Status and plans for software and physics analysis (WP1)

RD_FCC Collaboration Meeting - 17/2/2021

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Activities of WP1 - Physics analysis and software

- There are two main axis of activity:
  - **Physics analysis:**
    - « Case studies » for detector requirement
  - **Software development:**
    - Fast and Full simulation of the IDEA (sub)detector
    - development of local reconstruction (digitization, clustering)
    - development of global reconstruction algorithms (tracking, vertexing, hf-tagging, jets, tau-ID, etc)
- of course one cannot exist without the other

Status of physics studies in FCC-ee project

- Published several physics studies in the CDRs and arXiv to show the potential for physics of the FCC-ee program and motivate its importance for the future of HEP
  - the clean environement for physics at an e+e- collider allows predictions to be made from extrapolations from previous data, simplified analysis, full and fast simulation.
  - However, the next step will be to prepare for a « Physics, Experiment and Detector » (PED) CDR in a 4-5 years time that will include several detector concepts designed to be able to achieve physics results
- To make this a reality we need:
  - to choose the most significant benchmark measurements
  - to extract the detector requirements
  - to develop the software tools for the simulation of this detector concepts and the event reconstruction
  - to design detectors exploring all the most innovative ideas
- Physics Performance Coordination (PPC) is the forum where all these aspects come together, to coordinate and facilitate the progress of the various studies through sharing of information and common tools ==> P. A. + Emmanuel Perez coordinators

defining the « case studies »

- the physics landscape of the FCC-ee program extends in all possible directions:
  - the difference in the physics focus at the different $\sqrt{s}$
  - the difference in the event kinematic of running from 90GeV (and possibly below) up to 365GeV
  - the challenge of being able to achieve superbe precision on SM processes but also perform unique direct searches for new physics
- The list of interesting processes and measurement is extensive, and it has not been fully explored yet, even in terms of sensitivity.
- From this richness, we need to extract concrete benchmark measurements, the « case studies » that will be used to extract requirements on what is missing to achieve our ambitious goals: detector requirements, reconstruction tools, calibration techniques.

what is a « case study »?

- A « case study » is not really just a physics analysis, it is more the « reverse engineering » of a physics analysis
  - usually we have the input and we find the output (measurement) in a case study it is the opposite: we have a target for the output and we need to find the input.
- The baseline is physics measurement goal. It could be either the observation of a process or the accuracy of the measurement itself. For instance:
  - systematic uncertanties commensurate to the tiny statistical ones
  - maximize potential for discovery of FIP in the decays of Z or H
  - even just estimate new statistical limits
- Many ingredients contribute. The work to do is disentagle the various contributions and figure out how to push the maximum performance in all directions:
  - need to improve on baseline detectors to perform as needed
  - need to develop a detector simulation that allows this performance to be merged in the full analysis
  - need to develop reconstruction algorithms that fully exploit the detector information
  - need to develop calibration strategies and analysis techniques to shrink the uncertainties as needed

Current list of case studies

- The current list of « case studies » is collected at this link from the PPC page:
- https://hep-fcc.github.io/FCCeePhysicsPerformance/
  - btw the list corresponds also to White Papers proposed for Snowmass
  - very likely with more people and interest the list will grow
  - Some examples at the Z here, but they cover also flavour physics, Higgs, Top, BSM etc.

Case studies at the Z

- The ratio Rl: geometrical acceptance for lepton pairs
- The total Z width: track momentum (and angular) resolution, scale (magnetic field) stability
- Luminosity from diphoton events (for sigma^0_had): electron-photon separation, photon acceptance
- The muon pair forward-backward asymmetry A^mumu_FB: QED corections
- The forward-backward asymmetry of b quarks at the Z pole: flavour tagging, QCD corrections
- Lepton Flavor violation in Z and tau decays: lepton momentum scale

RAZOR - PRIN

- For each topic there is a dedicated area where to keep all the needed information, code, strategy, results
  - maintained by the analysers
  - common tools developed will be pushed back to the main FCCSoftware
  - progress is discussed in PPC meetings: https://indico.cern.ch/category/12894/

Example: b- and c-tagging, the coupling Hcc

Advanced flavour-tagging algorithm based on a Dynamic Graph Convolutional Neural Network (DGCNN) under development.

L. Gouskos, M. Selvaggi

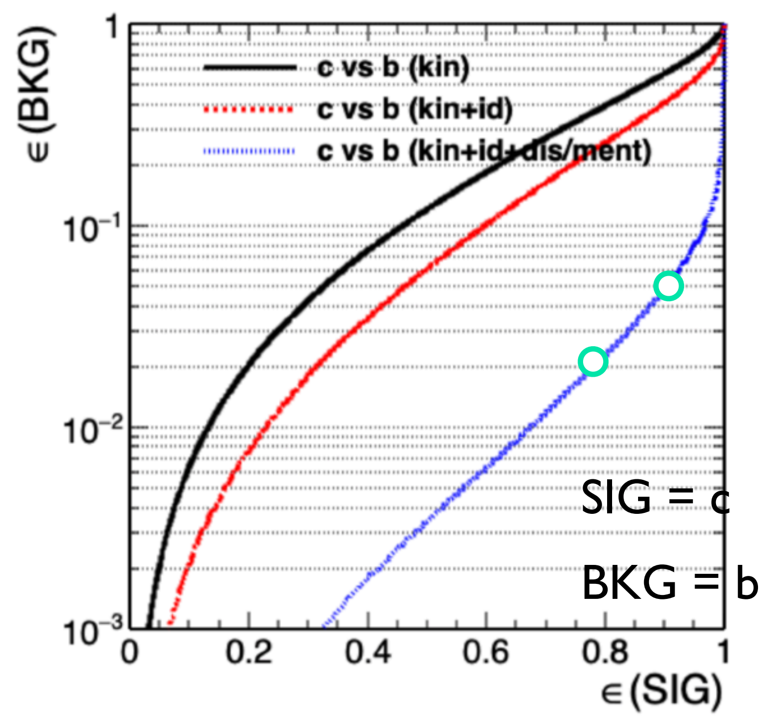
Inputs = kinematics and type (e / μ / γ / ch. had / neutral had) of Particle-Flow objects, d0 & z0 of the tracks

WP	Eff (c)	Mistag (g)	Mistag (ud)	Mistag (b)
Medium	80%	3%	1%	2%

Back-of-the-enveloppe estimation of the uncertainty of σ (ZH) x BR(Hcc) with the loose WP : 0.7% (no systematics)

Close to the uncertainty expected from an ideal (mistag = 0, eff = 1) tagging (0.6%) !

[Z($\nu\nu$)H(jj) events at 240 GeV]

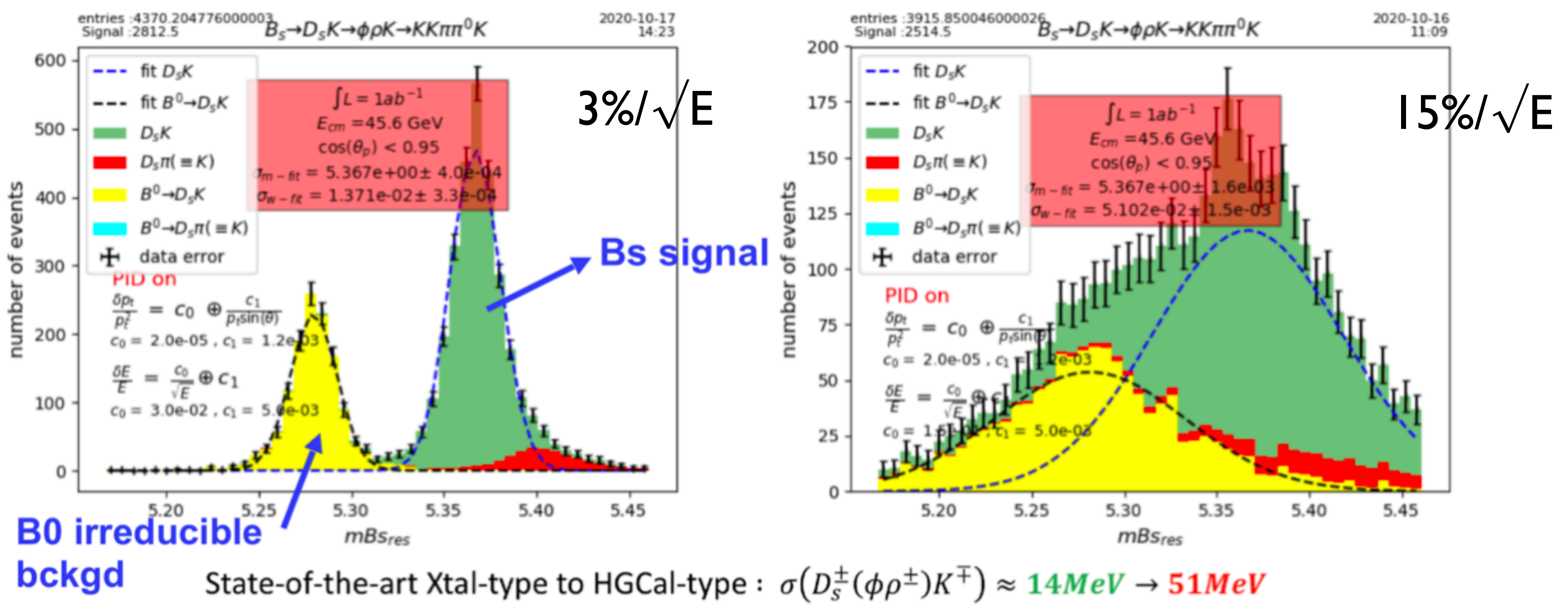


Performances look very promising !

Example: Requirements on Ecal from B physics

Roy Aleksan

EM resolution much better than 15% / √E needed for :
B physics: e.g. Bs → Ds K in modes with Pi0's requires < 5% / √E
Separation of Z → νe νe from the other neutrinos (single photon events, radiative return) also requires 5% / √E
Maximal sensitivity to rare / forbidden processes, Z → τ e or μ e, τ → μ γ



State-of-the-art Xtal-type to HGCal-type : $\sigma(D_s^{\pm}(\phi\rho^{\pm})K^{\mp}) \approx 14MeV \to 51MeV$

EM Granularity :
Very good transverse granularity required e.g. for tau physics
Requirements on the resolution of photon position and angles to be studied

next steps for case studies in RD_FCC?

- Today a few examples of work in progress/plans that are based on Delphes and the IDEA concept:
  - Higgs recoil study - *V. Diolaiti*
  - HF Asymmetries and tau polarization and asymmetry at the Z (RAZOR) - *G. Panizzo*
  - Search for axions - *L. Pezzotti*
  - B_s->D_sK - *M. Scodeggio*
  - Opportunities in EW measurements - *P. Azzurri*

- with more active analysts, it will become easier to help newcomers (from LHC) to get started with their own case studies
  - contact me for more details about your favorite physics and how to get started
  - maybe worth copying/storing MC samples locally?

FCC Software News

- Migration of the FCCSW toward key4Hep in progress
  - First step: event data model, edm4Hep
- Workflow based on Delphes fully available with new options:
  - cov matrix tracking + vertexing
  - edm: standard or edm4hep
- Workflow based on FullSim still in progress:
  - CLD only detector with full event reco
  - Several subdetectors being added
  - IDEA description in Geant standalone:
    - work in progress to produce output in edm4hep (at various stages, hits, tracks) for easier integration
    - more details later in Tassielli and Pezzotti presentations
    - *this is an item on the critical path*

Delphes samples

- ee production with Delphes is fast. Centrally produced samples available in eos at this link:
  - https://hep-fcc.github.io/FCCeePhysicsPerformance/General/#common-event-samples
- default output is edm4hep => allows easy use of common tools
  - for instance jet re-clustering and MC-truth matching if compared to standard Delphes output
- software in flux (==bug fixes+new tools) so new production coming up. Google here to add your needs:
  - https://docs.google.com/document/d/1-3L_8u542-dlaL6ws41PYmCgwzffgsleaQKs_qQb6AM/edit?usp=sharing
  - production seeting are the piece that need to be taken from validated examples (even for private production)

Immediate needs to get started

- Provide the recipes and tutorials to:
  - access the Delphes samples
  - unpack the Delphes edm4hep events
  - develop/add new algorithms (vertexing, hf tagging etc)
  - run the FullSim of IDEA
  - develop new local and global reco algorithms on (sub)detectors
  - develop/add analyses to study performance

- most of this information will be present on the Physics Performance or FCCSW pages ==> we will link it to our own RD_FCC new page as well
  - Check it out here: https://web.infn.it/RD_FCC/
    - thanks to Lorenzo Pezzotti for volunteering to set it up with me
    - All WP coordinators: please provide us text, pictures and information to be added in your pages.

Items for discussion & next steps

- Fast Simulation and Delphes: big contribution done both in feature developments and validation -> *need to continue*
- Full Simulation: good progress in development of local reco and studies for DCH and DR calo as separate sub-detectors. However,
  - *missing integrated detector concept description*
  - *missing muon detector geometry and simulation*
  - *Proposal:*
    - *to have the current (even if non-finalized) IDEA FullSim code into the FCC git repository for easier access and validation.*
    - *development of Edm4hep output for hits and tracks to allow easier integration between sub-components and global reco development*
- need for more software oriented contributors

Items for discussion & next steps (2)

- on the analysis side, good interest of new groups on relevant physics topics
  - RAZOR PRIN excellent experience
- critical mass on analyses essential to expand the awareness and consensus for future circular ee (FCC-ee/CEPC) in INFN
- on the practical side:
  - important to create a common knowledge base to progress faster and not get stuck in technicalities
  - regular meetings of WP1 needed
  - Specific choices on analysis setup cannot be a top-down decision, but come from a feedback from the users after trying out the options.
    - experiment unpacking the edm4hep data from Delphes.
    - try out the FCCAnalysis framework and evaluate the pros and cons

near term goals

- A natural deadline to inform the activities in the next months is the FCC-week at the end of June:
  - I suggest that during today's meeting we can create a list of achievable results both for the software simulation tasks and the case studies
  - today we might collect also new interests and proposals
- Also to keep propagating more information about RD_FCC and extend the participation from the various universities/INFN showing specific tasks and topics that can be joined (there is a lot!):
  - virtual meetings are not so effective (zoom fatigue)
  - one option is to prepare recorded (short) webinars on specific topics (HW, Physics) to be collected on our new web page and shared with our colleagues.
- This past year has been very heavy for everyone. However, we need to recognize the progress made, albeit slower then desired, and keep pushing to make the IDEA detector concept fully usable in physics analysis and performance studies.