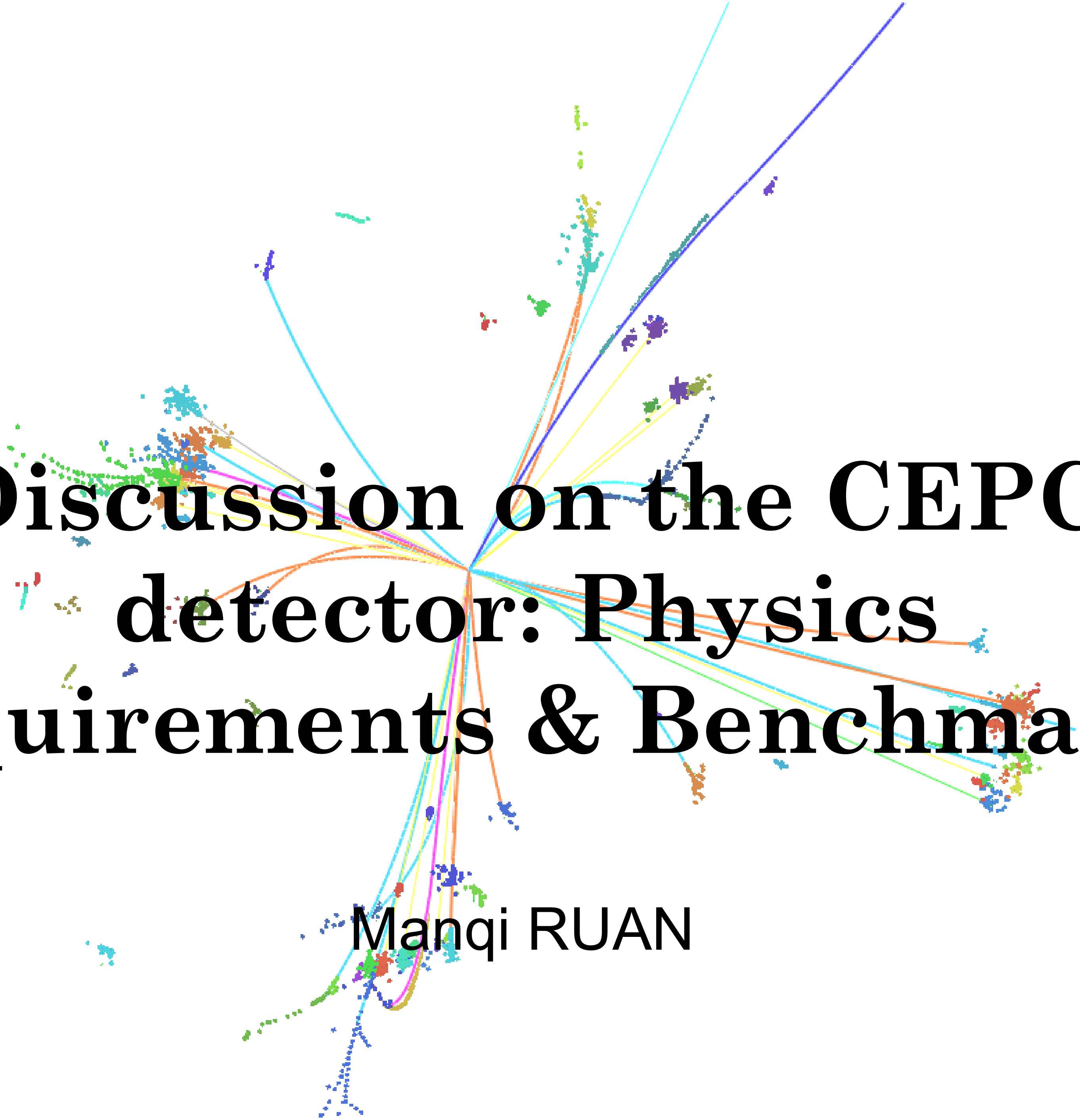
Discussion on the CEPC detector: Physics Requirements & Benchmarks



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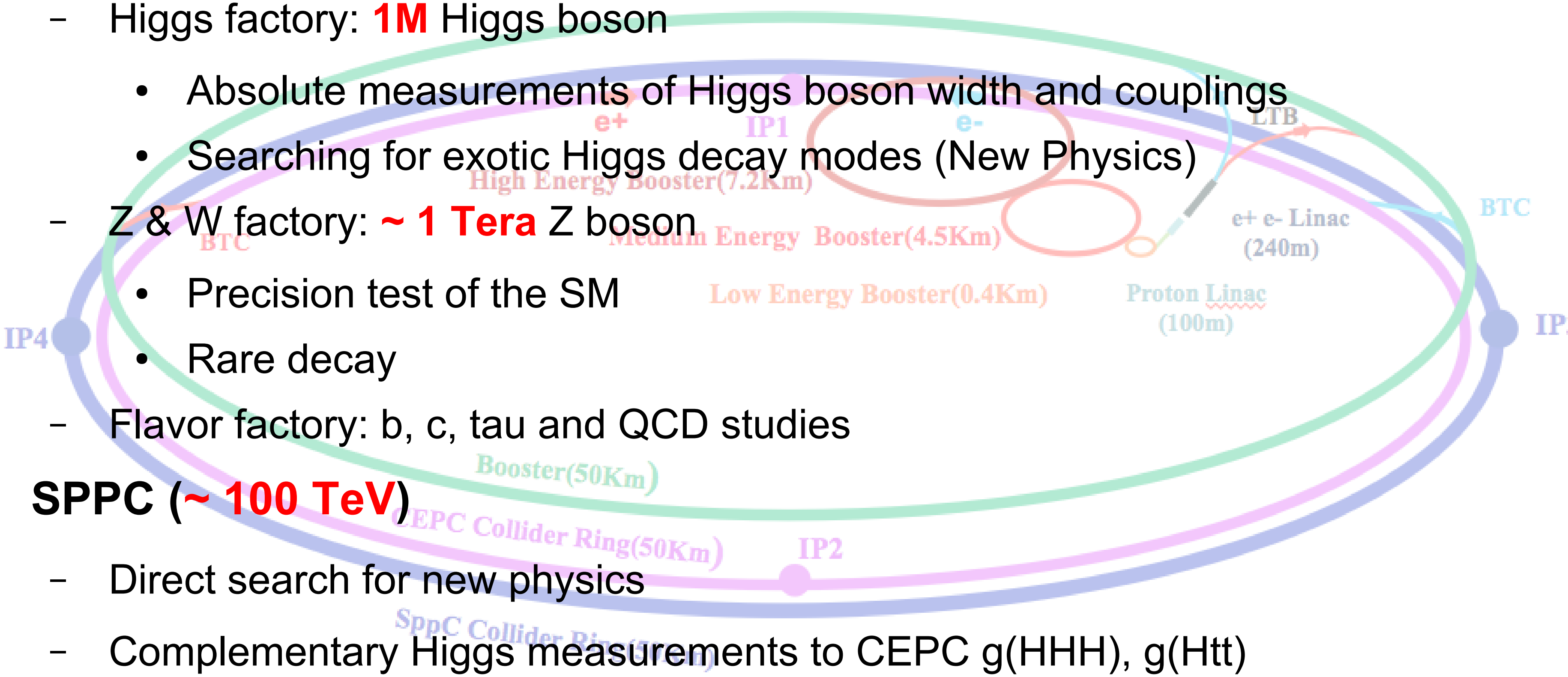
CEPC-SPPC: Higgs & Z

- **Tunnel ~ 100 km**
- **CEPC (90 – 250 GeV)**
  - Higgs factory: **1M** Higgs boson
    - Absolute measurements of Higgs boson width and couplings
    - Searching for exotic Higgs decay modes (New Physics)
  - Z & W factory: **~ 1 Tera** Z boson
    - Precision test of the SM
    - Rare decay
  - Flavor factory: b, c, tau and QCD studies
- **SPPC (~ 100 TeV)**
  - Direct search for new physics
  - Complementary Higgs measurements to CEPC g(HHH), g(Htt)
  - ...
- **Heavy ion, e-p collision...**



Complementary

Requirements at the CDR

Physics process	Measurands	Detector subsystem	Performance requirement
$ZH, Z \to e^+e^-, \mu^+\mu^-$ $H \to \mu^+\mu^-$	$m_H, \sigma(ZH)$ $\mathrm{BR}(H \to \mu^+\mu^-)$	Tracker	$\Delta(1/p_T) =$ $2 \times 10^{-5} \oplus \frac{0.001}{p(\mathrm{GeV}) \sin^{3/2}\theta}$
$H \to b\bar{b}/c\bar{c}/gg$	$\mathrm{BR}(H \to b\bar{b}/c\bar{c}/gg)$	Vertex	$\sigma_{r\phi} =$ $5 \oplus \frac{10}{p(\mathrm{GeV}) \times \sin^{3/2}\theta}(\mu\mathrm{m})$
$H \to q\bar{q}, WW^*, ZZ^*$	$\mathrm{BR}(H \to q\bar{q}, WW^*, ZZ^*)$	ECAL HCAL	$\sigma_E^{\mathrm{jet}}/E =$ $3 \sim 4\%$ at 100 GeV
$H \to \gamma\gamma$	$\mathrm{BR}(H \to \gamma\gamma)$	ECAL	$\Delta E/E =$ $\frac{0.20}{\sqrt{E(\mathrm{GeV})}} \oplus 0.01$

Table 3.3: Physics processes and key observables used as benchmarks for setting the requirements and the optimization of the CEPC detector.

Higgs factory

- Jets (Hadronic system), Tracks, Isolated Lepton/Tau, Flavor Tagging
  - Hadronic system
    - The majority of Higgs events has jet final states; many important EW measurements relies on multi-jet processes.
    - BMR < 4%: to separate qqH signal from qqX background with recoil mass
      - Benchmarked with signal strength measurements at qqH, H→invisible, H→tautau, and vvH, H→bb (hadronic)
    - To investigate innovative color singlet identification algorithm (optimize jet clustering-matching or beyond)
      - Benchmarked with WW/ZZ separation with full hadronic final state
      - Benchmarked with signal strength measurements of H→hadronic final states (bb, cc, gg, WW/ZZ→4 jet) at qqH processes
  - Relative track momentum resolution ~ 0.1%:
    - Benchmarked with H→mumu signal strength, and Higgs mass measurement via Higgs recoil analysis with llH channel.

Higgs factory

- Jets (Hadronic system), Tracks, Isolated Lepton/Tau, Flavor Tagging
  - Isolated Leptons and taus;
    - Many benchmarks: Isolated leptons eff*purity > 99% (eff > 0.995%, mis-id < 1%);
    - Benchmarked with $H \to$ tautau: Isolated Tau finding eff*purity > 70%.
  - VTX: efficiently separate the b, c, and light jets.
    - eff*purity of c-tagging at $H \to jj$ events. Aim for eff*purity >> 10% (i.e. 25%?)
    - Benchmarked with $H \to cc$ & $H \to gg$ measurements;

Z factory

- Z factory has extremely rich physics program, where a better detector is always better. More benchmark studies are needed, to quantify the Z factory potential & requirements.
- Detector acceptance: |cos(theta)| < 0.99, ... or better
- Tracks
  - Momentum threshold: ~o(100) MeV to find pions generated in D* decay ($D^* \rightarrow D$ + pi)
  - Momentum resolution < 0.1%: Benchmarks? Narrow resonance generated at IP?
- Photons
  - Photons: ~o(100) MeV to find photons decay from low energy pi-0
  - Energy resolution < 5%/sqrt(E):
    - π^0 reco. Eff*purity ~50% at $Z \rightarrow qq$ events
    - Benchmarks: $Bs \rightarrow 2\pi^0$, what else?
- Separation: to count number of π^0 in the $Z \rightarrow \tau\tau$ event
  - Separate photons from π^0 decay, with the energy of π^0 up to 30 GeV
  - Benchmark with tau decay Branching ratio measurements

Z factory

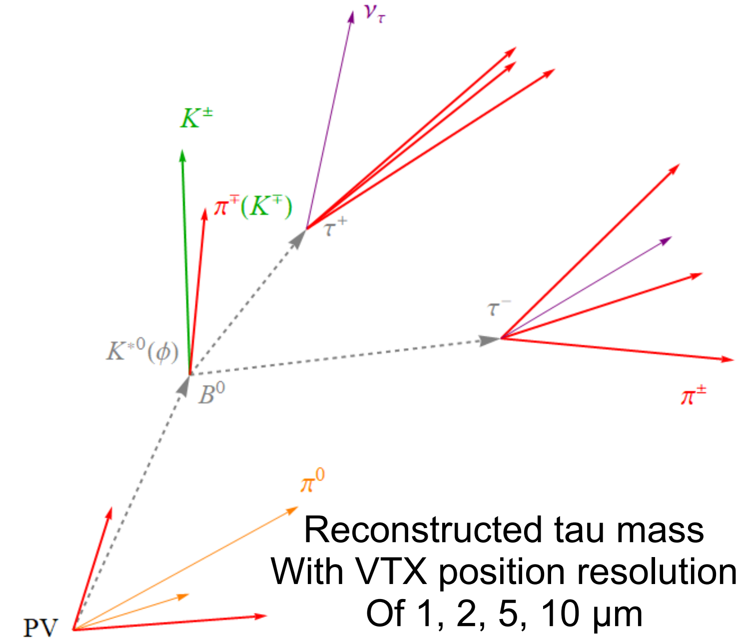
- Separation: find objective particles inside jets
  - Tracks are usually well separated, while clusters can easily overlap with each other.
  - Jet lepton: identification performance usually degrades w.r.t. Isolated leptons. the detector separation capability should ensure the degrading is marginal.
  - Benchmark: measurement with neutral hadron (Klong, Neutron) in the final state
- Identification:
  - Leptons (in jet): benchmark with R_K & R_D, and LFV measurements.
  - Tau (in jet): i.e. $Bc \to \tau\nu$, $b \to s\tau\tau$ analysis
  - Pion, Kaon&Proton: reco. eff*purity of objective particles decays into Kaon & proton final states (at IP, or decay from 2nd vertexes...).
    - D, Lambda_c, Lambda, Ds reconstruction require 3σ pi-kaon separation
    - Need dedicated benchmark analyses
  - Jet charge measurements for c/b-jets

$$R_{D^{(*)}} \equiv \frac{\mathrm{BR}(B \to D^{(*)}\tau\nu)}{\mathrm{BR}(B \to D^{(*)}\ell\nu)}, \ \ell = e, \mu$$

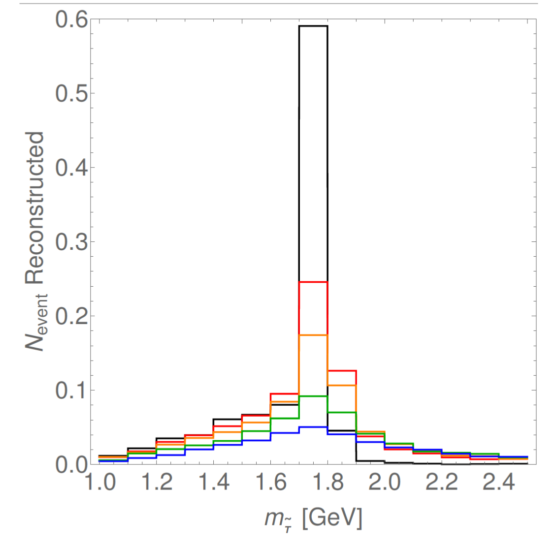
$$R_{K^{(*)}} \equiv \frac{\mathrm{BR}(B \to K^{(*)}\mu^+\mu^-)}{\mathrm{BR}(B \to K^{(*)}e^+e^-)}$$

Z factory

- Vertex
  - Understand the correlation between
    - VTX intrinsic performance
    - 2nd/3rd vertex reconstruction performance: efficiency/purity, and position resolution as a function of the vertex charge multiplicity & polar angle
    - Flavor tagging performance
    - Detailed performance study is needed!
  - Distinguish different vertexes
    - b→B*(PV)→B→D*(2nd V)→D(3rd V)→...
    - b→τ+X, ττ+X
  - Reconstruct accurately the decay vertex, such that the tau mass can be reconstructed in b→sττ event



Reconstructed tau mass
With VTX position resolution
Of 1, 2, 5, 10 µm



Extra: from the Discussion

- A natural tracking performance objective at the Higgs runs is to balance the tracking performance with beam energy uncertainty. For the Higgs recoil analysis via llH channel.
- For flavor channels – need to focus on the measurements that where CEPC have comparative advantages
  - LFV
  - B->tau + X
  - ...
- Systematic control: positron monitoring to the accuracy of 10 μm & stability is essential for EW... and maybe many others.

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