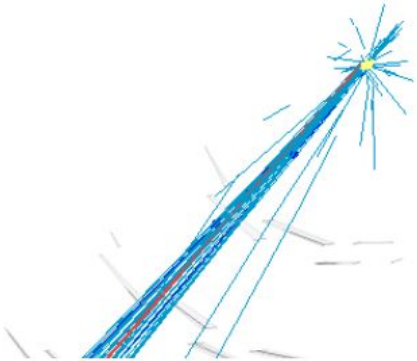
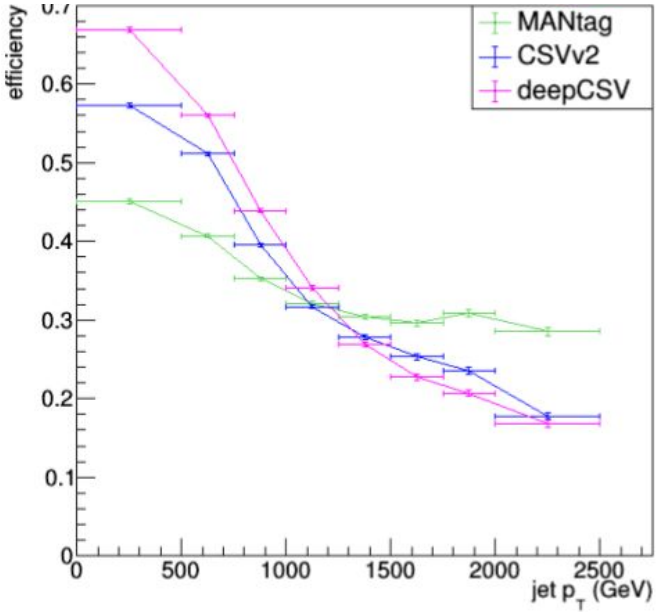
New ideas in b-tagging

A.Z.

- The current b-tagging algorithms loose efficiency very quickly for high-p_T jets
- A B hadron at 1 TeV can easily travel 10 cm inside the detector, well beyond the first pixel layers
- We can exploit this fact and build a better tagger by just counting the pixels multiplicity across different pixel layers
    - this approach has the great advantage to bypass track reconstruction inefficiency





- This very simple and low-level information, passed to a “basic” DNN, provides very interesting performances
- First preliminary studies show that the new tagger is able to outperform the much more complex official CMS taggers already at p_T larger than 1.2 TeV
- First application at LHC, so far
- Very interesting potential also for Future Accelerators FCC-hh