Status of Physics Analyses in ILD and Benchmarks

Keisuke Fujii, KEK
on behalf of the ILD physics WG

Priority No.1 = to realize ILC

What we need =

- **clear physics case**

Priority No. 2 = to realize ILD

What we need =

- **detector design, which is cost effective and technically feasible, to realize the physics**

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- **detector design, which is cost effective and technically feasible, to realize the physics**

ILD has been the main driving force to input physics simulation results to LCC Physics WG.

This is true also for the most recent LCC physics WG report:

arXiv:1710.07621v1 [hep-ex] 20 Oct 2017

Physics Case for the 250 GeV Stage of the International Linear Collider

LCC Physics Working Group

Keisuke Fujii[1], Christophe Grojean[2,3], Michael E. Peskin[4] (Conveners); Tim Barklow[4], Yuanning Gao[5], Shinya Kanemura[6], Hyungdo Kim[7], Jenny List[2], Mihoko Nojiri[1,8], Maxim Perelstein[9], Roman Pöschl[10], Jürgen Reuter[2], Frank Simon[11], Tomohiko Tanabe[12], James D. Wells[13], Jaehoon Yu[14]; Mikael Berggren[2], Moritz Habermehl[2], Sunghoon Jung[7], Robert Karl[2], Tomohisa Ogawa[1], Junping Tian[12]; James Brau[15], Hitoshi Murayama[8,16,17] (ex officio)

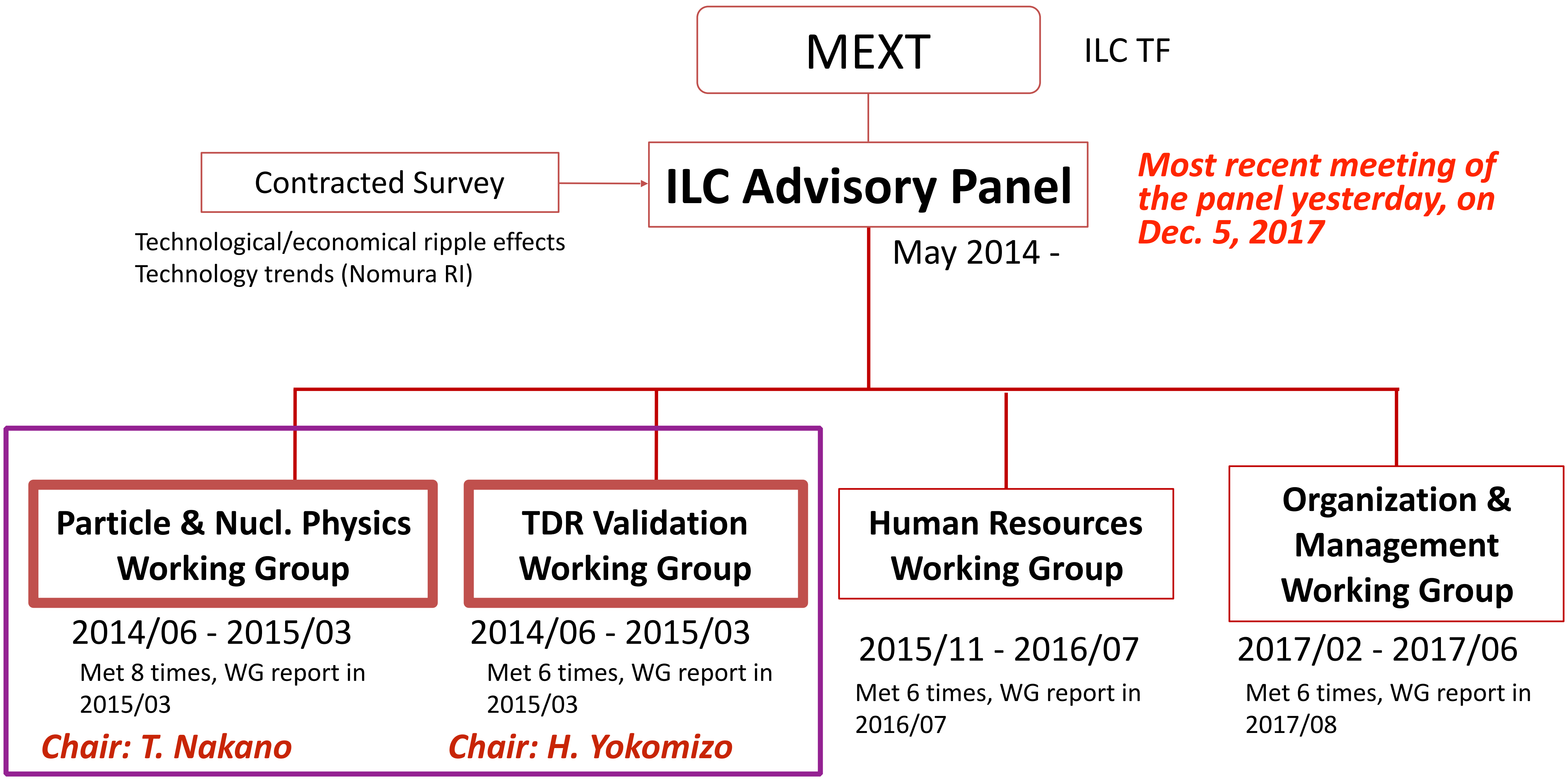
ABSTRACT

The International Linear Collider is now proposed with a staged machine design, with the first stage at 250 GeV with a luminosity goal of $2\,\mathrm{ab}^{-1}$. In this paper, we review the physics expectations for this machine. These include precision measurements of Higgs boson couplings, searches for exotic Higgs decays, other searches for particles that decay with zero or small visible energy, and measurements of e^+e^- annihilation to W^+W^- and 2-fermion states with improved sensitivity. A summary table gives projections for the achievable levels of precision based on the latest full simulation studies.

This report is the one of the two inputs (the other is a machine report) to the MEXT review of the 250 GeV ILC.

ILC Advisory Panel

Set up in May 2014 under MEXT ILC Task Force to investigate various issues concerning the possibility of hosting the ILC in Japan



New round started from January 2018, each met 5 times and finished their mission

http://www.mext.go.jp/b_menu/shingi/chousa/shinkou/038/index.htm

MEXT Particle and Nuclear Physics WG

Charge

Taking into account the recommendations made in the interim report by the MEXT ILC Panel, review the 250 GeV ILC physics case and clarify potential issues if any.

Members

1. Takaaki Kajita (deputy chair) : Cosmic Ray Research
2. *Sachio Komamiya* : HEP
3. Hideyuki Sakai : Nuclear Physics
4. Seiji Tanabashi : HEP (theory)
5. Eiji Chin : Accelerator
6. *Katsuo Tokushuku* : HEP
7. Takeshi Nakano (chair) : Nuclear Physics
8. Tsuyoshi Nakaya : HEP
9. Tetsuo Hatsuta : Nuclear Physics (theory)
10. Ryugo Hayano : HEP
11. Shigeki Matsumoto : HEP (theory)
12. Taku Yamanaka : HEP
13. Hiromi Yokoyama : Scientific Communication

1st meeting on Jan. 18

- **General remark from the secretariat (WG charge, history)**
- **Development of the LHC experiment: K. Hanagaki**
- **On the revision of the ILC project (Physics Case of the 250 GeV ILC): K. Fujii**
  LCC Physics WG Report（arXiv: 1710.07621）

2nd meeting on Feb. 5

- **Discussions in JAHEP on ILC250: S. Asai**
  Asai committee's report (arXiv: 1710.08639)
- **Physics potential of the ILC at 250 GeV: G. Weiglein**

3rd meeting on March 1: discussions on skeleton draft

- **Main points in the discussions so far**
- **Comparison of scientific case of 500 GeV ILC and 250 GeV ILC (Comparison Table)**

4th meeting on April 13:

- **About XFEL and FAIR mentioned in the LCB statement**
  - **XFEL: K. Tokushuku**
  - **FAIR: R. Hayano**
- **Discussions on 1st draft**

5th meeting on May 16: (the last meeting of the physics WG)

- **Answers from LCB about XFEL/FAIR (Why they are mentioned?)**
- **Discussions on 2nd (=updated) draft**
  → **update left to chairman's discretion**

Main conclusions of the report

Unofficial English translation by KF

Scenario for 250 GeV ILC based on the 13 TeV LHC results (from the point of view of scientific significance)

Strategy: ***Precisely measure Higgs couplings to other particles, and look for clues to elucidation of BSM physics.***
In addition, search for dark matter, extra dimensions, etc. with mainly indirect methods.

Outcome: ***If deviations from the SM are observed in the Higgs couplings, their sizes and deviation pattern will tell us the direction and the scale of the BSM physics.***
If observed, dark matter particles and/or extra dimensions will greatly advance particle physics.

- ***On the other hand, 13 TeV LHC results suggest that the chance to discover new particles through direct searches is low at ILC. It should be noted that the change from 500 GeV to 250 GeV made impossible to do precision top quark measurements.***
- ***The scenario above should be judged also from the point of view of the project cost to be shown by the TDR validation WG.***

The 5th (the last) meeting of the TDR Validation WG happened on May 17. Most of their sessions were closed. See Shin's talk in TCMB on Tuesday.

The ILC Advisory Panel met and received the two working group reports plus NRI's report on a commissioned study on the expected economic impact reevaluated for ILC250, yesterday on May 31, 2018!

The panel will meet again on June 19 to discuss their final report.

Subgroup Activities:

Contributions to This Workshop

1. Higgs/EW WG (Junping Tian, Graham Wilson)

1. Measuring the CP state of tau lepton pairs from Higgs decay at the ILC (Daniel Jeans) → *May 28*
2. Measurement of the ZH cross section using Z→qq in ILD (Guillaume Garillot) → *May 28*
3. Branching ratio measurement of h → μ+μ- at the ILC (Shin-ichi Kawada) → *May 28*
4. Determination of anomalous VVH couplings at the ILC (Tomohisa Ogawa) → *May 28*
5. Study of H→Zγ branching ratio at the ILC (Kazuki Fujii) → *May 28*
6. Effective Higgs couplings in models with extended Higgs sectors (non-ILD)
(Junping Tian) → *May 28*

2. BSM WG (Mikael Berggren, (Tomohiko Tanabe))

1. Precise measurement of two-fermion final states in 250 GeV ILC for BSM (Taikan Suehara, Hiroaki Yamashiro) → *May 29*
2. Natural SUSY with light Higgsinos
(KF on behalf of Tomohiko Tanabe, Suvi-Leena Lehtinen)
→ *May 29*
3. Review of WIMP search at mono-photon channel at 500 GeV ILC (Ahmed Mustahid) → *May 29*
4. Searches for light scalars in association with a Z boson at the 250 GeV stage of the ILC (Shin-ichi Kawada, Yan Wang)
→ *May 29*
5. Experimental techniques for Higgsinos with Δ(M)~1 GeV
(Mikael Berggren)
→ *May 29*

3. Top/QCD WG (Roman Poeshl, Ryo Yonamine)

1. EFT fit on top quark EW couplings (Martín Perelló Roselló) → *May 28*
2. Top quark mass measurement above the top threshold (Pablo Gomis Lopez) → *May 28*

plus some HLR talks:

1. Automatic colorization for jet clustering (Masakazu Kurata) → *May 31*
2. LCFIPlus performance test with new MC samples for ILD (Ryo Yonamine) → *May 31*
3. A first look of new MC samples for h → μ+μ- analysis (Shin-ichi Kawada) → *May 31*
4. Status of dE/dx in ILCSoft v02-00 (Ulrich Einhaus) → *May 31*

Homework from LCCPDeb

It is, however, ***necessary to confirm the new beam parameters would not harm the physics performance*** *with full simulation; noice that*

- *per bunch luminosity will be enhanced by a factor of about 1.6, which will increase 2-photon BG as well as low energy pairs (Small Δm processes, mW, …),*
- *longer beamstrahlung tail might affects analyses assuming a fixed E_{cm} (recoil M, …).*

Plan for 250 GeV Physics Studies

Ongoing and Planned 250 GeV Analyses

Higgs

- **Improve σ BR(h→WW*): Mila Pandurovic?**
- **EFT analyses: Tomohisa Ogawa**
- e+e-→ ννH: Junping Tian
- e+e-→Hγ: Yumi Aoki
- **H→ττ: Daniel Jeans**
- H→invisible: Yu Kato
- **H→μμ: Shin-ichi Kawada**
- mh: Graham Wilson, Junping Tian
- **H→exotic (new light particles, FC/LFV): ?**
- **H→Zγ: Kazuki Fujii**

Precision EW

- m_W: Robert Karl
- **2-fermion processes: μμ: Taikan Suehara**
- TGC: Robert Karl
- **e+e-→Zγ (A_{LR}), γγ: ?**

Top/QCD

- **bb: Sviatoslav Bilokin → who to take this over**
- **Single top production: ?**

BSM: Direct search

- Dark Matter: ***Shoal Amjad***, Tomohiko, Masakazu, ..
- **Extra light states** (light extra higgses, dark photon, ..)
  - **ZX (m_X<125GeV): Yan Wang**
- **Higgsinos: Tomohiko + Swathi (for very low ΔM)**

Blue: presented at ALCW 2018

Brown: new analyses

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Priority No. 2 = to realize ILD

What we need =

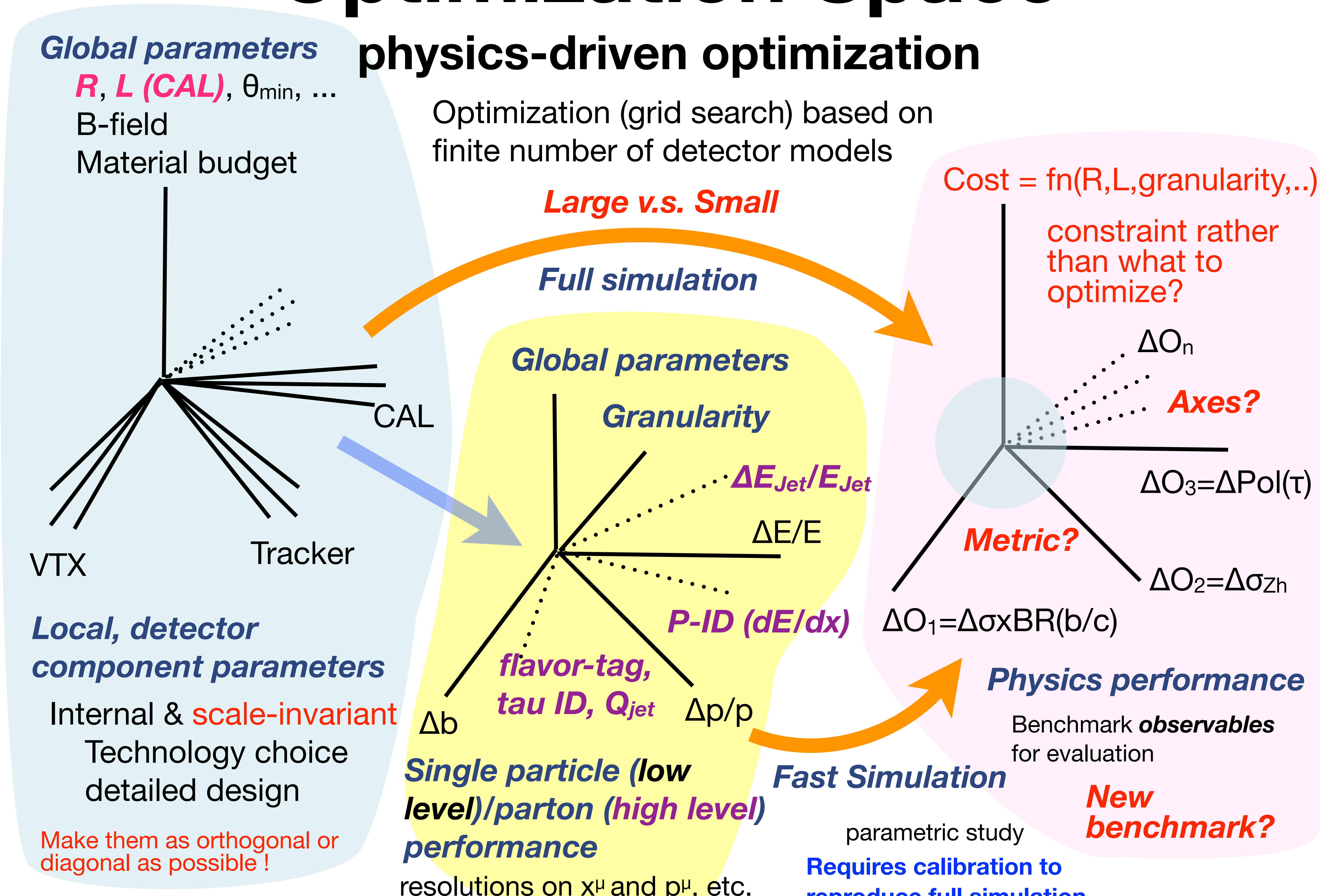
- **detector design, which is cost effective and technically feasible, to realize the physics**

Remark

As for the decision making by the Japanese government, since it is getting out of our hands, our priority is shifting more to the second one, though it is still important to make a good physics case for the strategy discussions in our community.

Benchmark Studies

Optimization Space



Based on K.Fujii AWLC14, Fermilab, 12 May. 2014

Criteria and Conditions

- For detector optimization, we need to set the right axes in the evaluation space:
  - Choose appropriate benchmark processes so as to orthogonalize / diagonalize the detector aspects to be optimized as much as possible.
  - For the metric for the evaluation space, we now know that we'd better put enough weight to precision Higgs studies and BSM scenarios with compressed mass spectra. We'd better put higher metric weight also to benchmarking of (expensive) sub-detectors which are expected to survive machine upgrades.
- Analysis improvements
  - We need to control systematics more than ever for the 125GeV Higgs boson and comprehensive EFT analyses and the detector design must allow this.
  - If the physics performance is limited by analysis rather than the detector performance, improve the analysis! This applies also to high level detector performance such as tau ID, vertex charge ID, etc.
  - ***To detect and understand performances that are limited by analysis rather than detector, the benchmark analyses should be compared to cheated versions (see Jenny's talk in Ichinoseki) .***
  - Don't easily compromise PFA performance but improve jet or color-singlet clustering (crucial for self-coupling measurement and many others)!

We should fully exploit the ILD potential!

Based on K.Fujii AWLC14, Fermilab, 12 May. 2014

Relevant Experimental Issues

Acceptance

- $p_{t,min}$ (as determined by B-field, θ_{min}, R_{min})
  - **tracking** → low p_t tracks (compressed spectra)
  - **flavor tagging** (material budget, angular coverage) → for low θ tracks
  - **particle ID (mu/π/e/γ)** → for soft/low θ tracks
- θ_{veto} (missing pt, ISR-tag) for e/γ → for μ, hadron, too

Resolution

- **momentum** (tracker): $\Delta p_t/p_t^2$ → recoil mass
- Jet Energy Resolution (***JER/PFA***):
  - what processes are driven by JER? → single bosons
  - but many others are mostly driven by jet clustering
- ***dE/dx, TOF*** → b(c)-jet charge ID
- **two-track, displaced vertices** (kink) → tau ID
- **non-pointing photons**
- **π^0/η^0 reconstruction**
- **split photon merging**

BG tolerance

- vertex detector ***occupancy***
- pileup mitigation using ***time stamping*** (Tracker/CAL), ***vertex detection***

Systematics control

- monitoring of machine parameters: E, luminosity, polarization
  → need to know the ***luminosity spectrum*** (recoil mass, ttbar threshold)
- E_{jet} scale, p scale, flavor tagging, …

Based on K.Fujii AWLC14, Fermilab, 12 May. 2014

benchmark processes for detector optimisation

process	physics	detector	Ecm	
H—>cc	BR	c-tag JER	any	H.Ono
H—>μμ	BR	high P tracking	500 GeV	S.Kawada
H—>ττ	BR, CP	τ reconstruction, PID track separation	250 GeV	D.Jeans
H—>bb	M_H, BR	JES, JER b-tag	500 GeV	A.Ebrahimi J.Tian
H—>invisible Z—>qq	Higgs Portal	JER	250 GeV	Y.Kato
eνW—>eνqq	M_W, TGC	JES, JER	500 GeV	K.Cotera G.Willson
tt-bar—>6-jet	top coupling A_{FB}	b-tag, JER jet charge	500 GeV	S.Bilokin Y.Sato
$\chi_1^+\chi_1^-, \chi_2^0\chi_1^0$ near degenerated	natural SUSY	low P tracking PID	500 GeV	J.Yan
γXX	WIMPs	Photon ER & ES Hermiticity	500 GeV	M. Habermehl

in total 9 = 5 (Higgs) + 2 (EW) + 2 (BSM)

Updated list of benchmarks

Physics Benchmarks - reminder

WG	Process	Physics	Detector	ECM	Who
Higgs & EW	**H->bb/cc/gg**	**BR**	**c-tag, b-tag, JER**	**500 GeV**	**NN + NN**
	H->bb	mass	JER, JES	500 GeV	Ali Ebrahimi (10%) + Junping Tian **+ NN**
	ee->tautau	A_FB, tau-pol, A_LR	tau-reco	500 GeV	Daniel Jeans **+ NN**
	H->mumu	BR	momentum resolution	500 GeV	Shin-ichi Kawada **+ NN**
	H->invisible	BR limit	JER, hermeticity	500 GeV	Yu Kato **+ NN**
	WW->qqlv	MW, TGCs, beam pol.	JES, JER, electron, mu	500 GeV	Kostiantyn Shpak **+ NN**
	vvqqqq	QGCs	JES / JER	1 TeV	Jakob Beyer **+ NN**
	gamma Z->qq/ee/mumu	**A_LR, sigma_tot, JES**	**photon, JER/JES, e, mu**	**500 GeV**	**NN + NN**
Top, Bottom & QCD	tt->bbqqqq	x-section, AFB	b-tag, vertex charge, PID	500 GeV	Sohail Amjad **+ NN**
BSM	low deltaM Higgsinos	natural SUSY	low-p tracking, PID, hermeticity	500 GeV	Swathi Sasikumar **+ NN**
	mono-photons	WIMPs / WISPs	photon reco, BeamCal	500 GeV	Ahmed Mustahid **+ NN**
	Zh, mh < 125 GeV	limit on ZZh coupling	p res, e reco, JER, hermeticity	500 GeV	Yan Wang **+ NN**

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	H->invisible	BR limit	JER, hermeticity	500 GeV	Yu Kato **+ NN**
	WW->qqlv	MW, TGCs, beam pol.	JES, JER, electron, mu	500 GeV	Kostiantyn Shpak **+ NN**
	vvqqqq	QGCs	JES / JER	1 TeV	Jakob Beyer **+ NN**
	gamma Z->qq/ee/mumu	**A_LR, sigma_tot, JES**	**photon, JER/JES, e, mu**	**500 GeV**	**NN + NN**
Top, Bottom & QCD	tt->bbqqqq	x-section, AFB	b-tag, vertex charge, PID	500 GeV	Sohail Amjad **+ NN**
BSM	low deltaM Higgsinos	natural SUSY	low-p tracking, PID, hermeticity	500 GeV	Swathi Sasikumar **+ NN**
	mono-photons	WIMPs / WISPs	photon reco, BeamCal	500 GeV	Ahmed Mustahid **+ NN**
	Zh, mh < 125 GeV	limit on ZZh coupling	p res, e reco, JER, hermeticity	500 GeV	Yan Wang **+ NN**

More manpower highly welcome!

Since the MC production is on-going and the full 500 GeV samples will be ready soon, we need to work on benchmark analyses for these new 500 GeV samples!

The 250 GeV physics analyses could be done also at 500 GeV.

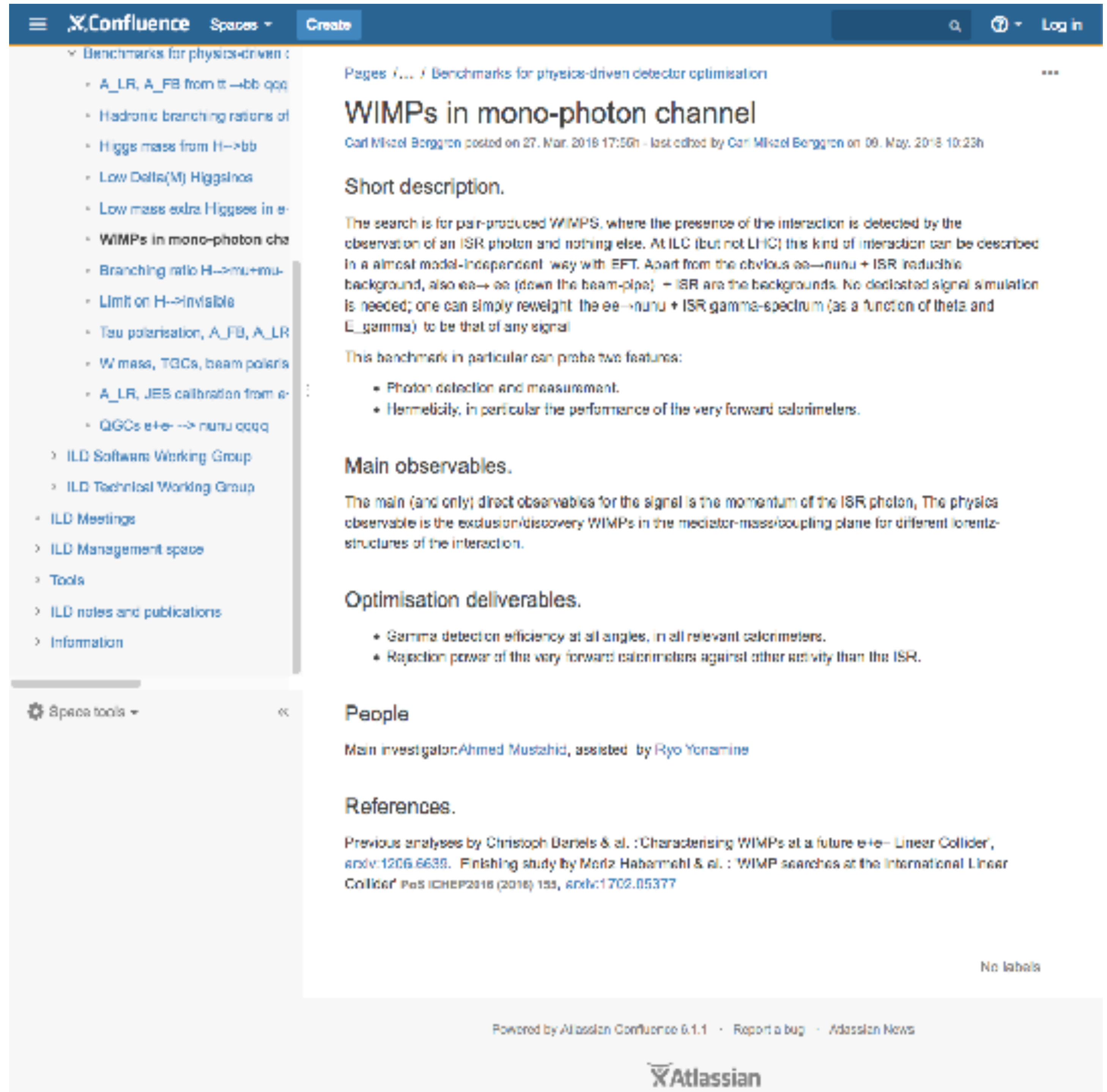
All the people working on the physics analyses are strongly requested to take a look at the new 500 GeV sample.

We started a portal page for the benchmark processes in our ILD confluence page.

Confluence Pages for Benchmark Processes

Webpages for Benchmarks

- https://confluence.desy.de/display/ILD/Benchmarks+for+physics-driven+detector+optimisation
- currently maintained by the physics WG conveners
- still evolving
- hand over to responsible analysis persons later?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Benchmarks for physics-driven
- A_LR, A_FB from tt →bb qqq
- Hadronic branching rations of
- Higgs mass from H-->bb
- Low Delta(M) Higgsinos
- Low mass extra Higgses in e-
- WIMPs in mono-photon cha
- Branching ratio H-->mu+mu-
- Limit on H-->invisible
- Tau polarisation, A_FB, A_LR
- W mass, TGCs, beam polaris
- A_LR, JES calibration from e-
- QGCs e+e- --> nunu qqqq

ILD Software Working Group
ILD Technical Working Group
ILD Meetings
ILD Management space
Tools
ILD notes and publications
Information

Space tools

Pages / ... / Benchmarks for physics-driven detector optimisation

WIMPs in mono-photon channel

Carl Mikael Berggren posted on 27. Mar. 2018 17:56h - last edited by Carl Mikael Berggren on 09. May. 2018 10:23h

Short description.

The search is for pair-produced WIMPS, where the presence of the interaction is detected by the observation of an ISR photon and nothing else. At ILC (but not LHC) this kind of interaction can be described in a almost model-independent way with EFT. Apart from the obvious ee→nunu + ISR irreducible background, also ee→ ee (down the beam-pipe) + ISR are the backgrounds. No dedicated signal simulation is needed; one can simply reweight the ee→nunu + ISR gamma-spectrum (as a function of theta and E_gamma) to be that of any signal

This benchmark in particular can probe two features:

- Photon detection and measurement.
- Hermeticity, in particular the performance of the very forward calorimeters.

Main observables.

The main (and only) direct observables for the signal is the momentum of the ISR photon, The physics observable is the exclusion/discovery WIMPs in the mediator-mass/coupling plane for different lorentz-structures of the interaction.

Optimisation deliverables.

- Gamma detection efficiency at all angles, in all relevant calorimeters.
- Rejection power of the very forward calorimeters against other activity than the ISR.

People

Main investigator:Ahmed Mustahid, assisted by Ryo Yonamine

References.

Previous analyses by Christoph Bartels & al. :'Characterising WIMPs at a future e+e− Linear Collider', arxiv:1206.6639. Finishing study by Moritz Habermehl & al. : 'WIMP searches at the International Linear Collider' PoS ICHEP2016 (2016) 155, arxiv:1702.05377

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An Example of Individual Process Pages

Low Delta(M) Higgsinos

Carl Mikael Berggren posted on 27. 3. 2018 14:55h - last edited by Carl Mikael Berggren on 03. 4. 2018 11:53h

Short description.

The model studied is a SUSY model with the lightest bosinos being higgsinos. Xi^0_2 and Xi^+-_1 are mass-degenerate, and very close (~ 1 GeV) in mass to Xi^0_1, which is the LSP. No other SUSY particles are assumed to be produced at ILC energies. The very low mass differences implies that the signal events resembles gammagamma events. Therefore, it is required that the signal events are acompagned by a detected ISR photon

This benchmark in particular can probe four features:

- Detection of very low pt tracks.
- Identifying these particles.
- Detecting, identifying and measuring ISR photons.
- Identifying and rejecting tracks for gammagamma→low pt hadrons and beam-strahlung.

In addition, as for any missing pt-signal, hermeticty is also important.

Main observables.

The main direct observables for the signal are the momentum and identity of the visible decay-products of bosino decays, and the properties of the ISR-photon. With these observations, the masses of the SUSY particles can be reconstructed. The physics observables are the masses of the three SUSY particles and the production cross-sections.

As a main background, also the properties of the gammagamma→low pt hadrons is a main output: Cross-sections, branching-ratios to different vector-mesons, production vertex position.

Optimisation deliverables.

TBA

People

Main investigator: Swathi Sasikumar , assisted by Jenny List and Mikael Berggren.

References.

Previous study (partly based on SGV, no low-pt hadron and beam-strahlung overlay): 'Tackling light higgsinos at the ILC', EPJC (2013) 73:2660, arXiv:1307.3566

We strongly request all the people working on physics analyses to proactively contribute to the benchmark analyses for the new 500 GeV samples as much as possible!

What we want in the IDR

“Science with ILD” Chapter of IDR

Ties’s comment on this chapter

ILD performance for key channels. This should summarize what we consider the relevant ILD performance numbers.

At the time of this document no decision on a new ILD baseline will have been done. We need to discuss how to handle this with regard to the physics performance.

It is also rather clear that for the relevant analyses we will have a mixture of “old” and “new” simulation and reconstruction. We will not be able to fully re-do all analyses in the new software and improved reconstruction.

Document the ILD performance on key points, as reference for the next couple of years.

“Science with ILD” Chapter of IDR

Ties’s comment on this chapter

ILD performance for key channels. This should summarize what we consider the relevant ILD performance numbers.

At the time of this document no decision on a new ILD baseline will have been done. We need to discuss how to handle this with regard to the physics performance.

→ Maybe we should stick to the L model to be consistent with the physics performance numbers used in various official LCC physics documents, which are from LOI and DBD assuming a large model.

It is also rather clear that for the relevant analyses we will have a mixture of “old” and “new” simulation and reconstruction. We will not be able to fully re-do all analyses in the new software and improved reconstruction.

→ 250 GeV results are absolutely necessary in IDR. We have to live with analyses done with the DBD samples.

Document the ILD performance on key points, as reference for the next couple of years.

Science with ILD (my personal draft outline)

1. Introduction
2. Precision Higgs measurements
   - 2.1. σZh and mh measurement wit recoil mass technique at 250 GeV
   - 2.2. Measurements of cross section times branching ratios at 250 GeV
   - 2.3. CP mixture
   - 2.4. Angular analyses to look for anomalous Lorentz structures
   - 2.5. Improvements expected at 500 GeV
3. Other precision EW measurements
   - 3.1. 2-fermion processes (ee, μμ, ττ, bb, cc, qq)
   - 3.2. TGCs
   - 3.3. QGCs and other SM processes (if any)
4. Model-independent determination of Higgs couplings
   - 4.1. SM EFT framework
   - 4.2. Expected coupling precisions and implications
5. Invisible (+ exotic) Higgs decays
6. Precision Top measurements
   - 6.1. Top at threshold
   - 6.2. Form factor measurements in the open top region
7. Cubic Higgs coupling
   - 7.1. ZZh production at 500 GeV
   - 7.2. vvhh production at 1 TeV
8. Direct searches
   - 8.1. Low mass scalars
   - 8.2. mono-photon searches
   - 8.3. Higgsinos in natural SUSY
   - 8.4. Other searches
   - 8.5. Prospects at higher energies
9. In direct searches
   - 9.1. 2-fermion processes
10. Physics summary

More discussions on this and mid-term and longer-term planning tomorrow morning at 9:00 in Room 405+406 together with Software Working Group.

Everybody interested is welcome!

Summary

For physics simulation studies for 250 GeV, we would use DBD samples + new signal samples with the old framework until the new framework becomes fully functionaland validated to be at least as good as or better than the DBD time.

However, we need to test the new beam parameters with the factor of 1.6 higher luminosity at 250 GeV. *This can be done with most relevant subset of physics processes and* ***should be done in a relatively short time frame.***

With the new 500 GeV samples produced, ***everybody working on physics analyses is strongly asked to work proactively on the benchmark processes*** *to meet the IDR dead line.*

For performance comparison for different options (other than the "L" to "S" comparison), we also need dedicated 500 GeV simulation results. → Priority (higher metric weight) should be given to benchmarking of (expensive) sub-detectors which are expected to survive machine upgrades.

For 1 TeV *it is probably rather impracticable to produce full background samples. We can do (maybe non-central?)* ***dedicated MC production for only main background processes****.*

For longer term physics studies, ***priority should be given to 250 GeV*** *with full background samples.*