Work package 1:
Software, Computing, Physics
NEWS

P. Azzi (CERN/INFN Padova), N. De Filippis (Politecnico/INFN Bari)

RD-FCC Meeting

February 17, 2023

MARK YOUR CALENDARS

- First USA FCC Workshop @BNL, 24/26 April https://www.bnl.gov/usfccworkshop/
  - send abstract
- *End of April: Draft of internal notes*
- CSN1 May 17-19
- FCC Week 2023, @London, 5-9 June

SUMMARY OF IDEA DESCRIPTION STATUS IN JANUARY 2023

SUBDETECTOR	GEANT	DD4HEP	DIGI	RECO
VERTEX	YES, BEING UPDATED	YES, BEING UPDATED	YES (simplified?)	YES
DRIFT CHAMBER	YES	IN PROGRESS	YES	YES, NEEDS UPDATING*
PRESHOWER (needs check)	YES (simplified)	NO	NO	NO
DUAL READOUT CALORIMETER	YES	YES	YES	IN PROGRESS PFLOW- Similfellow
CRYSTAL CALORIMETER	YES(standalone)	NO Similfellow dedicato	YES(standalone)	IN PROGRESS
MUONS	IN PROGRESS	NO	YES(standalone)	NO

*MAYBE TRACKING NEEDS UPDATING FOR HIGH MOMENTA

Near and medium term priorities

Simulation:

- Forming new experts in DD4HEP description. —> Streamline the sub-detector Plug&Play technology
  - Similfellow on DD4HEP ECAL crystal (Flavia)
- IDEA Description in FullSim with and without the ECAL Crystal option

Reconstruction

- Develop reconstruction for GEANT description (AIDA Innova project). Validate/update tracking available.
- In DD4HEP: Review/integrate/reuse the algorithms developed from the Linear Collider and LHC(ECFA workshop)
- Foster integration in Key4Hep for packages such as Pandora (ParticleFlow) and ACTS(Tracking)
  - Similfellow on Pflow reconstruction with Pandora (Adelina)

Analysis

- Consolidate current approach based on RDataFrame. Adding reduced format for simplified navigation
  - similfellow on analysis tools (Agostino)
- New Tutorials and examples to help newcomers
- Provide visualisation tool (event Display) -> something exists, need to become familiar https://hep-fcc.github.io/fcc-tutorials/full-detector-simulations/Visualization/Visualization.html

GOALS about simulation/reconstruction for June FCC week

- Full simulation of IDEA in Geant4
  - prototype of PFlow reco?
  - validation of output in EDM4HEP
  - setup MC generation at CNAF
- Complete Geometry simulation in DD4HEP
- Prepare new tutorials

Plans for mid-term report: physics

- **[from management] Draft documents by end of April.**
  - results should be presented as table/plots showing detector requirements obtained from the study

➔ **Candidates:**

- Higgs hadronic : extract detector requirements (CALO)
- AFB(bb): requirements on b-tag->vertex?
- Anomalous top couplings: requirements on b-tag->vertex?
- *Bs->DsK: requirement on vertexing/PID? also ECAL?*
- *Anything else new?*

Case Studies vs Detector Requirements(WIP)

NEED TO SELECT SUBSET OF STUDIES TO PERFORM

	Track mom. reso	Impact Par reso	PID	ECAL reso	ECAL granularity	HadronicMassRes. PFlow	lep/pi separ.	Comments
mH from recoil mass, Z(mumu)H	+							
tau -> 3 mu	+ (collimated tracks)							
B-field monitoring from JPsi, D0's	+ (low momenta)							
B0, Bs to mumu	+						+	
Z(ll)H(qq) for Hbb, Hcc, Hgg		+				+		
Vcb from W decays		+ (high purity WP)						
EW HF observables (Rb, Rc, AFB)		+						
B to K* tau tau		++ (soft tracks)	+		+ (pi0 in jets)			also efficiency for low p tracks
Tau Lifetime		+						systematics to be understood
gamma from Bs->Ds K	+	+	+	++				
Z(ll)H(ss) (BSM)		+	+			+		
Vcs from W decays		+	+ (high purity WP)					
B->pi0pi0				+	+			
B->pi0pi0 w/ Dalitz		+			+			
Tau polarization (Z to tautau)			+	+	+	+(tau reco)		
ve coupling Z->vvgamma				+				
tau->mugamma				+	+(spatial)			
ALPS, ee->agamma				+	+(spatial)			
sigma(ZH) from recoil avec Z->qq						+		also testing Pflow algo
Higgs width: ee->vvH, H->bb		+				+		also testing Pflow algo
bb,cc,gg coupling ZH-> qqqq		+				++(association)		testing association/jet clustering
m(top) direct in ee->tt->qqbqqb,lvbqqb	+	+		+		++(association)		testing association/kinematic fit
Higgs Width ZH->qqqqqq		+				++(association)		testing association/kinematic fit
m(W) direct reconstruction	+			+		++		kinematic fit
AFB(bb,cc)		+				+(jet charge)		
H->inv						+		
Total x-section at the Z								inclusive. calo selection, ECAL & HCAL resolutions
LLP, very displaced objects								granularity of ECAL,HCAL,timing, Muons
electron Yukawa, H->gg (at the pole)						++		qq/gg separation

https://docs.google.com/spreadsheets/d/1BzRUynbNe_khX8LAgeQQz2tE9LV25i4rlVY83oX_ftY/edit?usp=sharing

Other news

Announcement of the EURIZON Detector School

The EURIZON school on particle detector technologies will take place at **Kutaisi International University (KIU) in Kutaisi**, **Georgia**, on July 17-28, 2023.

https://www.kiu.edu.ge/eng/home

Full support by the Georgian Minister of Science and Education Prof. Dr. Mikheil Chkhenkeli

Website of the school:
http://indi.to/EURIZONdetschool
The deadline for applications is **March 28, 2023.**

EURIZON Detector School (1)

Lectures topics:

- Calorimetry – E. Sicking, R. Ferrari
- Characterization of detectors – B. Ristic
- Communication in science, presentation skills – D. Barney
- Evolution on working detector systems from R&D to construction, operation and performance – D. Abbaneo
- Gaseous detectors – M. Abbrescia, M. Bianco
- Neutron detectors – B. Guerard
- Non-collider detectors – B. von Krosigk
- Particle identification – M. Schmidt
- Photon detection – S. Gambetta, S. Jakobsen
- Quantum sensing – M. Doser
- Readout- FPGA- trigger- DAQ- synchronization – F. Pastore, S. Lange, J. Hegeman
- Silicon detectors – M. Deveaux, S. Spannagel
- Tracking – J. Baudot

EURIZON Detector School (2)

Hands-on exercises:

- Drift Tubes characterization – N. De Filippis, M. Primavera, B. D'Anzi
- MPGD lab. - G. Bencivenni, M. Giovannetti, G. Cibinetto, S. Gramigna
- ROOT tutorial - M. Schmidt et al.
- Geant 4 tutorial - M. Schmidt et al.
- Cosmo boxes – M. Schmidt et al.
- SiPM characterization A – M. Schmidt et al.
- SiPM characterization B - L. Linssen, E. Sicking et al.
- Silicon Pixel characterization - L. Linssen, E. Sicking et al.
- Testbeam data analysis with Silicon Pixel - S. Spannagel et al.
- Simulation of silicon pixel detector and spatial resolution - S. Spannagel et al.
- Landau distribution with Silicon Strip - S. Spannagel et al.
- Do It Yourself Particle Detector - O. Keller

Plans for the next meeting

- Testbeam analysis results
- Plans for the testbeams in 2023
- Organization of the new similfellows work
- Increasing collaboration:
  - Collection of thesis topics for our web page
  - Summer Student opportunities at CERN/DESY/FERMILAB/INFN: need to have projects ready

BACKUP

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M. Selvaggi , J. Eysermans

C. Grojean, G. Durieux, J. De Blas

Case studies - Higgs Physics

Some **chosen** priority case studies for Higgs physics (of course not the FULL program!)

Goals of a “case study”:

- to identify major systematics
- dependence on detector performance or machine conditions
- Develop strategies for evaluation/reduction of systematics at the analysis level

- M(H) and in HZ, Z in leptons
- M(H) and in HZ, Z in hadrons
- Invisible Higgs
- $H \to bb, cc, ss$ couplings
- $\Gamma(H)$ in ZH
- $H \to ZZ^*$ $\Gamma(H)$ in *bbvv events*
- $HZ\gamma$ coupling
- Higgs self-coupling
- $ee \to H$, s-channel production

IT contribution: Aly Reham(BA, similfellow 2022) studying ZH with H->hadrons for calo energy resolution

Flavor physics- Case studies

Many ongoing activities, lots of work to do:

- Improved Delphes suitable for a first pass and setup of the analysis tools.
- Excellent benchmarks for track and vertex resolution, Particle ID, EM resolution for final states with neutrals
- Some arXiv available, need to be verified with proper simulation, reconstruction and analysis tools.

$B_u/B_c \to \tau\nu_\tau$: paper out, new improved version in progress

$B_s \to D_s K$: test bench for vertexing tools and EM calo requirement (including neutrals) https://arxiv.org/abs/2107.02002

$B_s \to K^*\tau\tau$: testing effects of detector performance on background reduction (vertexing res., PID)

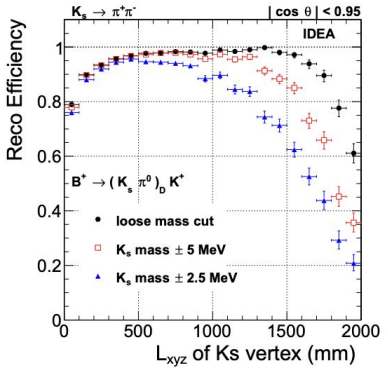
$B_s \to \phi\phi$ https://arxiv.org/abs/2205.07823 strong requirements on mom resolution, vertexing, PID. Relevant for CP violation and NP

$B^+ \to D^0 K^+$: to measure γ_s. Study of effects of vertexing, resolution, but also comparing different performance of tracker concepts (2107.02002, 2107.05311)

$B_s \to K^*\nu\nu$: relevant for NP. Vertexing and PID crucial

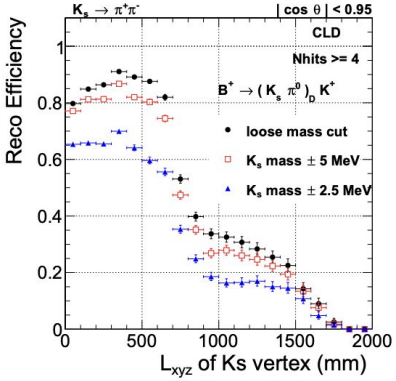
Study example for with new tools *E. Perez*

https://arxiv.org/pdf/2107.05311.pdf



IDEA

Good efficiency also at big displacements



CLD big effect of losing a layer hit

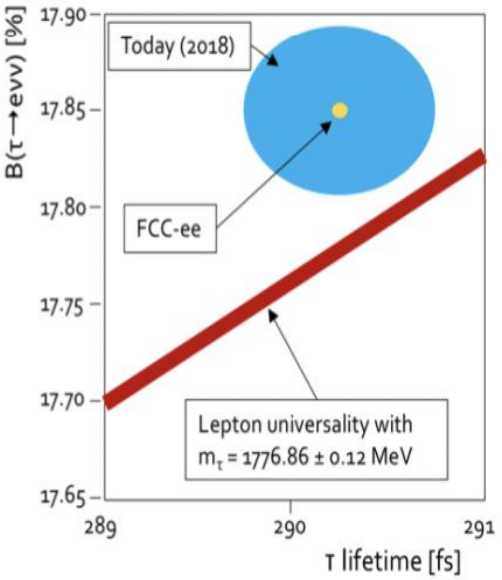
Modified default card, similar vtx res, worse mass res.

Tau Physics Case Studies

Tau physics very rich source of measurements constraining the detector requirements.

Some initial studies starting with Delphes, focusing on tool development for tau identification.

- FullSimulation necessary for further steps and detector requirements
- Some initial studies already happening in the context of the development of reconstructions tools (such as Tau ID in DR Calorimeter)



Tau lifetime

Tau mass

Tau leptonic BR

Tau polarisation and exclusive BR

LFV in Z and tau decays

LFU tests

* NP expectation from current anomalies in the range (0.2 – 4.0) × 10-3 (SM theory precision ~ 10-5)
* Belle-II can (at most) reach an error ~ 0.3 × 10-3
* FCC-ee could go below 10-4

sensitivity good enough to probe BSM models "explaining" current flavour R_K anomalies $(b \to c\tau\nu)$

Electroweak & QCD Case Studies

EWK (Z)

Z width

R_b, R_c, R_ℓ

$A_{FB}(bb, cc)$

$A_{FB}(muons)$

Luminosity from di-photons/NP

Coupling of Z to ν_e (NP)

EWK (W)

W polarisation

M(W) from direct reconstruction

$\sigma(WW)$ for M(W), **TGCs**

Vcb from $W \rightarrow cb$

W leptonic BRs

√s via radiative returns

QCD

$\alpha_S(M_Z)$

Quark and Gluon

fragmentation studies

CONVENERS EWK

C. Paus

G. Wilson

A. Freitas

CONVENERS QCD

D. D'Enterria

P.F.Monni

Tera-Z program is a dream for EWK measurements. Bound to bring very strong requirements also on acceptance and stability and alignment of the detector (construction tolerance, design choices)

Some preliminary papers/studies with parameterised approach.

- Few studies started with new tools and detector simulation: , TGCs, Z width

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…In progress

Top physics - Case Studies

Top physics studies can happen during different running phases:

- **Threshold run** for ultra-precise mass measurement and other properties
  - Needs excellent control of beam energy, beam energy spread, luminosity spectrum () and ISR : generator description to study effects
- **√s=365GeV for measurement of other properties** such as Electroweak couplings or anomalous couplings (FCNC). Also possible at **√s=240GeV** for anomalous single top production
  - Constraints on jet reconstructions, b-tagging, fitting algorithms, overall performance of detectors in full event reconstruction

Top events due to their large number and variety of particles in the final state are a fundamental validation tool for the software and detector performance!

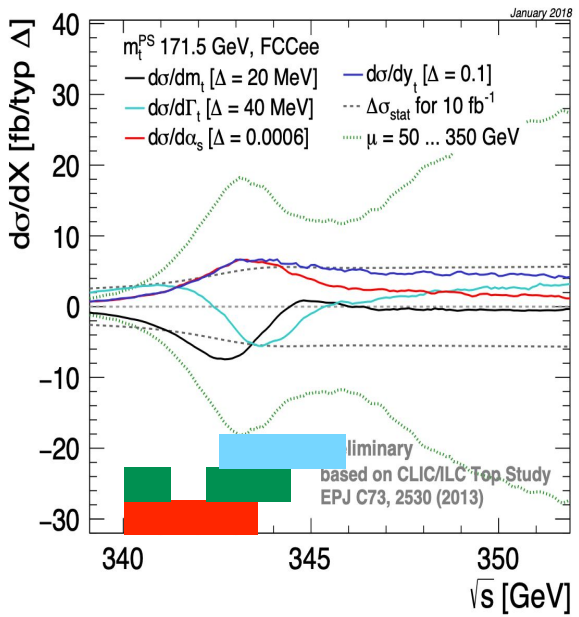
Properties at threshold(mass, width, Yukawa)
EWK couplings
Anomalous Couplings(FCNC)
EFT Interpretations

H. Kahnpour(UD) see Slides

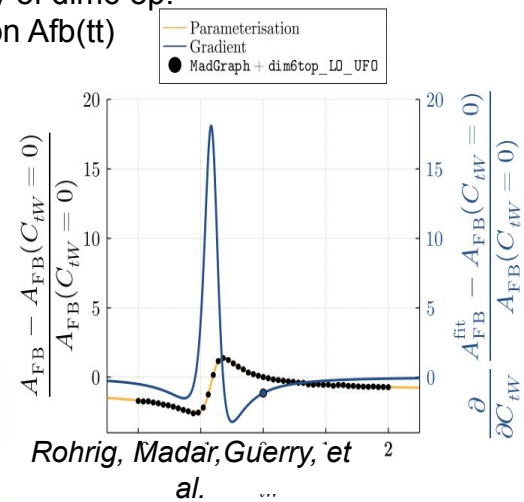
sensitivity to:

mass
width
Yukawa

F. Simon



Study of dim6 op. on Afb(tt)



Direct BSM Case Studies

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R. Gonzalez-Suarez, **G. Polesello**

S. Heinemeyer, T. You

Tera-Z statistics pushes the limits of the sensitivity to feebly interacting particles.

In particular, can explore the range of small coupling and potentially large displacements.

Rich interaction between phenomenologist and experimentalist especially for the LLP case

https://arxiv.org/abs/2203.05502

Heavy Neutral Lepton

Exotic Higgs

Dark Photons

Axion Like Particles

Detector Requirements

- Sensitivity to far-detached vertices (mm → m)
  1. Tracking: more layers, continuous tracking
  2. Calorimetry: granularity, tracking capability
- Larger decay lengths ⇒ extended detector volume
- Full acceptance ⇒ Detector hermeticity
- Timing???

- Help develop/validate new tools for analysis with Delphes
- FullSim, advancement in Geant simulation, machine backgrounds etc, needed to fully explore the ultimate sensitivity reach.