ILD Status and plans

Mary-Cruz FOUZ

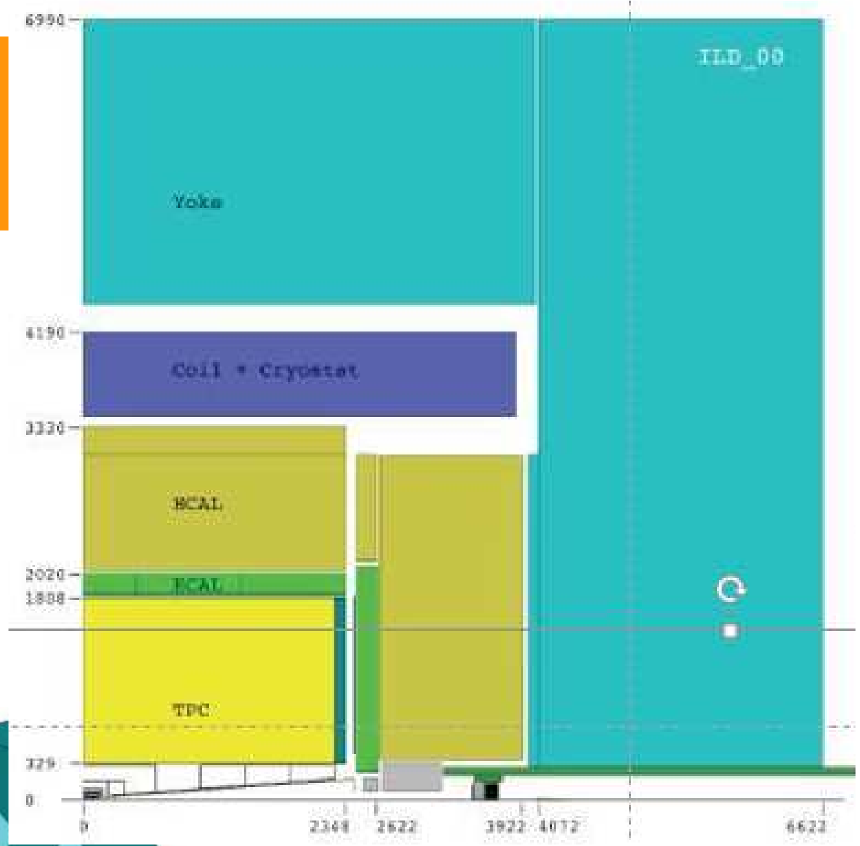
CIEMAT (Madrid-Spain)

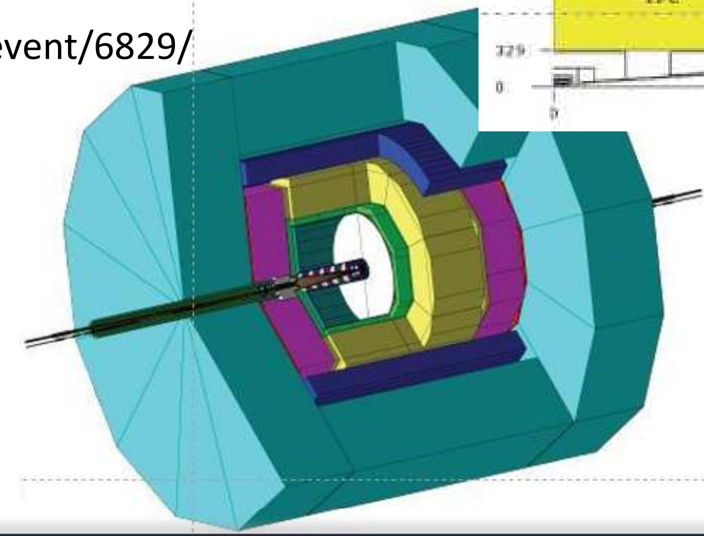
On behalf of the ILD Detector group

Outline

- The ILD group organization

- Integration & infrastructures
  Bring ILD design closer to reality and adapting it to the Kitakami site
  ➔ ILD Topical Integration meeting @ LAL Orsay 8-9 October 2015
  https://agenda.linearcollider.org/event/6829/





- ILD Optimization

- Physics analysis

- Status of ILD subdetectors

A summary overview of the different components
Much more details of the different topics can be found in the detector, physics and ILD parallel sessions.
More results also presented in the previous Calorimetry & Vertex/Tracking talks at this session

ILD group organization

ILD formed an **institute assembly (IA)** (**62** institutes signed up)

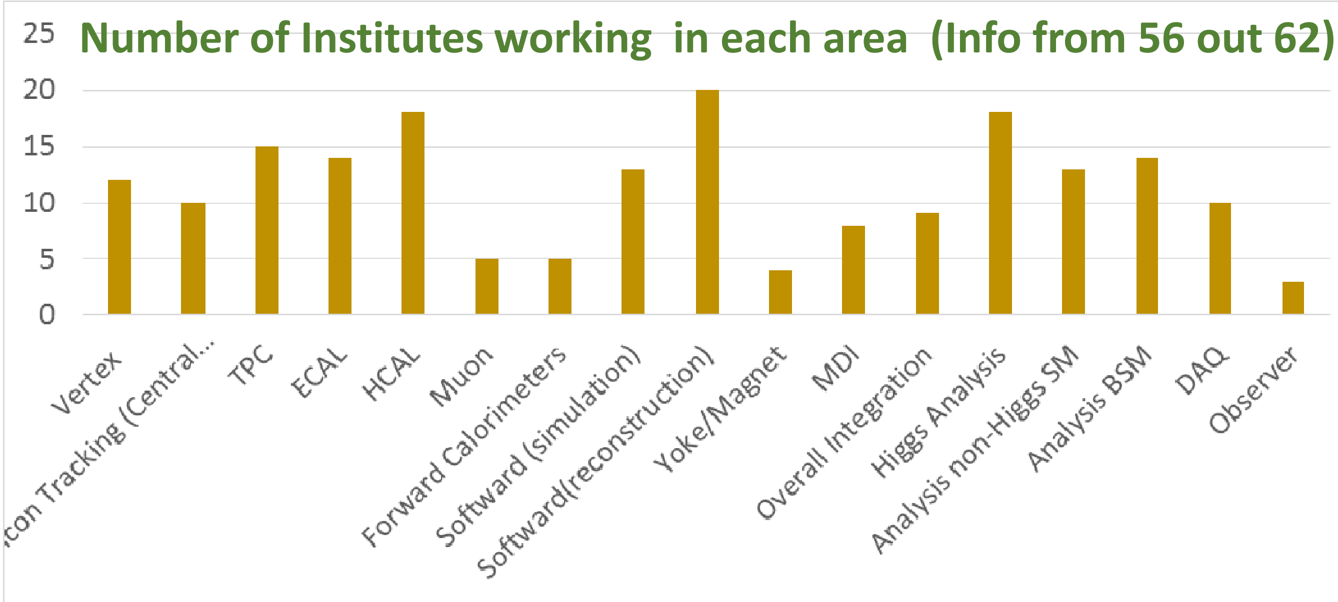
A first set of rules stablished

IA chairman elected (October 2014)
→ Jan Timmerman

Rules for the organigram and election

Spokesperson elected (May 2015)
→ Ties Behnke

Management organization ongoing



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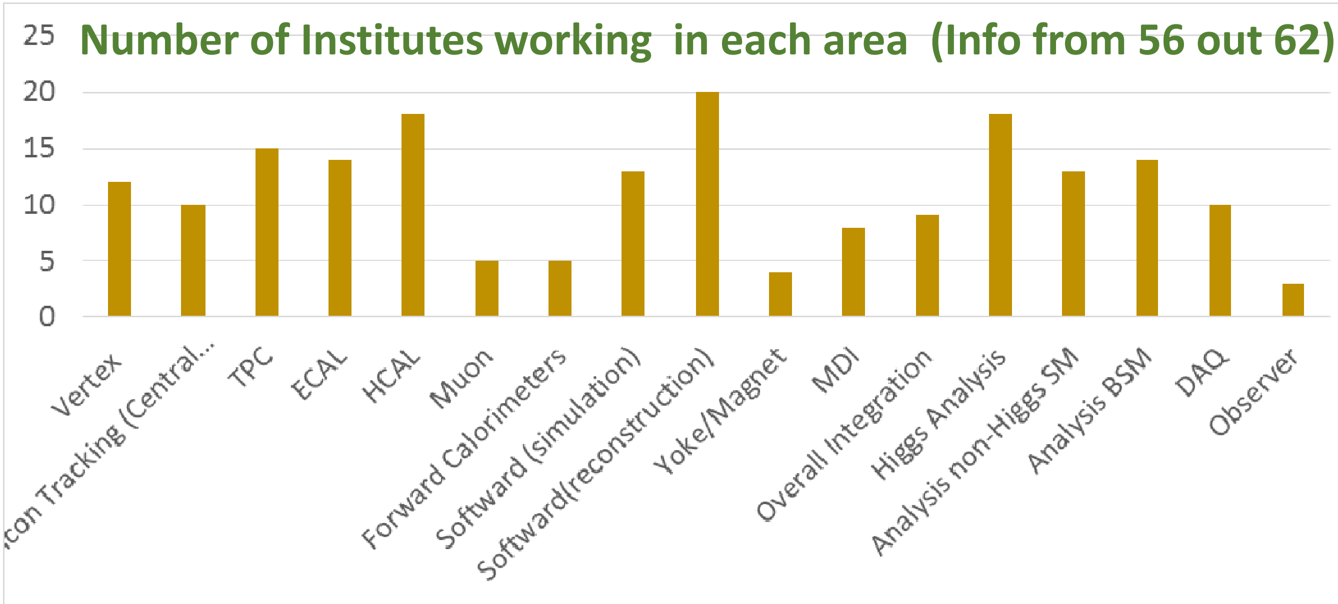
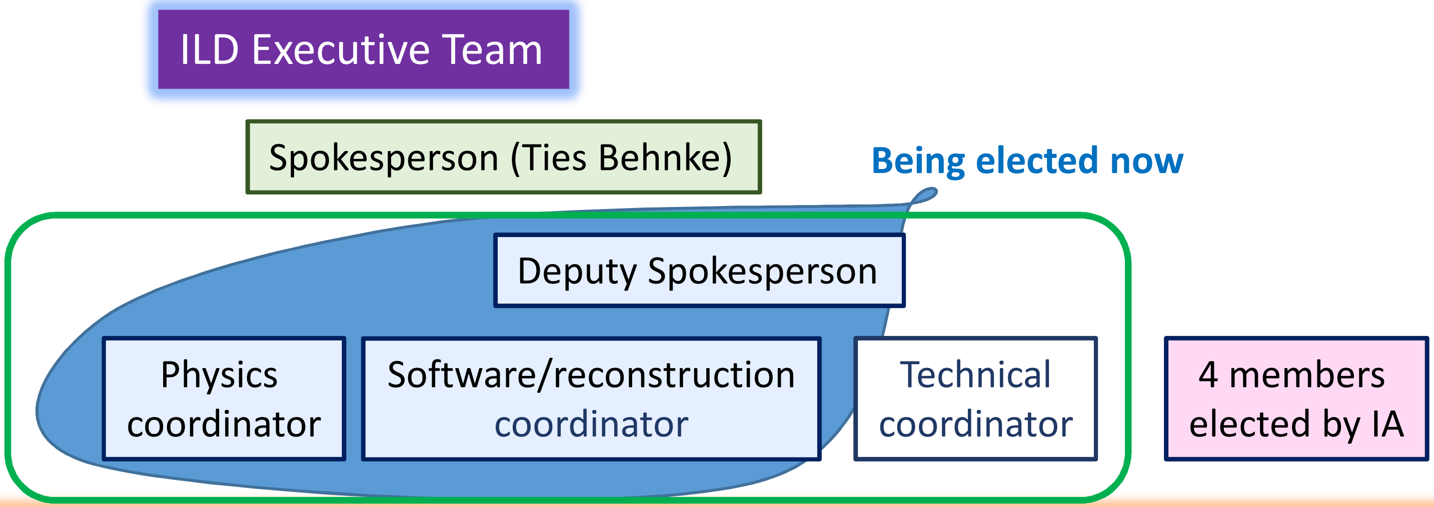


Proposed by the SP
Approved by IA



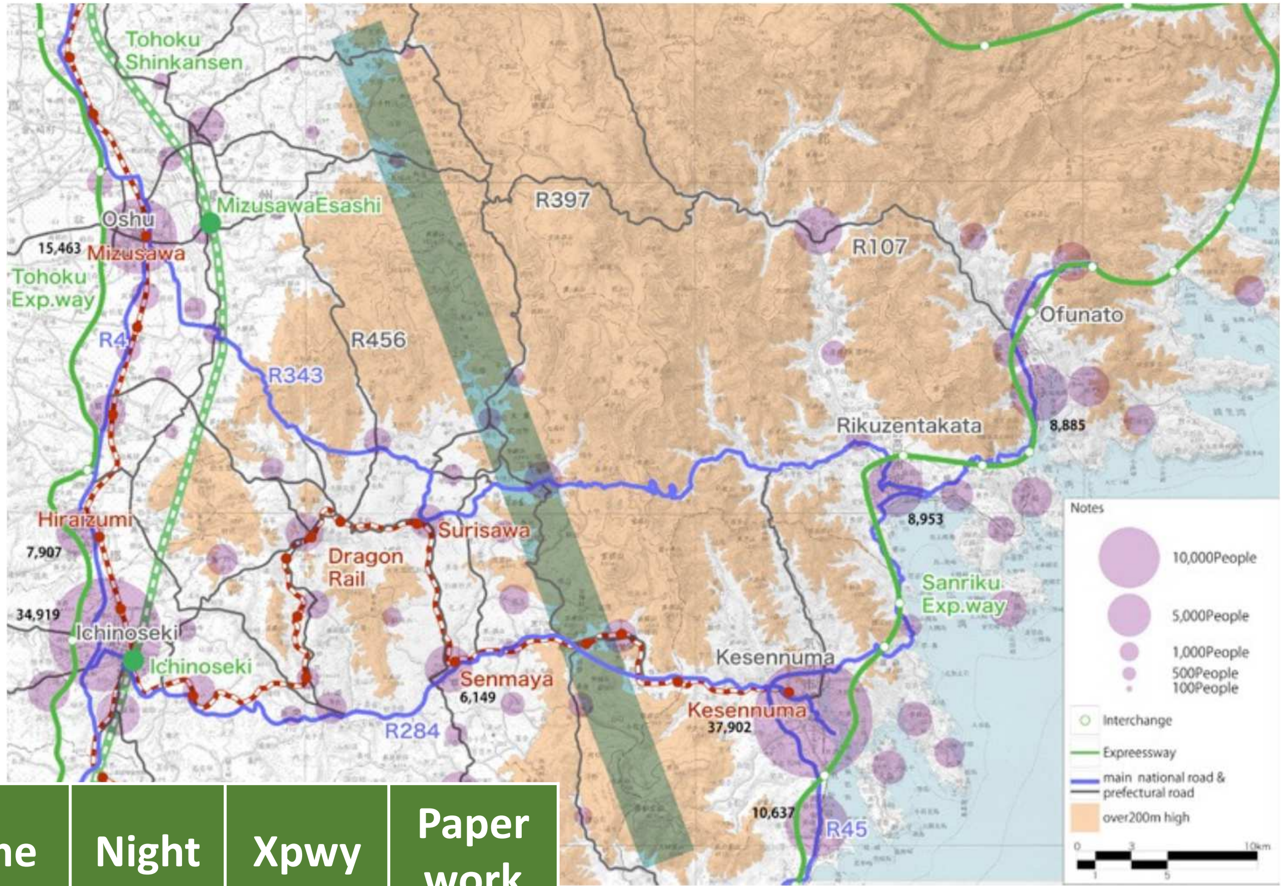
ILD Integration in Kitakami

- Adapt ILD assembly to developing plans of the Kitakami infrastructures
- What can be done at the IP campus?
- What can be done at the central lab campus, ~30km away?
- Requires coordination with subdetector collaborations

Transportation

T. Onuki

KITAKAMI Site: Transportation



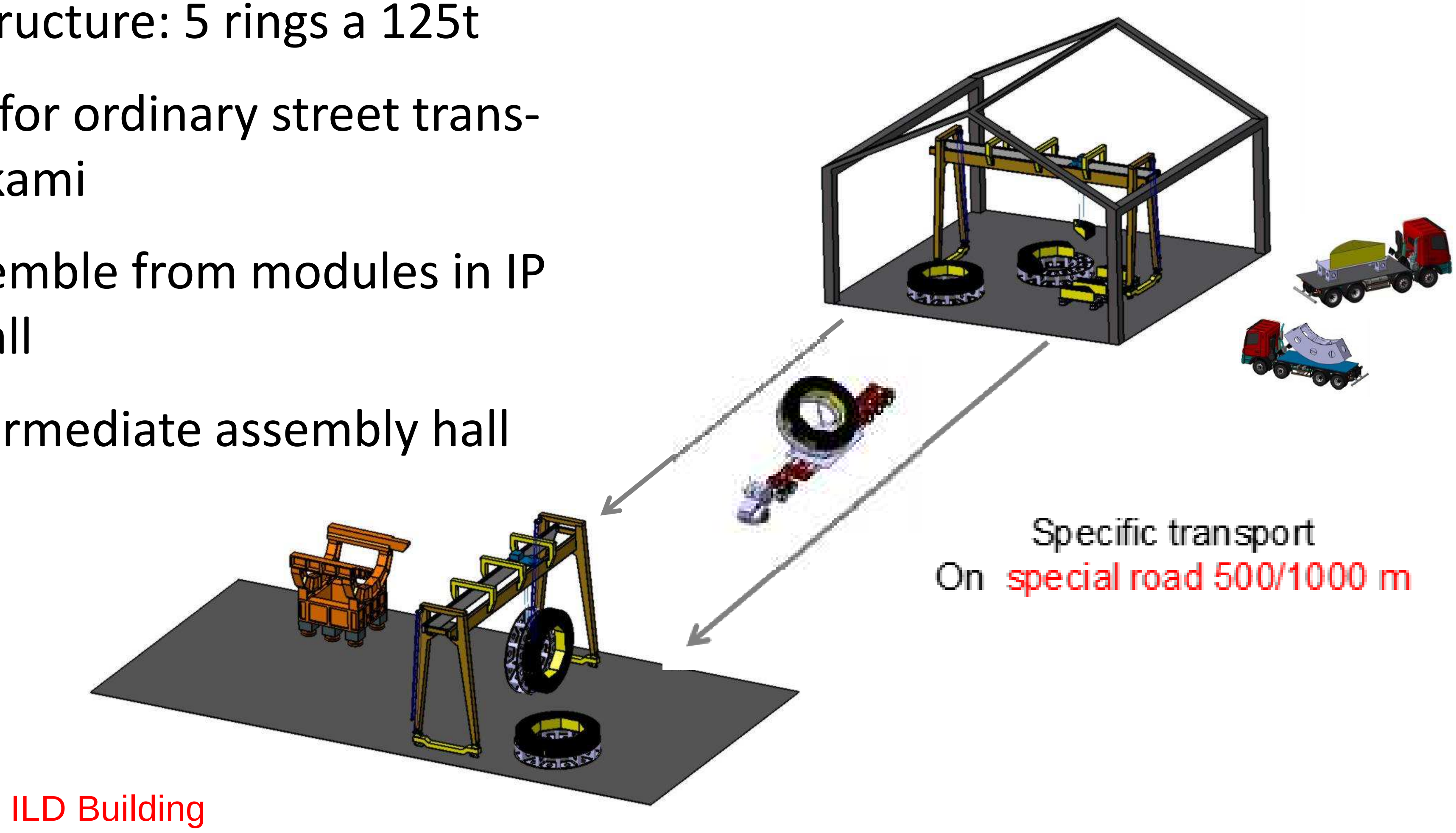
- Limitations on heavy load transports need to be understood
- Important for heavy ILD parts, e.g. magnet and yoke

Total weight	Trailer /track	Our package	Daytime	Night	Xpwy	Paper work
25 ton	~10 tons	~15 tons	YES	YES	YES	0
44 ton	~20 tons	~24tons	YES/NO	YES	NO	1
80 ton	~30 tons	~50tons	NO	YES	NO	10

T. Sanuki

SDHCAL Assembly Study

- SDHCAL structure: 5 rings a 125t
- too heavy for ordinary street trans-port in Kitakami
- either assemble from modules in IP assembly hall
- or use intermediate assembly hall close by
- dedicated road to IP

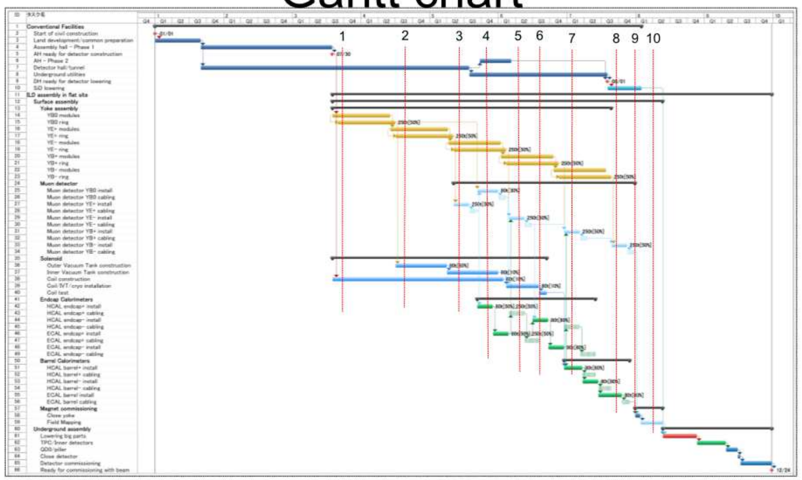


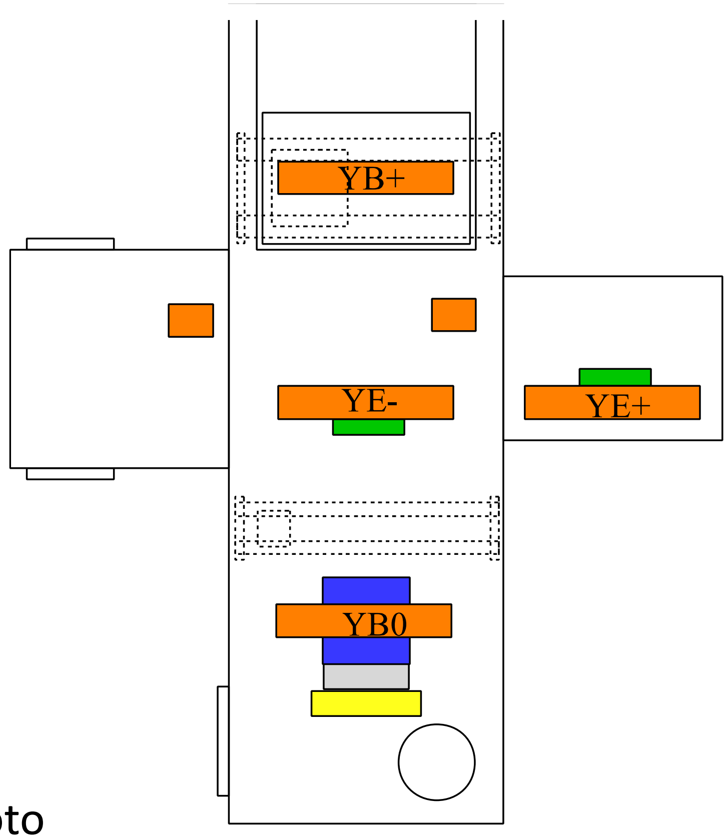
https://agenda.linearcollider.org/event/6829/session/4/contribution/14/material/slides/0.pdf

ILD Infrastructure Requirements and Timelines

- Develop coordinated list of requirements for ILD assembly:
  - assembly space, cranes, clean rooms, etc.
- Define central ILD assembly timeline that includes subdetector dependencies

Gantt chart



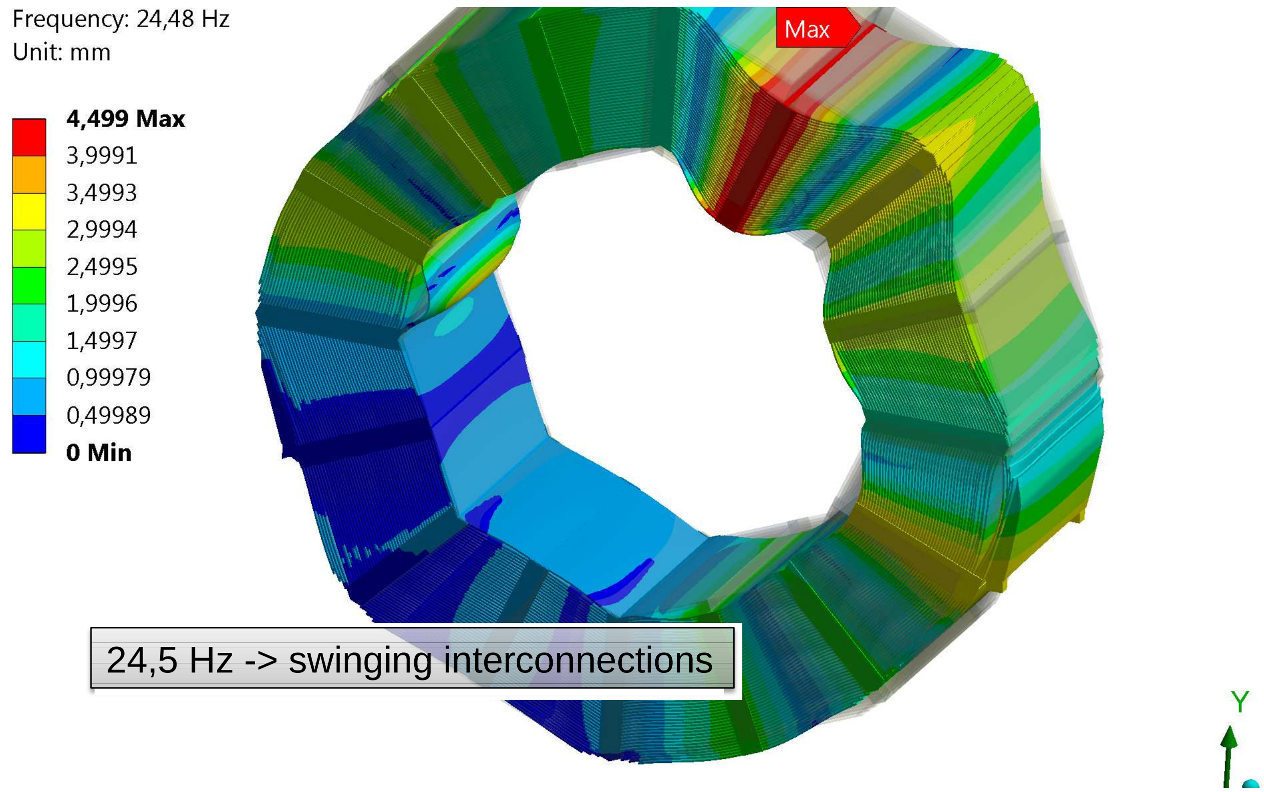


Y. Sugimoto

Seismic Studies: AHCAL

- AHCAL group has started dynamic simulations of structural behaviour with real earthquake data from Kitakami

- Need to understand seismic protection for complete ILD detector during assembly and operations



F. Sefkow

https://agenda.linearcollider.org/event/6829/session/3/contribution/12/material/slides/1.pdf

ILD Optimization

Redesign ILD to **optimize the performance and reduce the cost** taking into account the physics goals we want to achieve. **For achieving the physics goals**, **what do we need?**

Good Detectors + **Good reconstruction tools**

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The reconstruction tools are not only needed for the future analysis but they are need NOW since they play a crucial role on the evaluation of the performance of the detector and on its optimization.

It is crucial to understand all aspects of our **simulation and reconstruction software** in order **to take good decisions** on the detector design.

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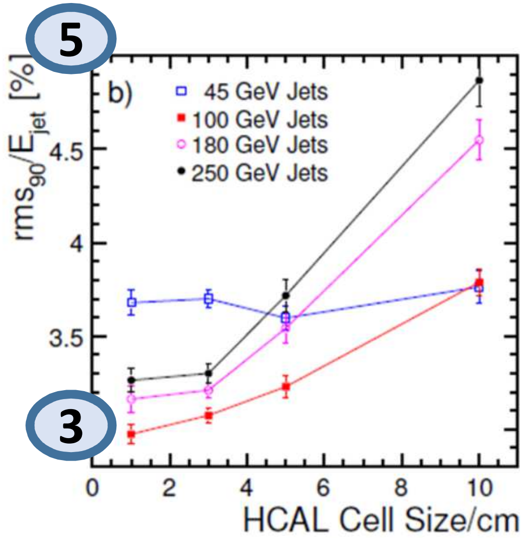
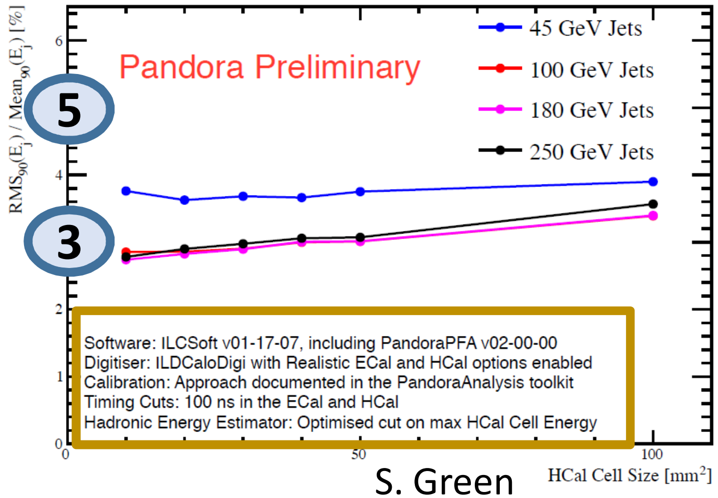


OLD ↔ NEW

Changes

- **Pandora version**
- **Timing cuts**
- **Digitizers**
- **Hadronic E truncations**
- **Calibration**



S. Green

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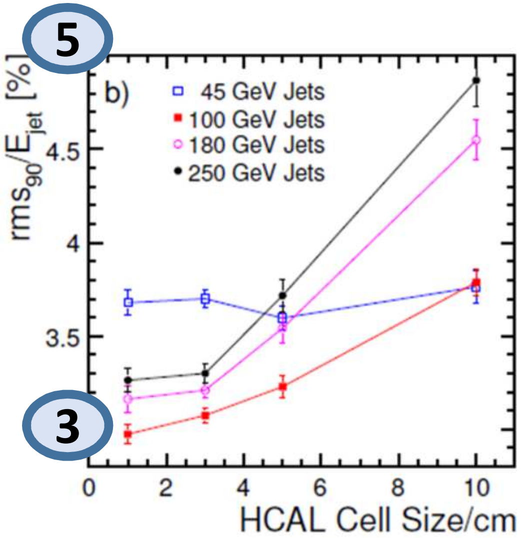

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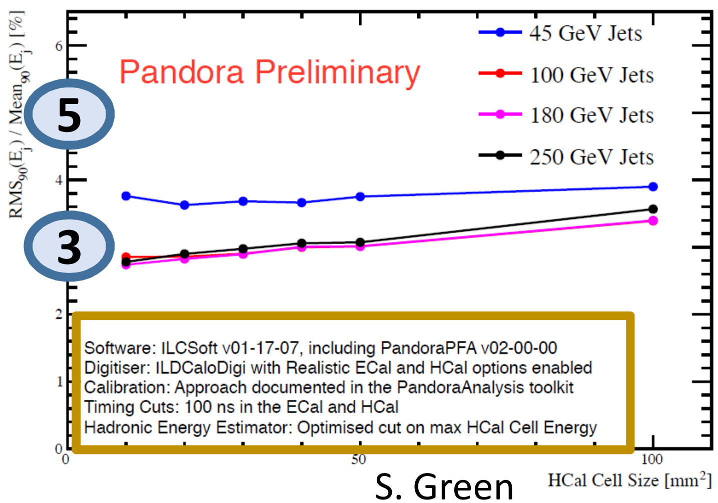


S. Green

Important developments on reconstruction are going on

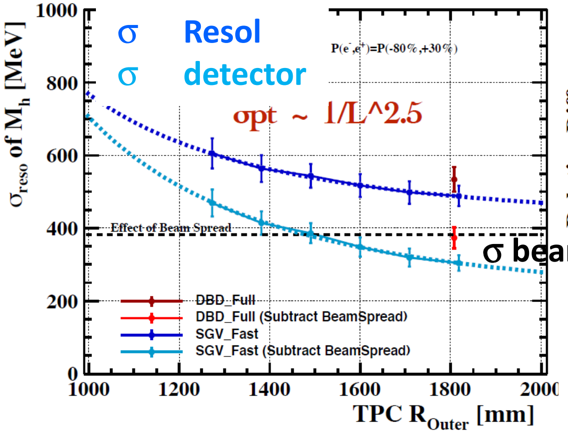
A High Level Reconstruction Week took place at DESY on 6-10 July 2015

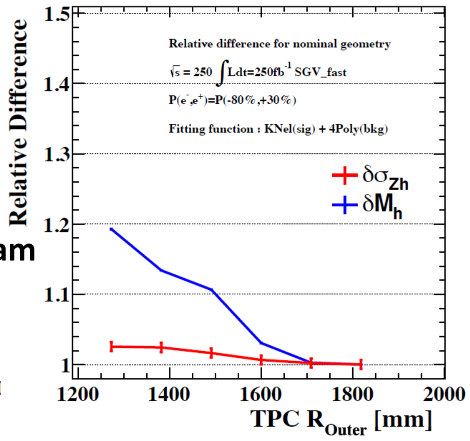
Different studies has been performed or are going on for different subdetectors, in particular changing sizes

ILD Optimization – Impact of TPC radius

Ciemat

250 GeV L=250fb^{-1}





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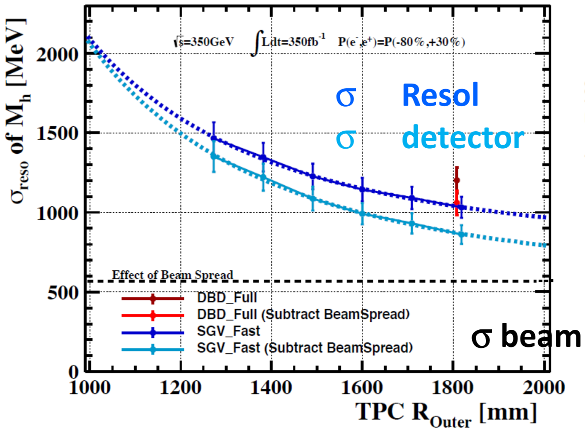
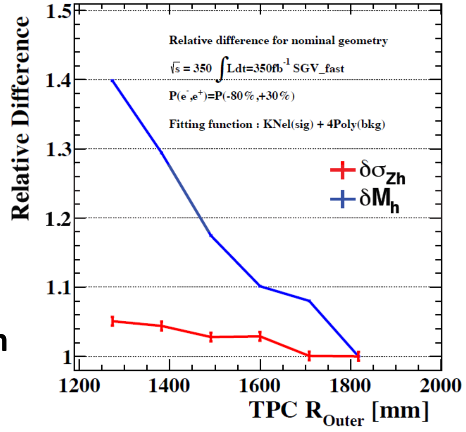




T. Owaga

Degradation (R:1.8 m ➔ 1.4m)

σ_resolution : ~10%
σzh precision: < 5%
Mh precision: ~12%

26% more data needed to recover nominal precision

Degradation (R:1.8 m ➔ 1.4m)

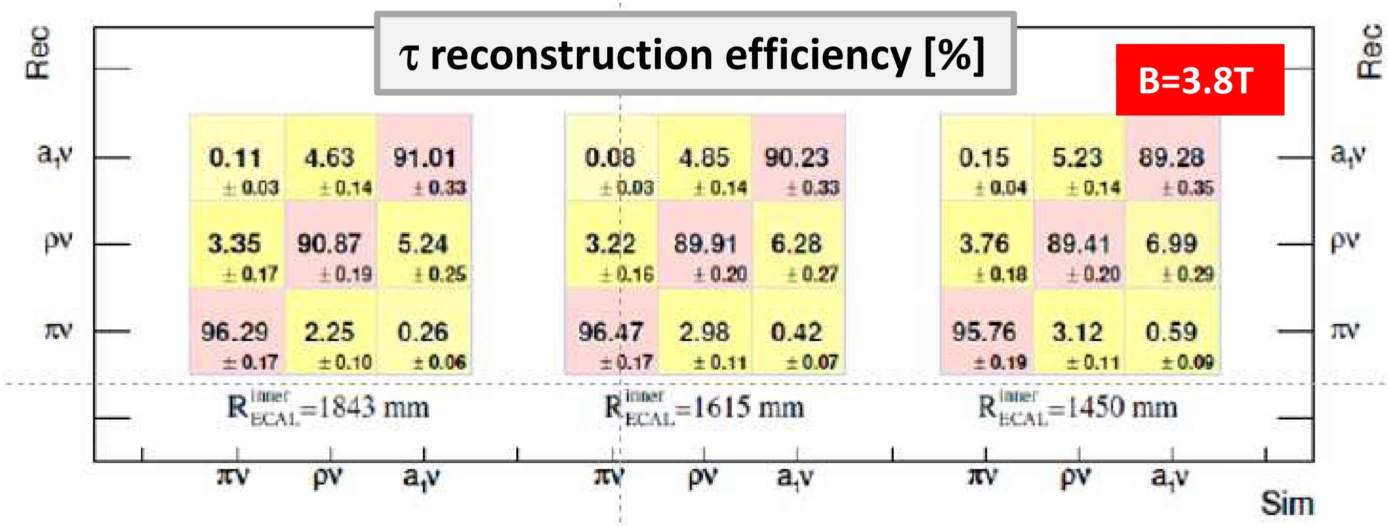
σ_resolution : ~25%
σzh precision: > 5%
Mh precision: ~30%

69% more data needed to recover nominal precision

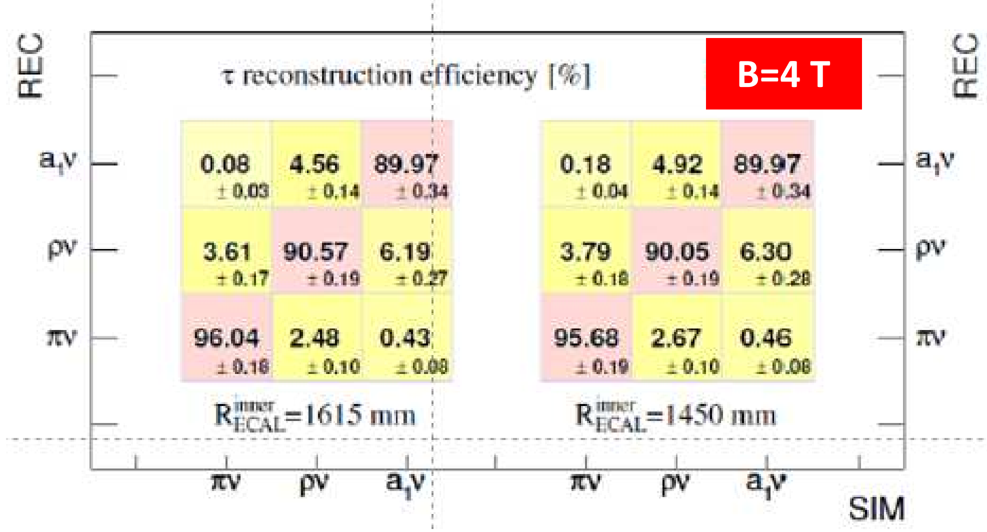
Degradation (R:1.8 m ➔ 1.6m) Mh precission ~4%

Degradation (R:1.8 m ➔ 1.6m) Mh precission ~10%

ILD Optimization – Impact of ECAL radius



If **B is increased** similar performance for smaller detector



The slight improvement of the efficiency **does not justify the increase of B**

T.H. Tran
arXiv:1510.05224

ILD optimization – AHCAL Cell Size Optimisation and Software Compensation

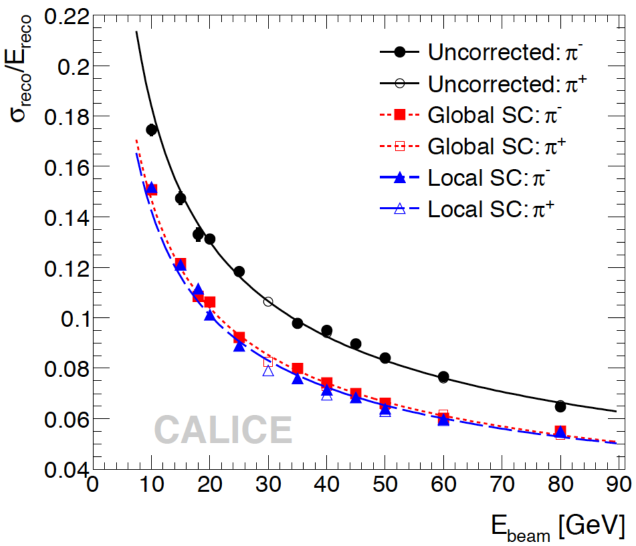
- **Cell size dependence apparently reduced compared to results from LoI:**
  - HCAL cell energy truncation degrades resolution at high energy for high cell size
  - But: improve energy resolution at smaller energy

➢ Idea of cell energy truncation mimics software compensation

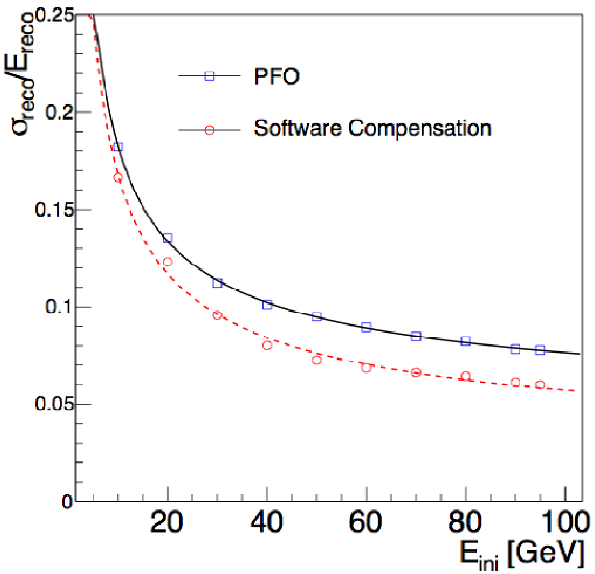
➢ Software compensation can do better and must be applied properly

- **Software compensation techniques** used in CALICE gave **strong improvements** on single hadron energy resolution by **20%** in energy range from 10 to 80 GeV

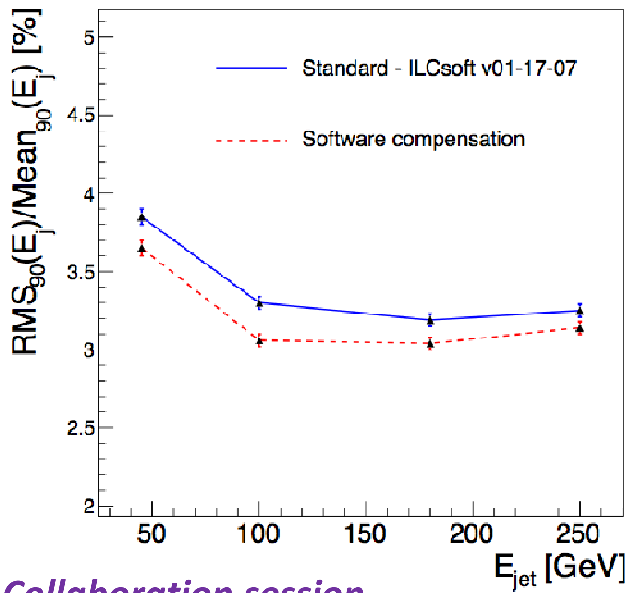
Now implemented in latest **Pandora** version



Testbeam results reproduced



Improvement also at jet level



See also talk from Lan Tran Huong. Pandora and its impact in ILD optimization @ ILD Collaboration session

Physics Analysis at ILD

Many Physics Analysis are ongoing , and some will be presented at this conference:

HIGGS

- **Leptonic recoil - J. Yan (KEK)** full investigations at 250, 350 and 500 GeV, left right beam polarisations, model independence
- **Self-coupling - M. Kurata (Tokyo U')** combined HH—>bbbb (by C.Duerig) and HH—>bbWW*, improvement from kinematic fitting
- **Top-Yukawa coupling - Y. Sudo (Kyoshu U')** improved isolated lepton (w/ tau) finder, new jet pairing, new high stat 6f
- **Anomalous HVV coupling - T. Ogawa (KEK & Sokendai)** full investigation of HZZ coupling, significantly higher sensitivity than snowmass study (by theorist)
- **Higgs mass using H—>bb - A. Ebrahimi (DESY)** new study, has big impact on running plan at 250 GeV
- **BR of H—>μμ - M. Faucci (RHUL)** revisit (previously by C.Calancha), employ latest rec/ana algorithm

BSM

- **Stau co-annihilation at LHC & ILC - M. Berggren (DESY)** joint study of STC model with colleagues from CMS, arXiv: 1508.04383
- **SUSY mass meas. from kinematic edge - M.Chera (DESY)** update of Point5 study with focus on advanced methods to determine the edge positions / masses (finite response filters, calibration etc)
- **Monophoton WIMP search - T. Tanabe (Tokyo U')** update of LoI-time study by C.Bartels, in particular impact of Bhabha veto efficiency (new BeamCal reconstruction), photon reco (newest Pandora), impact of beam spectrum, improved ISR treatment etc

SM/Systematics

- **Modelling of γγ—>low-pt hadrons - S. Sasikumar (DESY)** generator- and detector-level study

TOP

- Electroweak top couplings - Experimental Status - **R. Poeschl (LAL)**
- Measurements of top-couplings using full leptonic final states - **R. Le Diberder (CNRS/IN2P3/LAL)**
- Top Threshold – Experimental status – **F.Simon (Max-Plank-Institut fuer Physik)**

Reconstruction

- **Tau reconstruction - D. Jeans (Tokyo U')** new novel algorithm using impact parameter, to be used in Higgs CP

Higgs CP mixture study

The Higgs CP mixture study includes **two complementary analysis** using

→ **anomalous HVV coupling** (**Higgs CP odd contribution comes via loop correction**, **small but HVV coupling most precisely measured**)

→ **Hff coupling** (**Direct tree level contribution**, but **statistically limited** and **tau decay plane reconstruction not trivial**)

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Meanly Hττ coupling

Significant work on:

- **Novel τ reconstruction using impact parameter**
- **τ decay mode separation**

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Ciemat

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Traditional reconstruction method for **hadronic τ decays assume the $\tau\tau$ center of mass and invariant mass are known No precise IP knowledge. Limitation if there is unseen ISR**

Another method use **"collinear approximation" ν || visible tau jet Limitation if τs are back to back**

New method: **no assumption on $\tau\tau$ center of mass and invariant mass or ISR/beamstrahlung. It needs precise knowledge of IP (resol ~10μm) and not extra ν in event**

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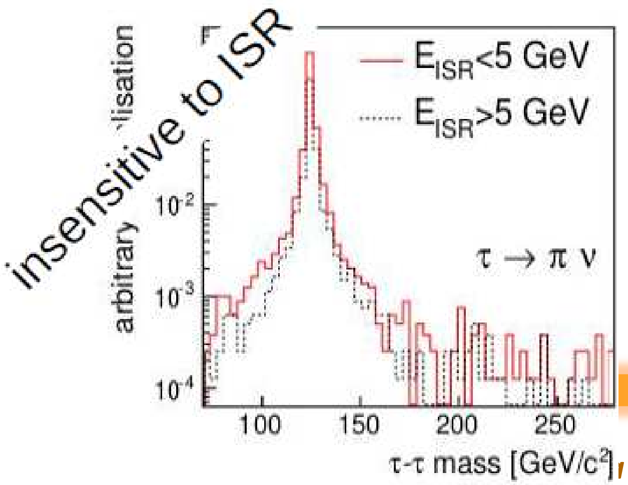
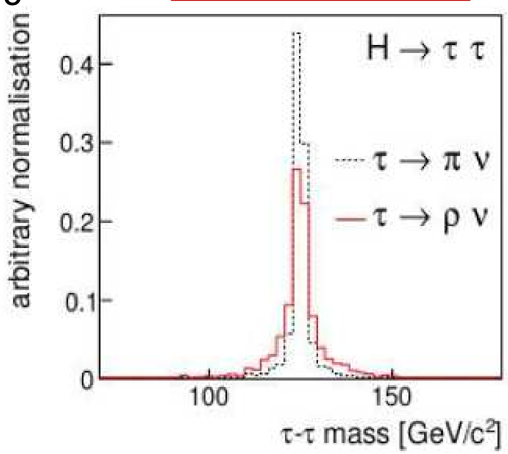
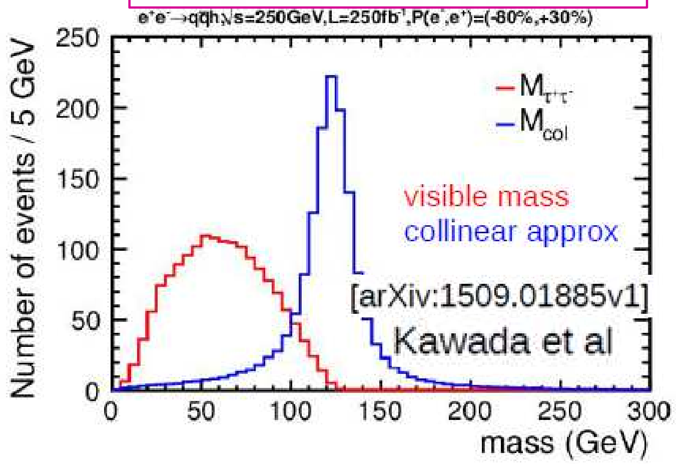


arXiv:1507.01700
D.Jeans

New method



Collinear approximation



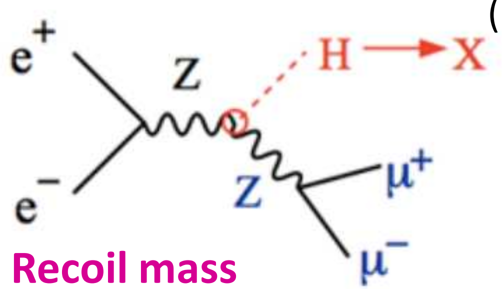
Model independent measurement of recoil mass and absolute Higgs cross section

Ciemat

A pair of isolated energetic leptons (μ/e) with invariant mass close to Z mass

(bkg: ZZ, gZ, WW→$l^+l^-\nu\nu$)

J.Yan, J.Tiang, H. Fujii



Recoil mass

$$M_X^2 = (p_{CM} - (p_{\mu^+} + p_{\mu^-}))^2$$

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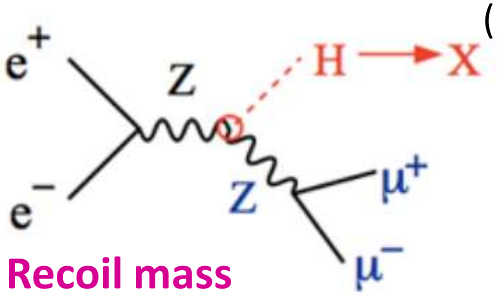

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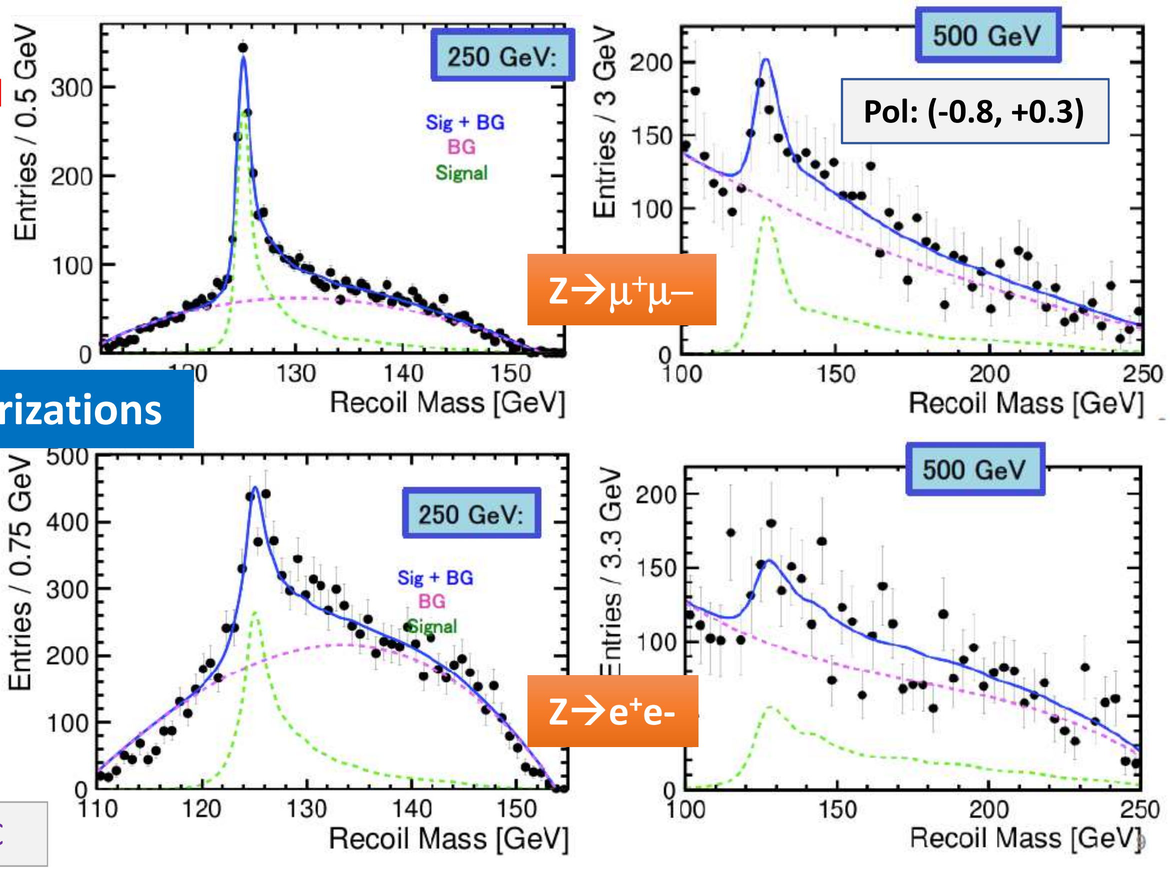

Consistent analysis for all center of mass & polarizations

Precision scaled to the full H20 scenario
Z→μ+μ− and Z→e+e- combined

Cross section: **0.89%**
Mass: **11.8 MeV**

TDR	
	2.5%
	32 MeV

Paper draft of Leptonic Higgs Recoil Analysis at the ILC

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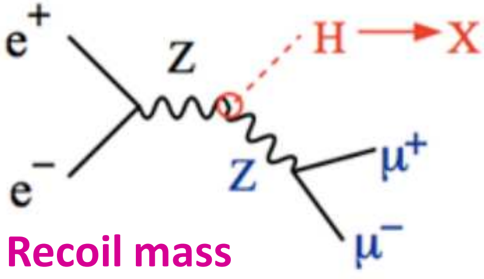

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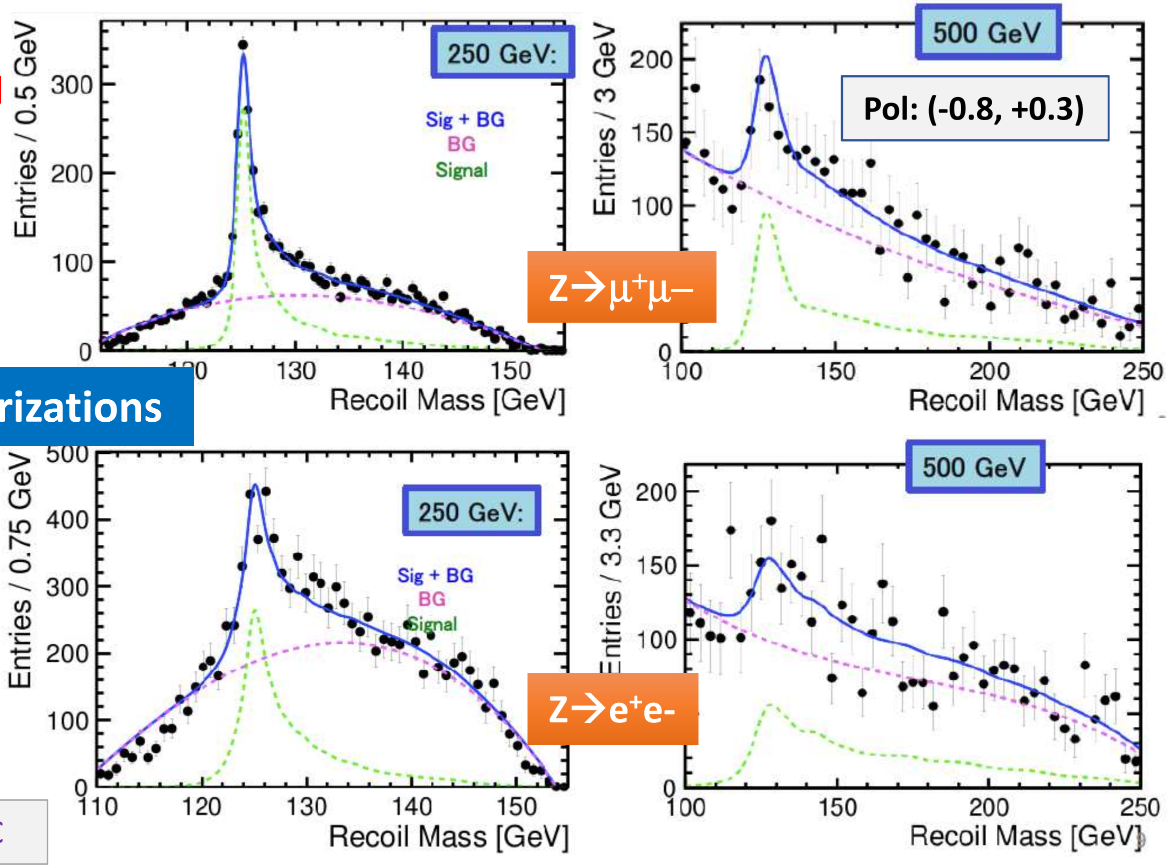

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It has been also proven that, even for **hadronic recoil,** the cross section doesn´t depend strongly on the H decay and is possible to make a **model independent measurement of** g_{HZZ} **from the recoil mass.**

M.A. Thomson. arXiv:1509.02853v1

Light Higgsinos studies

Scenario

3 light Higgsinos: $\tilde{\chi}_1^{\pm}$ $\tilde{\chi}_1^0$ $\tilde{\chi}_2^0$

Almost mass degenerate $\Delta M(\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^0)$ & $\Delta M(\tilde{\chi}_2^0, \tilde{\chi}_1^0)$

All other SUSY particles are heavy. Up to few TeV

dm770

Mass Spectrum	
Particle	Mass (GeV)
h	127
$\tilde{\chi}_1^0$	166.59
$\tilde{\chi}_1^{\pm}$	167.36
$\tilde{\chi}_2^0$	167.63
H's	$\sim 10^3$
$\tilde{\chi}$'s	$\sim 2-3\times 10^3$

$\Delta M(\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^0) = 0.77$ GeV !

Processes

$e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^-$

$e^+e^- \to \tilde{\chi}_1^0\tilde{\chi}_2^0$

$\tilde{\chi}_1^{\pm} \to \tilde{\chi}_1^0 W^{\pm *}$

$\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 Z^{0*}$

$\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \gamma$

Semileptonic decays

$BR(\tilde{\chi}_1^{\pm} \to \tilde{\chi}_1^0\, \pi) \approx 60\ \%$

$BR(\tilde{\chi}_1^{\pm} \to \tilde{\chi}_1^0\, \mu^- \nu_\mu) \approx 13\ \%$

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μ and π final state particles are **very soft p_T <2 GeV**. **μ and π separation** plays an **important role** in the analysis

The μ stops in the calorimeters and are confused with π. Pandora doesn´t work for the separation at so low momentum

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All other SUSY particles are heavy. Up to few TeV

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$\tilde{\chi}$'s	$\sim 2-3 \times 10^3$

$\Delta M(\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^0) = 0.77$ GeV !

Processes

$e^+e^- \to \tilde{\chi}_1^+ \tilde{\chi}_1^-$

$e^+e^- \to \tilde{\chi}_1^0 \tilde{\chi}_2^0$

$\tilde{\chi}_1^{\pm} \to \tilde{\chi}_1^0 W^{\pm *}$

$\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 Z^{0*}$

$\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \gamma$

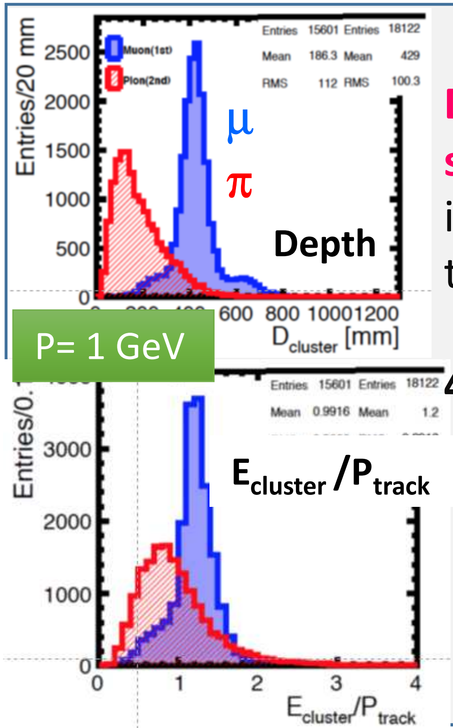
Semileptonic decays

$BR(\tilde{\chi}_1^{\pm} \to \tilde{\chi}_1^0 \pi) \approx 60\ \%$

$BR(\tilde{\chi}_1^{\pm} \to \tilde{\chi}_1^0 \mu^- \nu_\mu) \approx 13\ \%$

μ and π final state particles are **very soft p_T <2 GeV**. **μ and π separation** plays an **important role** in the analysis

The μ stops in the calorimeters and are confused with π . Pandora doesn´t work for the separation at so low momentum



Differences between shapes of μ and π clusters in the calos can be used to separate them.

4 cluster variables used:

- **Depth**
- **$E_{cluster}$ / P_{track}**
- **Radius distribution**
  - **Mean & RMS**

Light Higgsinos studies

Scenario

3 light Higgsinos: $\tilde{\chi}_1^{\pm}$ $\tilde{\chi}_1^0$ $\tilde{\chi}_2^0$

Almost mass degenerate $\Delta M(\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^0)$ & $\Delta M(\tilde{\chi}_2^0, \tilde{\chi}_1^0)$

All other SUSY particles are heavy. Up to few TeV

dm770

Mass Spectrum

Particle	Mass (GeV)
h	127
$\tilde{\chi}_1^0$	166.59
$\tilde{\chi}_1^{\pm}$	167.36
$\tilde{\chi}_2^0$	167.63
H's	$\sim 10^3$
$\tilde{\chi}$'s	$\sim 2-3\times 10^3$

$\Delta M(\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^0) = 0.77$ GeV !

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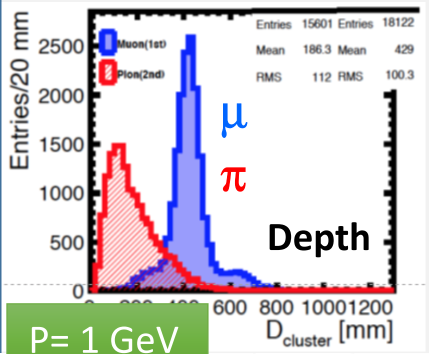

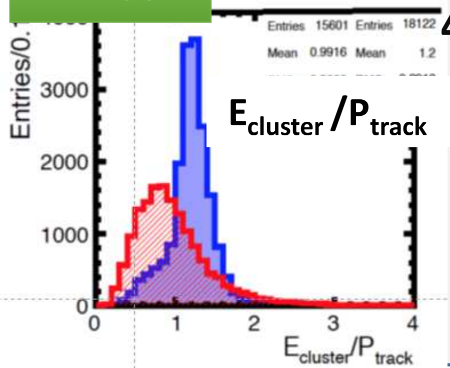

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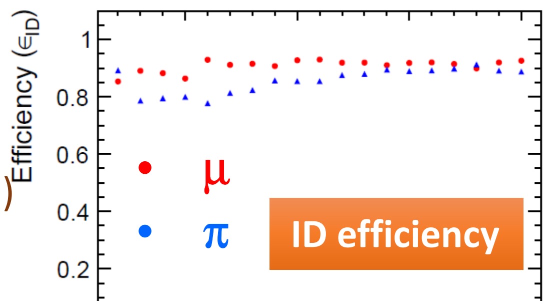
Depth
$E_{cluster}$ / P_{track}
Radius distribution
Mean & RMS

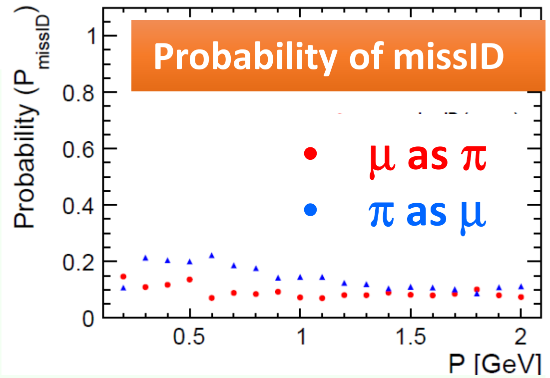
Different TMVA (Toolkit for Multivariate Analysis) **methods compared**

The **best** (based on bkg rejection) was the **BDT** (Boosted Decision Trees)

$\varepsilon_\mu \approx 90\%$

$\varepsilon_\pi \approx 85\%$





H.Sert

Subdetectors developments

Many developments are ongoing (on the R&D itself and directly related to ILD)
Some of them are presented at this conference

Previous talks in this session:

Recent developments in LC calorimeter R&D. D. Jeans (U. Tokyo)
Recent developments in LC vertex/tracing R&D. Dominik Dannheim (CERN)

Talks at ILD sessions

Tracking news in ILD. P. Colas (CEA/IRFU)
Status and news from the ECAL. T. Suehara (U. Kyushu)
Status and news from the HCAL. K. Krüger(DESY)

vertex/tracking parallel sessions and Calorimetry/Muon Systems Tracks sessions

Many talks covering different aspects of the different technologies
"generic" R&D, and/or R&D directly related to ILD

Tracking

Ciemat

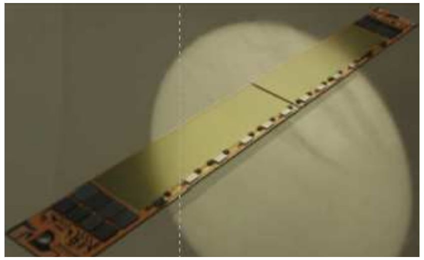
Vertex

3 pixel technologies being developed
Fine Pixel CCD (FPCCD), DEPFET , CMOS

Synergy with other experiments.
Specific developments for other experiments can serve to demonstrate the feasibility for ILD

DEPFET (BELLE-2 PXD)

- **1st complete ladder functional (50x55/85 μm^2 pixels)**
- **PXD9 pilot production of sensors : yield assessed**



CMOS (ALICE- ITS & CMB-MVD)

- **ALICE- ITS final prototypes 5μm & 4μs demonstrated**
  ➔2-Side ILD ladder concept with 1-2 μs time stamping achievable.
- **Chips fabricated and tested this year demonstrate that we can envisage a tracker based on large CMOS pixels**

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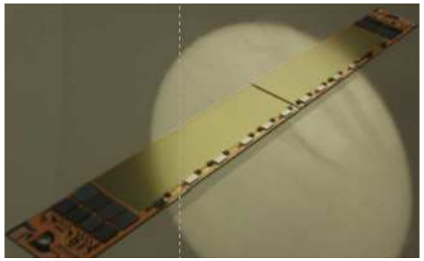

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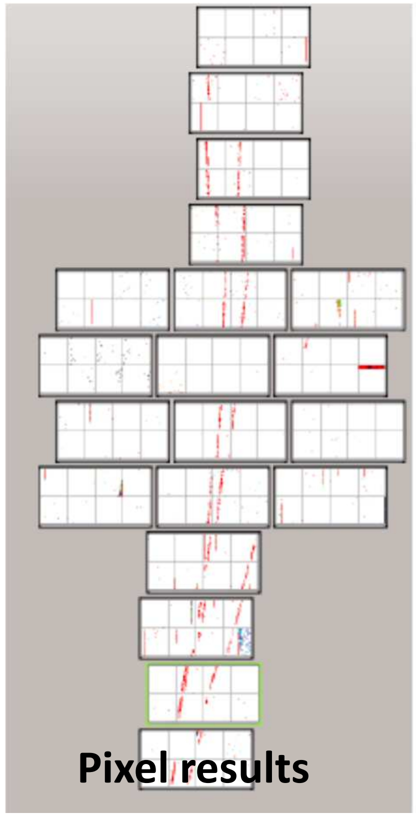
TPC

Some goals: $\delta(1/p) < 10^{-4}GeV^{-1}$ for TPC, $\delta(dE/dx)<5\%$, material X_o~5%rad, 25%longit.

Teststand 1T magnet in T24/1 beam @ DESY



GEM, Micromegas, or **Pixel Prototypes** (17 x 22cm^2) fit into endplate

See more details in Paul Colas' tracking talk at the ILD meeting on Thursday.

Forward Tracker

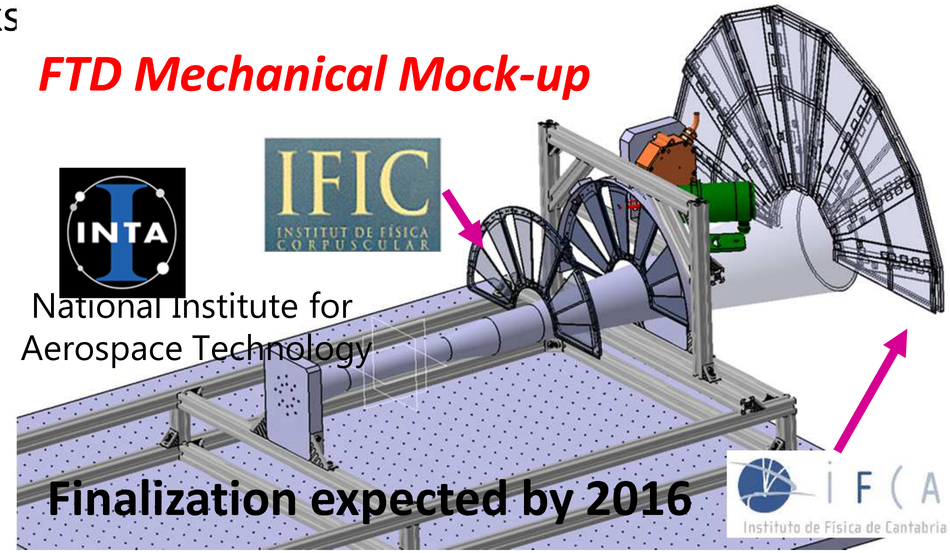
Developments in several areas: Covered in different talks

- R&D on several Silicon detector options
- Cooling
- Assembly and integration
- FTD mechanical mock-up
- Material budget

FTD mechanical mock-up

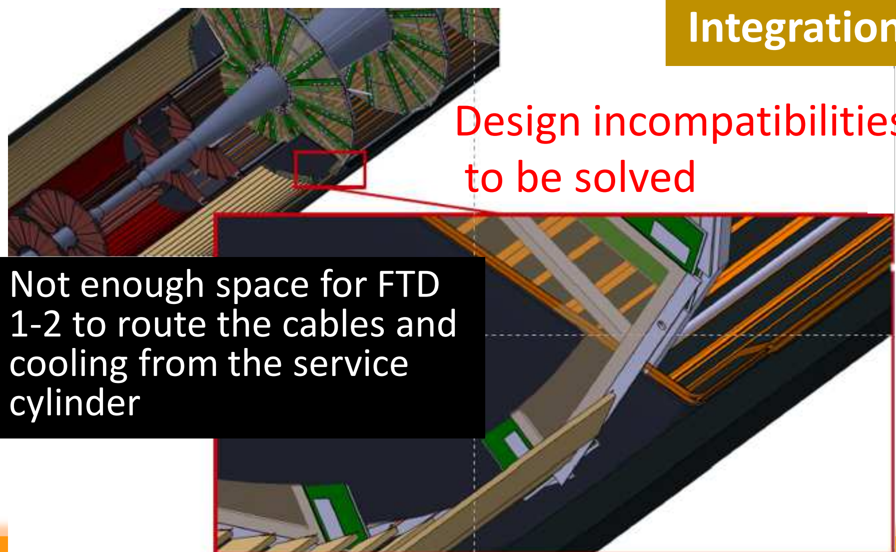
Important work in a complicate area

FTD Mechanical Mock-up

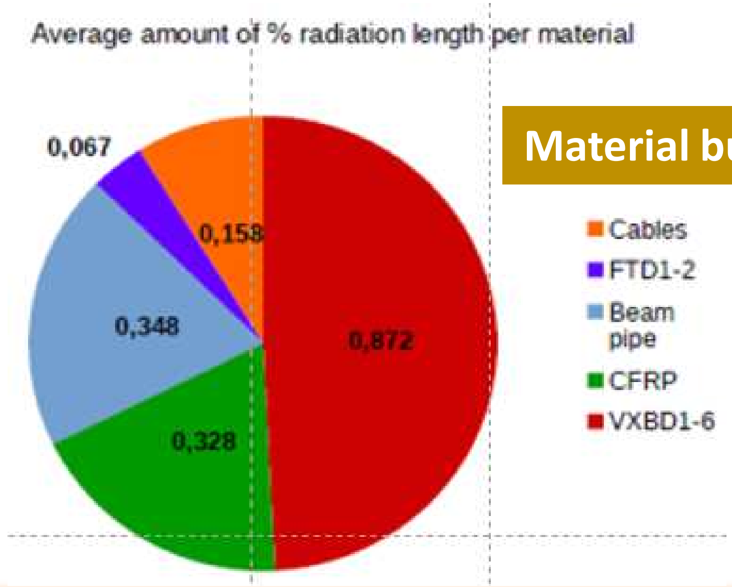


Allow to test air recirculation, sensors deformation & cooling, new materials and their properties, assembly process , cabling and cooling rooting and design incompatibilities

Integration



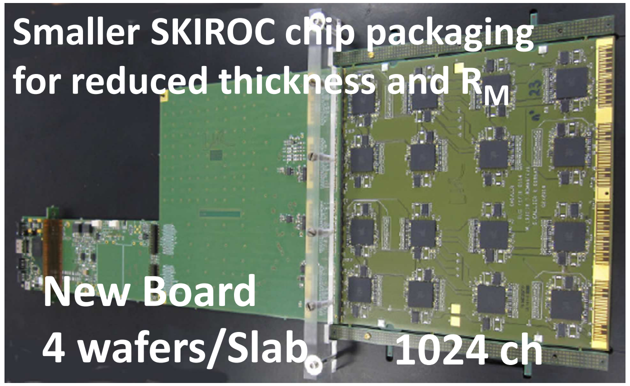
Material budget



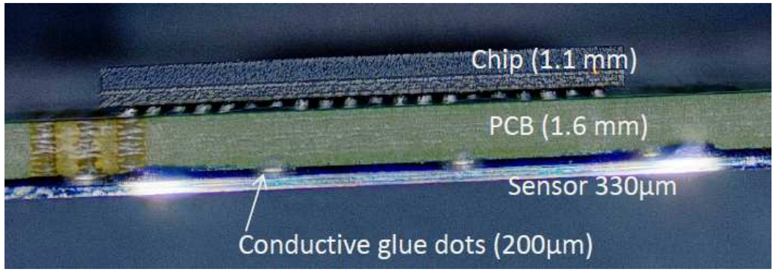
Silicon-Tungsten ECAL

Ciemat

Absorber: **Tungsten**
Detector: **Silicon sensor**
Embedded electronics



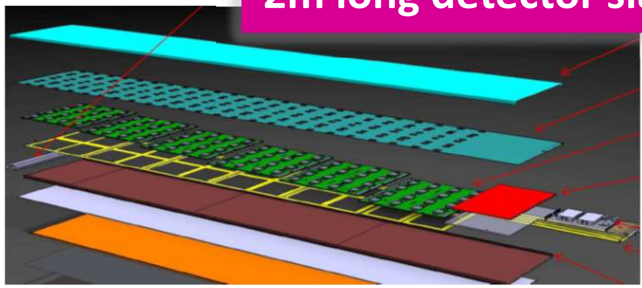
PCB planarity ≤ 400 μm
Precise robotic gluing of sensor (20 μm precision)

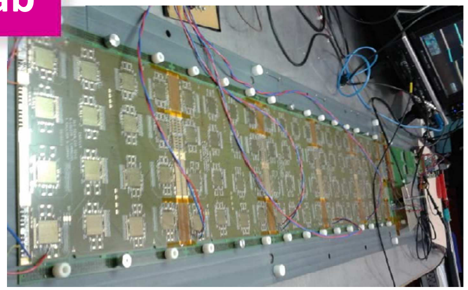


Synergy with CMS-HGCAL project → SPS test beam 4-16 Nov.
Radiation tests ongoing

4 Slabs + "baby"
3x3 or 4x4 cells

2m long detector slab





FE boards chained forming up to **2m** long detector SLAB → **Full size ILD detector slab**

4 short SLABs being assembled at LAL
1 long SLAB to be tested in 2016

Cost optimization (options)
• "Smaller ILD" → performance study
• Hexagonal sensor → integration
• 8-inch, 700μm wafer → LFoundry
• Partial usage of scintillator (hybrid ECAL)

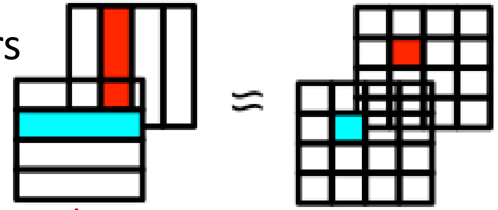
Design optimization
• No guard-ring → tabletop OK → TB
• Thickness → 500 μm tested → TB

Scintillator ECAL

Absorber: **Tungsten**
Detector: **Plastic scintillator strips**
Readout: MMPC

Odd layers orthogonal to even layers
→ 1x1cm^2 effective granularity

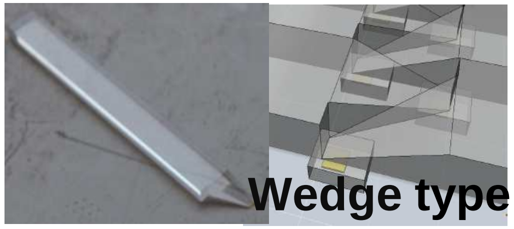
Less readout channels than using pixels
but shower reconstruction more complicated

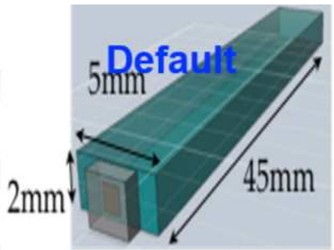


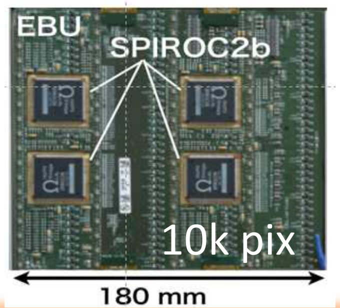
CERN Beam test Aug.2015

3 EBUs : Transverse + Longitudinal + Transverse
10 K pixels **10 K pixels** **1600 pixels** **/ 1×1mm^2**

Bottom readout **Baseline readout**

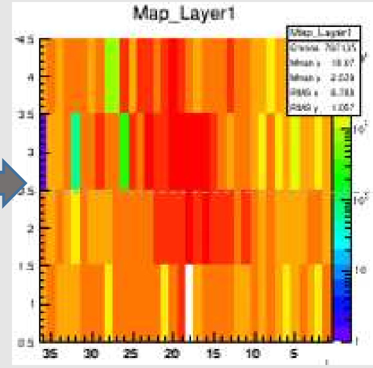




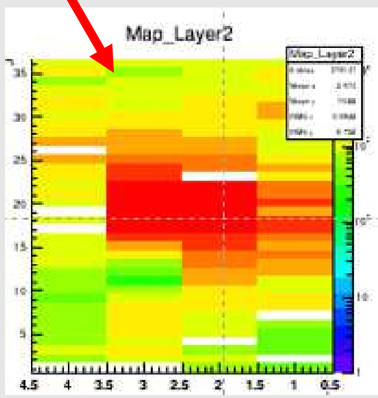


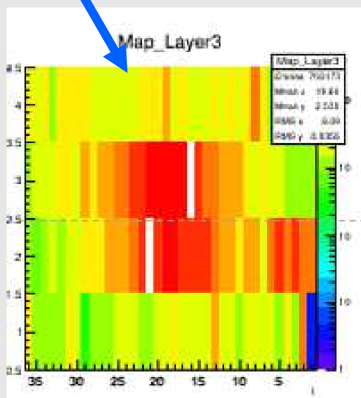
Test beam data

First layer
a bit noisy



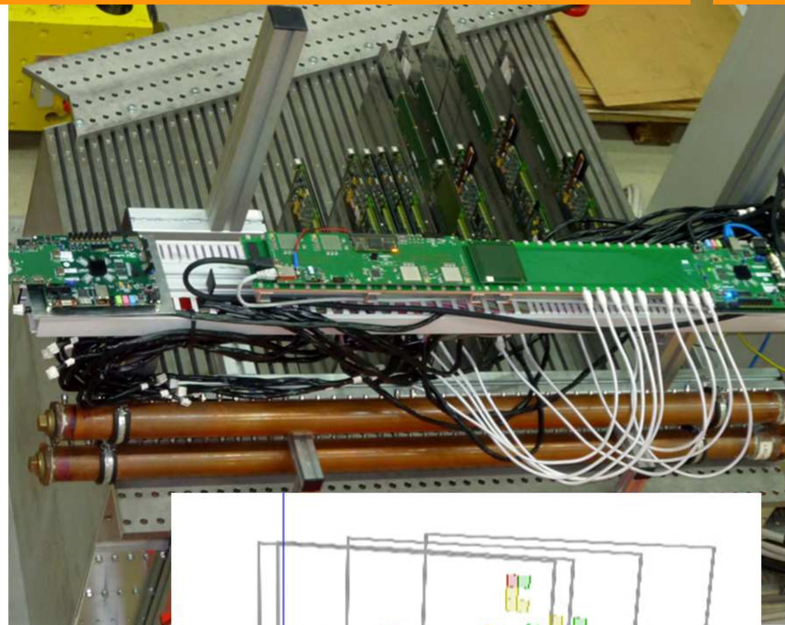
2nd & 3rd layers O.K
Longitudinal & **transverse** info available

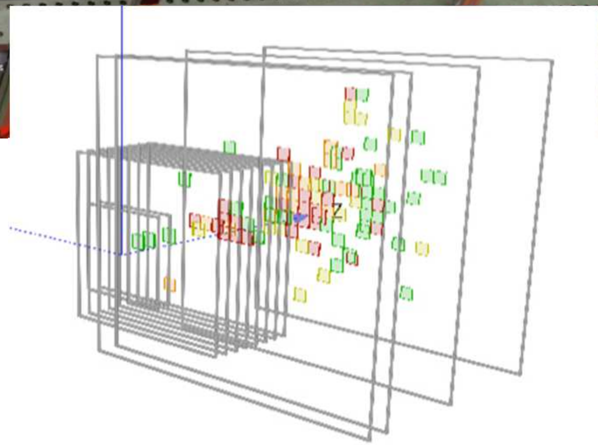




Analog Hadronic Calorimeter (AHCAL)

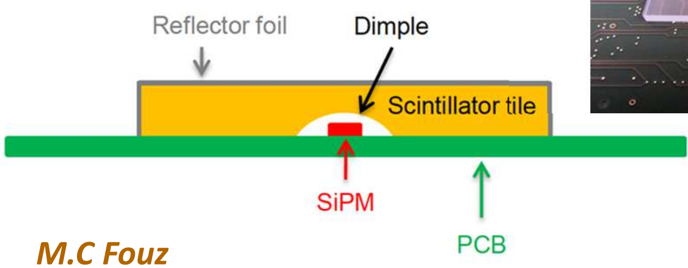
Absorber: **Steel** (2 cm)
Detector: **Plastic scintillator** (3x3 cm2)



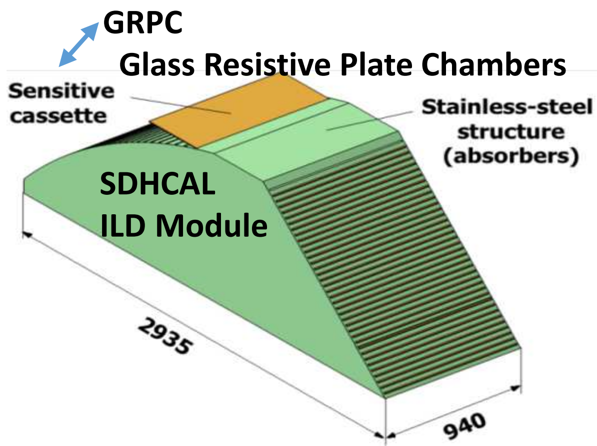


- 4 weeks testbeam at SPS in 2015
  - first SPS test beam with 2nd generation electronics and DAQ
  - successful demonstration of the system integration (DAQ, power etc)
- established electronics design with surface mounted SiPM and automated assembly
- latest generation SiPMs has dramatically improved performance
  - Very good device-to-device uniformity
  - practically noise-free

R&D on using scintillator strips is also ongoing
Odd layers orthogonal to even layers



Semi-digital Hadron Calorimeter (SDHCAL)



Absorber: **Stainless Steel** (2mm)

Sensor: Glass Resistive Plate Chambers (**GRPC**)

Readout: **$1x1cm^2$ pads, semi-digital readout** with **3 thresholds**.

A ~1m3 prototype validated the technology as appropriate for the ILD : good resolution and high track capabilities

See also M.C Fouz´s talk: Technological SDHCAL prototypes for future lepton colliders @ Wednesday Calorimeter session

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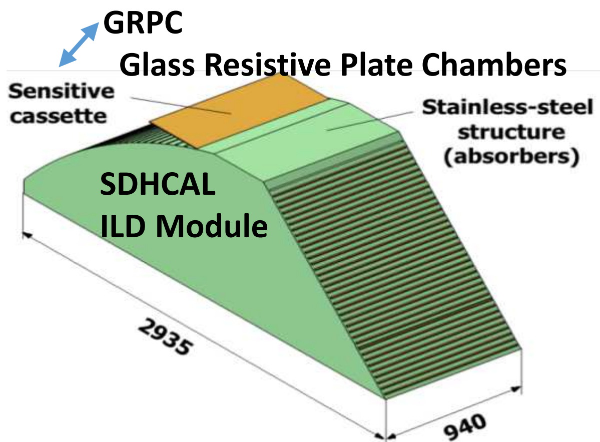

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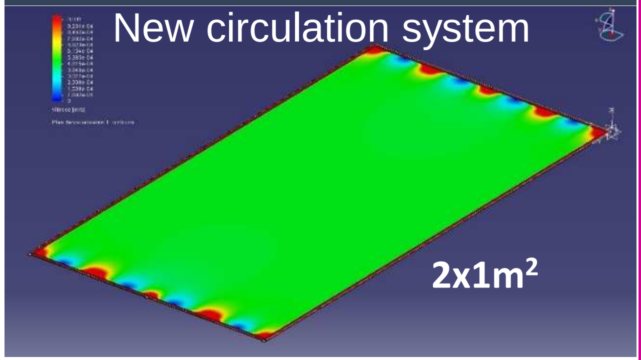
NEW PROTOTYPE MAIN GOALS

- Build a **few large GRPC** with the final dimensions foreseen for ILD
- Equip the GRPCs with a **new version of the electronics being developed**
- Design and build, with the same procedures as the final one, an **absorber mechanical structure capable to host up to 4 large GRPC ($290x91m^2$)**

The most important issue for the GRPC going from $1x1m^2$ to 2x1 or $3x1m^2$ is the homogeneous gas circulation design



Electronic Developments

New version of ASIC – HADROC3
Readout chip

New PCB design
PCB host ASICs and readout pads

New DIF (Detector InterFace)
DIF interconnects PCB-ASICS with the DAQ (slow control,power pulsing,readout)

Mechanics

1m3 prototype **assembled** with bolts now electron beam welding (EBW).

Tests with small prototypes look reasonable but need optimization to reduce deformations

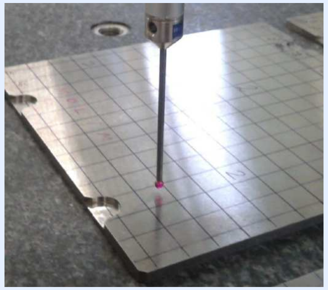
Plates planarity <1mm required
Achieved using roller leveling

See also M.C Fouz´s talk: Technological SDHCAL prototypes for future lepton colliders @ Wednesday Calorimeter session

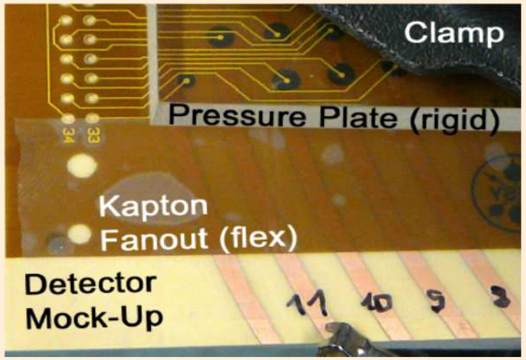
FCAL: BeamCal & LumiCal. Recent developments

Baseline: Tungsten sandwich calorimeter with small Moliere radius

Sensors: Silicon (LumiCal), GaAs (BeamCal)



Production of highly precise tungsten absorber plates (flatness <50μm) for a compact prototype calorimeter



Novel connectivity schemes produce thin sensor planes (small Moliere radius)

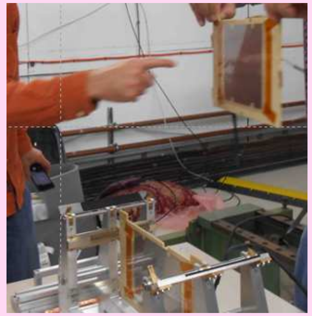
Test beams

October 2014 at CERN
first 4-layer prototype

Analysis almost complete

Oct. 2015 DESY
1st thin layer prototype (<1mm)

Data analysis just started



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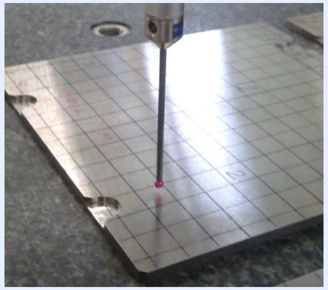

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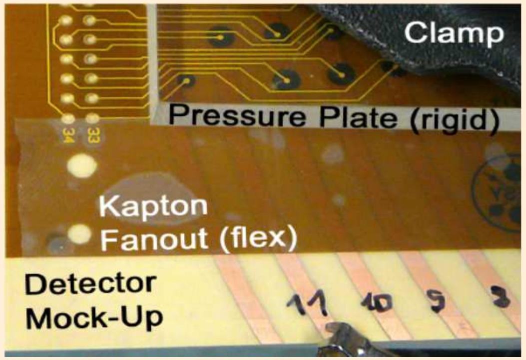

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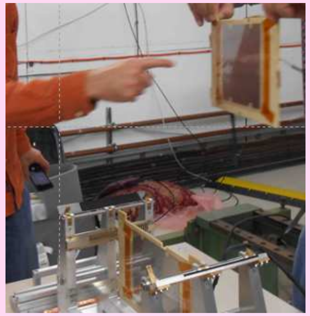

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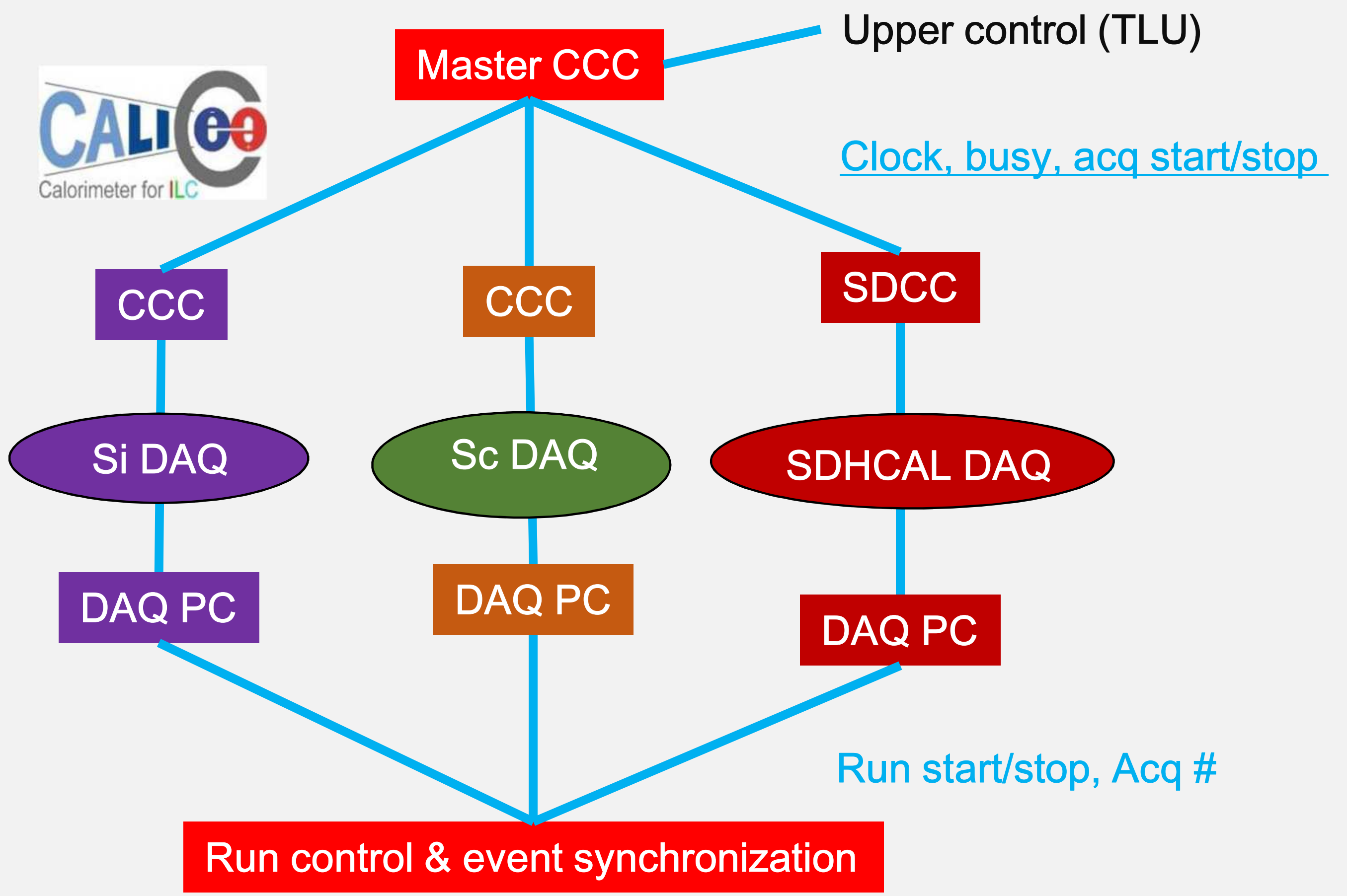
PLANS

Thin sensor planes – new connectivity scheme
Dedicated FE & ADC ASICS 130nm technology
Demonstration of power pulsing

Energy & spatial resolution (Luminosity & angular spectrum)
Bias in the angular measurements (systematic uncertainty)

Common DAQ



- **Taskforce** by experts formed **to integrate individual DAQs**
- Specification is under intensive discussion
- Common test beam will be in next year

AIDA 2020

Includes a
dedicated Workpackage

common effort including
all subdetectors

Outlook

ILD is doing fine. Little funding and not growing **but people interested and active**

Good simulation and reconstruction tools are crucial to guarantee a good design of ILD. Work still ongoing.

On route for a systematic re-optimization of the detector gained a significantly better understanding of our tools.

Fruitful collaboration with R&D groups. Many **activities going on including the construction of first big modules with new electronics**. **R&D oriented to ILD not only to the technology itself.**

Many **physical analysis ongoing,** the **next step focus in systematics, e.g. impact of beam background, beam spectrum, control samples, etc.**

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Many thanks to all the people that helped to prepare this presentation

V. Balagura, T. Behnke, V. Boudry, K.Büsser, R. Cornat, S. Green, K. Kawagoe, K.Krüger, J. List, W.Lohmman, D. Moya, A.Ruiz, F. Sefkow, R. Settles, T.Suehara, T. Takeshita, J.Tian, L. Tran, I.Vila, M.A. Villarejo, M.Vos M. Winter

if I forget somebody

BACK UP

Higgs CP mixture study – Anomalous HVV coupling

The Higgs CP mixture study includes analysis using

→ **anomalous HVV coupling**

→ **Hff coupling**

Anomalous HVV coupling

The **determination of Higgs couplings to SM particles** (gauge bossons, leptons and quarks) is **needed to probe the Higgs mechanism for generation SM particle masses**

Deviation from the SM are parametrized by higher-dimensional operators. A theory with SM operators but free Higgs couplings can be regarded as an **effective theory which contains additional higher-dimensional operators suppressed by powers of Λ .**

arXiv: 1011.5805

The ***Lagrangian*** can be parametrized as →

$$\mathcal{L}_{HVV} = 2M_V^2\left(\frac{1}{v}+\frac{a}{\Lambda}\right)HV_\mu^+V^{-\mu}+\frac{b}{\Lambda}HV_{\mu\nu}^+V^{-\mu\nu}+\frac{\tilde{b}}{\Lambda}H\epsilon^{\mu\nu\rho\sigma}V_{\mu\nu}^+V_{\rho\sigma}^-$$

SM (CP-even) Correction [a] — Tensor Couplings CP-even [b] — Tensor Couplings CP-odd [bt]

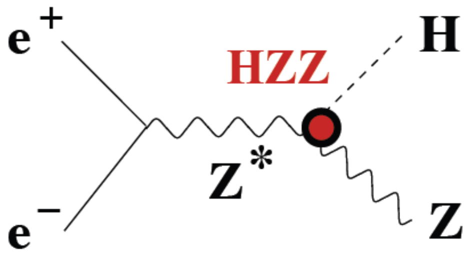
a, b and $\tilde{b}$ couplings = real dimensionless coefficients. SM recovered in the limit ***a, b,*** $\tilde{b}$ → 0

- ***a*** represents corrections to the SM term
- ***b and*** $\tilde{b}$ parametrize the leading dimension-5 non-renormalizable interactions

The purpose is to estimate how the ILC is sensitive to the anomalous couplings if they are small

Anomalous HZZ couplings

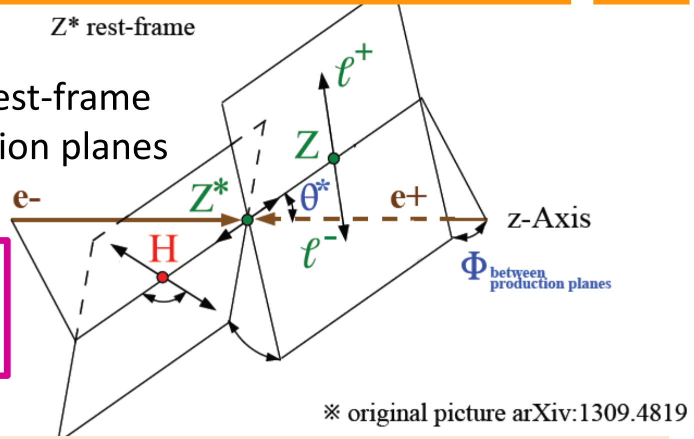
Production process



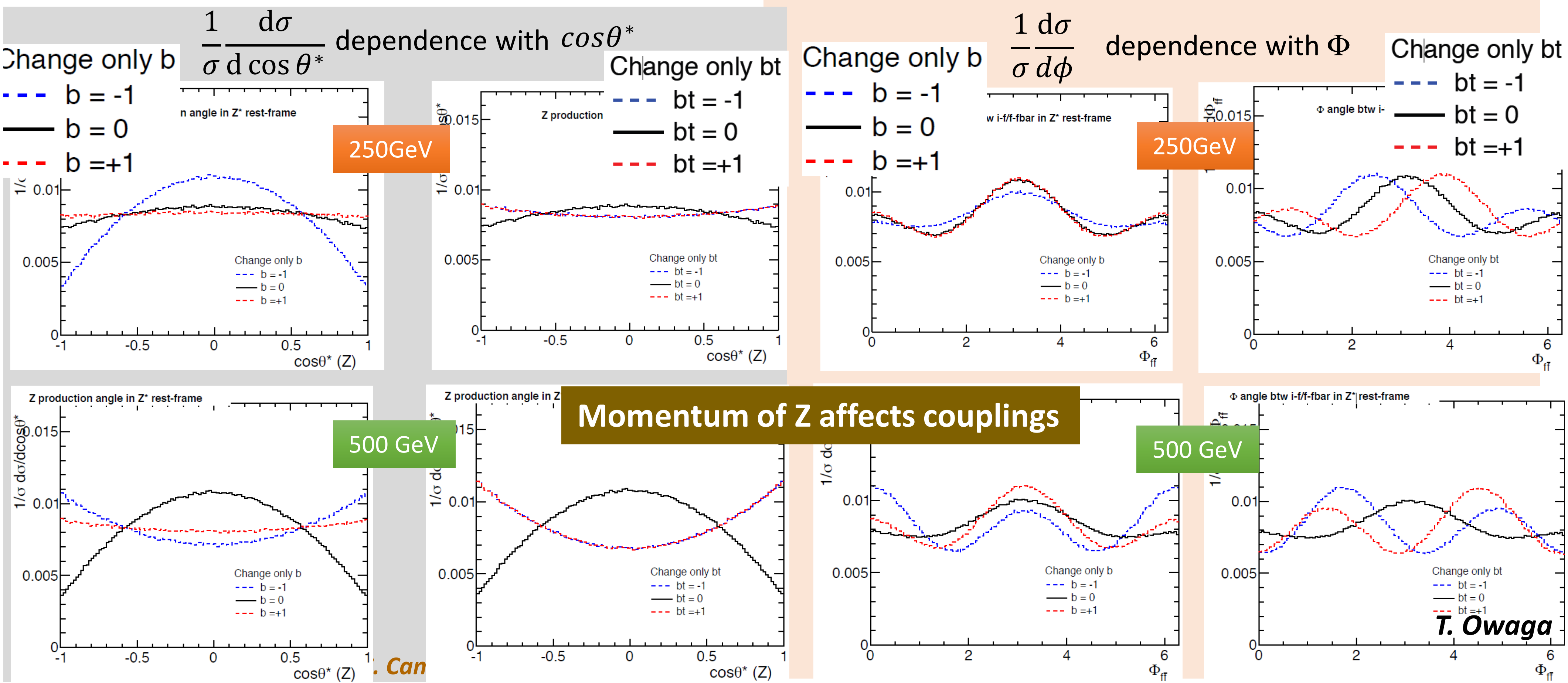
θ*: Production angle of Z in Z* rest-frame

Φ : Angle between two production planes in Z* rest-frame

Both angles are sensitive to anomalous couplings



※ original picture arXiv:1309.4819



Anomalous HZZ couplings – sensitivity using χ^2 test

Ciemat

Cuts for background suppression set to maximize the significance

$$Signif = \frac{N_{sig}}{\sqrt{N_{sig} + N_{bkg}}}$$

For increasing sensitivity.

➔ Sum of significance for each bin on histograms of θ* and Φ

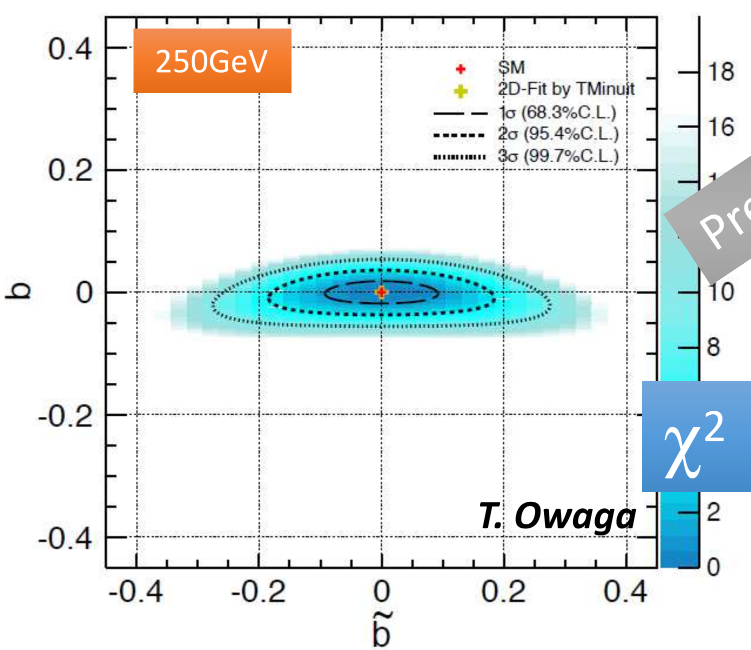
Observed #signal and its error

$$\sum_{i}^{bins} \left(\frac{S_{obs}(i)}{\Delta S_{obs}(i)} \right)^2$$

The χ2 to be minimized (detector acceptance is included and #expects events are **after** bkg suppression)

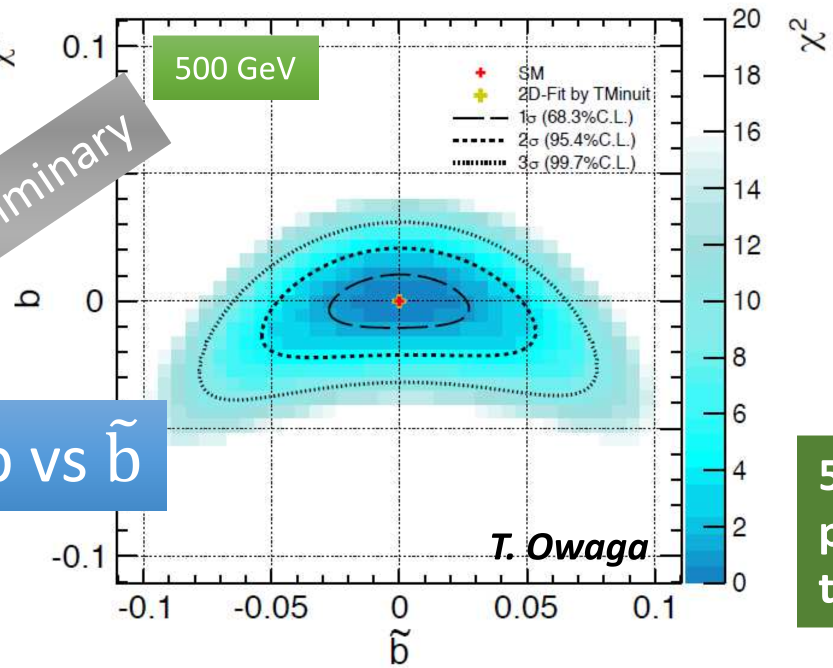
Effect of angular distribution / **Effect of cross section**

$$\chi^2 = \sum_{bin=1}^{n} \left(\frac{y_{bin}^{SM\ w/accep} - f^{BSM\ w/accep}(x_{bin}; a, b, \tilde{b})}{\delta y_{bin}^{SM}} \right)^2 + \left(\frac{N^{SM} - N^{BSM}}{\delta\sigma \cdot N^{SM}} \right)^2$$



Preliminary

χ^2 b vs $\tilde{b}$



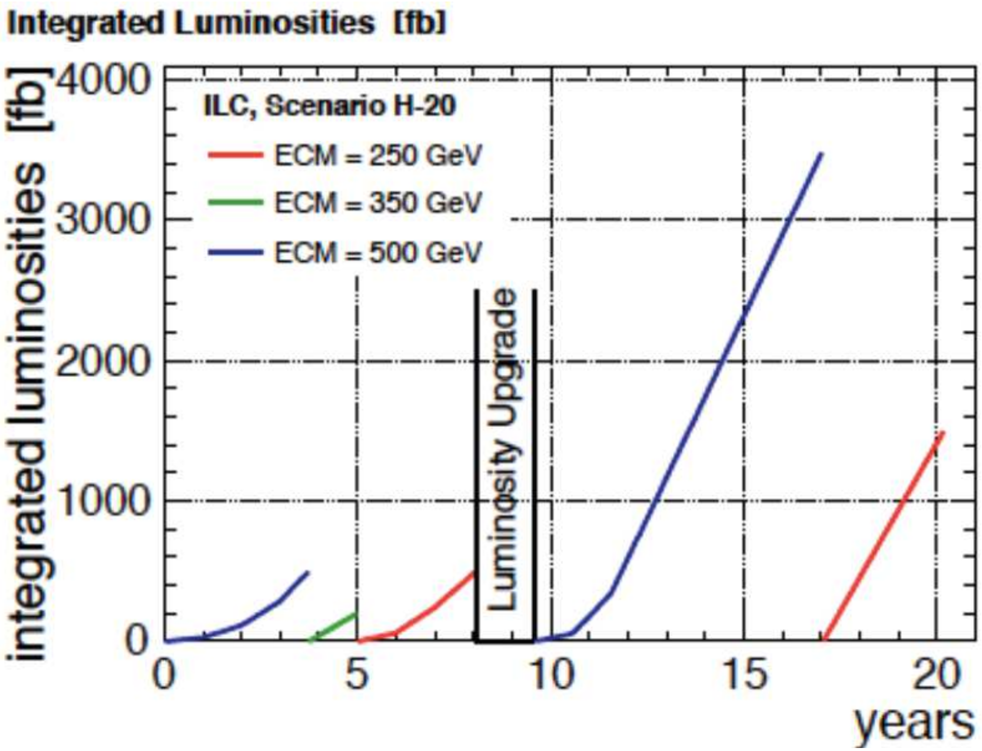
SM
2D-Fit by TMinuit
1σ (68.3%C.L.)
2σ (95.4%C.L.)
3σ (99.7%C.L.)

500 Gev results are probably very sensitive to anomalous couplings

Model independent measurement of recoil mass and absolute Higgs cross section

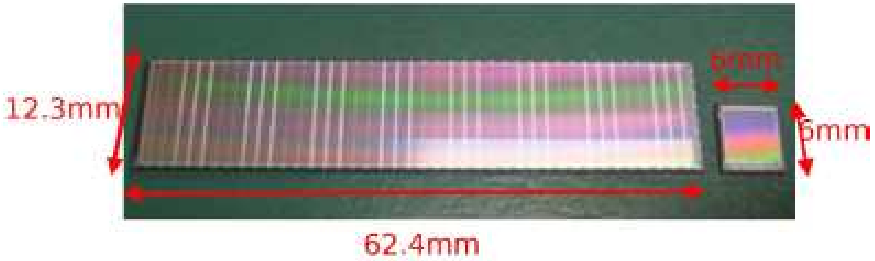
Precision scaled to the H20 scenario
Z→μ⁺μ− and Z→e⁺e- combined

ECM=250GeV		xsec	Mass [MeV]
(2 ab−1)	left	1.14%	14.7
	right	2.20%	20.2
	combined	**1.01%**	**11.9**
ECM=350GeV		xsec	mass
(0.2 ab−1)	left	5.16%	144.5
	right	9.87%	285.6
	combined	**4.57%**	**128.9**
ECM=500GeV		xsec	mass
(4 ab−1)	left	2.96%	279.5
	right	2.99%	327.6
	combined	**2.10%**	**212.6**
All channels		**xsec**	**mass**
(full H20 run)		**0.89%**	**11.8**

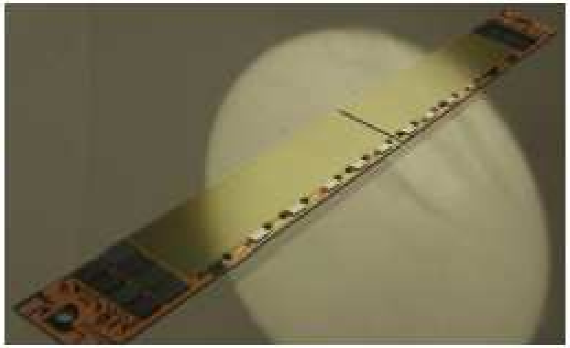


Vertex detector related activities

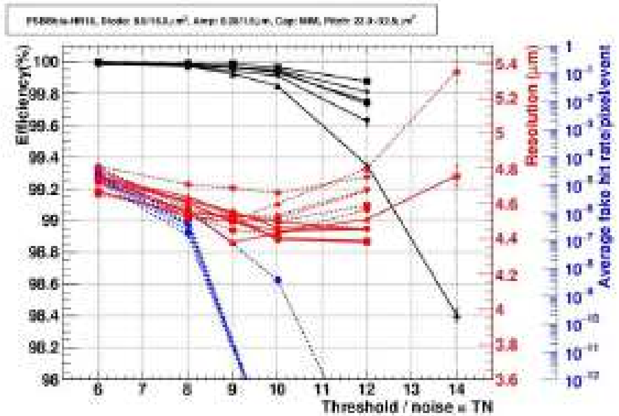
- 3 pixel technologies developped continuously : **FPCCD, DEPFET, CPS**
- **Fine Pixel CCD :**
  - 6x6 μm^2 pixel slabs under study ▷ ▷ ▷
    - ↪ neutron dammage may be ∼ OK
  - double-sided ladder prototyping started



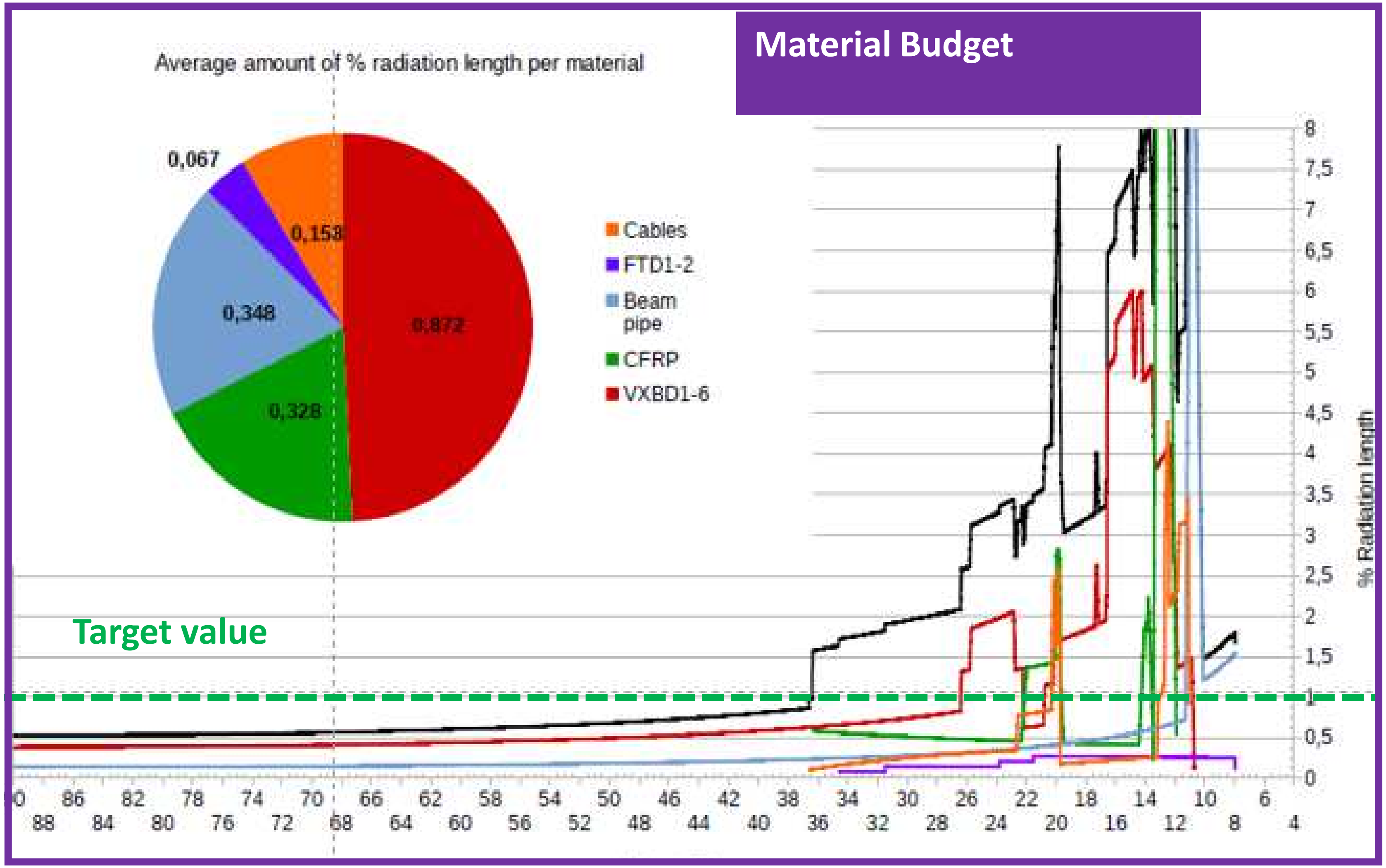
- **DEPFET :** R&D driven by BELLE-2 PXD (2018)
  - 1st complete BELLE-2 ladder (50x55/85 μm^2 pixels) functionnal ▷ ▷ ▷
  - PXD9 pilot production of sensors : yield assessed
  - power cycling of ladder at ILC frequency validated outside of mag. field
  - micro-channel cooled pixel detector under development



- **CMOS Sensors:** driven by ALICE-ITS & CBM-MVD ($\geq$ 2020)
  - added value of CPS validated by 2 years of phys. run of STAR-PXL
  - 5 X faster sensor (1.6 10^5 pixels) assessed: effi., resol., noise of 6 chips ▷
  - ALICE-ITS final prototypes : 5 μm & 4 μs demonstrated
    - ↪ 2-sided ILD ladder concept with 1-2 μs time stamping achievable



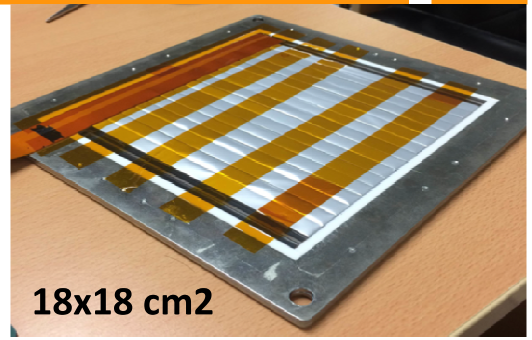
Material budget



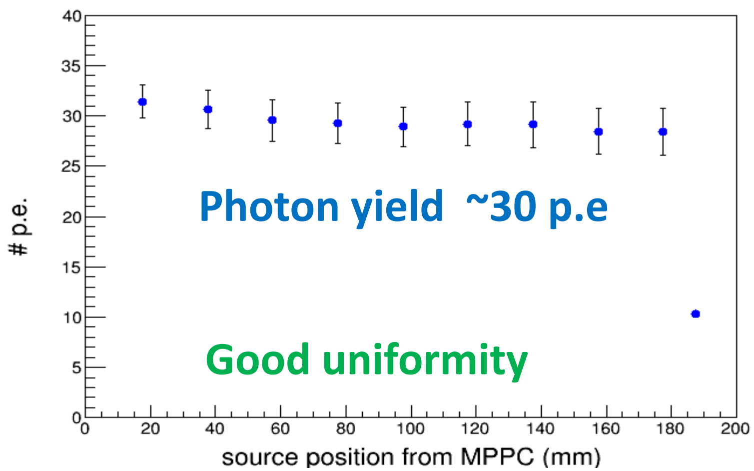
Scintillator Strip HCAL

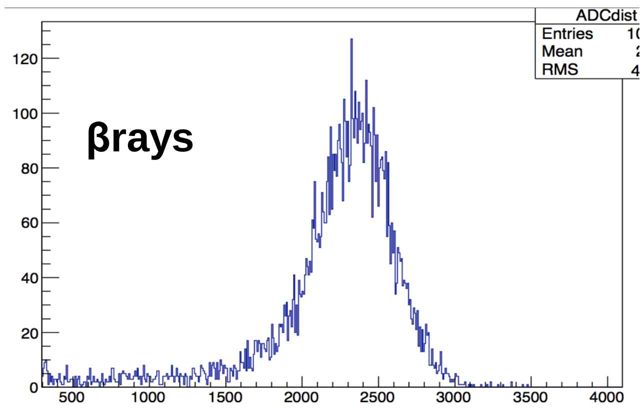
Ciemat

Strip 18 cm long.
Scintillator 3mm thick
Readout:
WLFS (Wave Length Shifting Fiber) + MMPC with 1600 pix 25µm



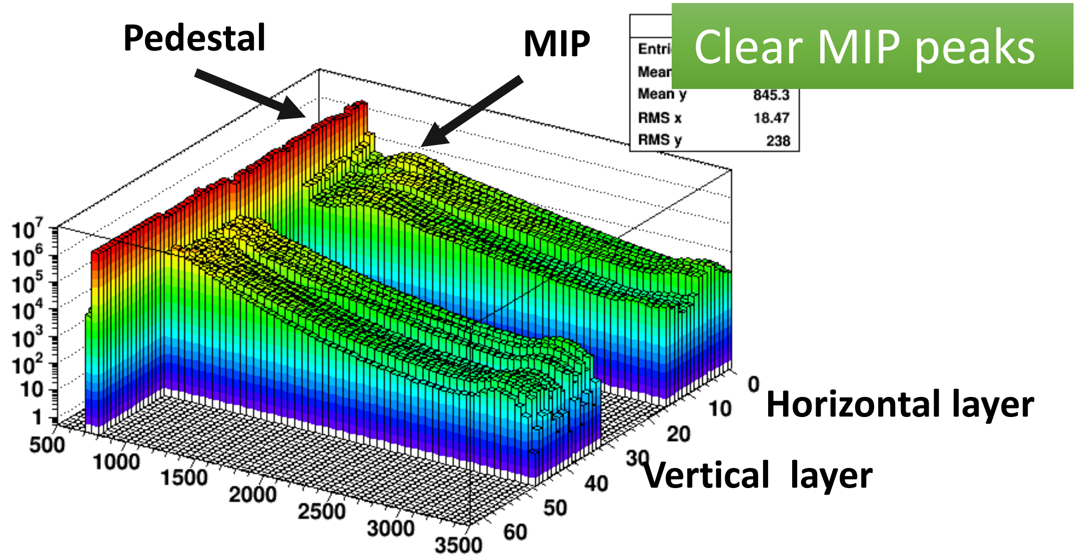
Tests @ Lab



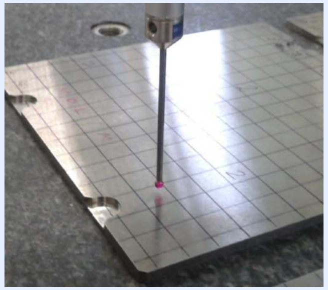


Test Beam

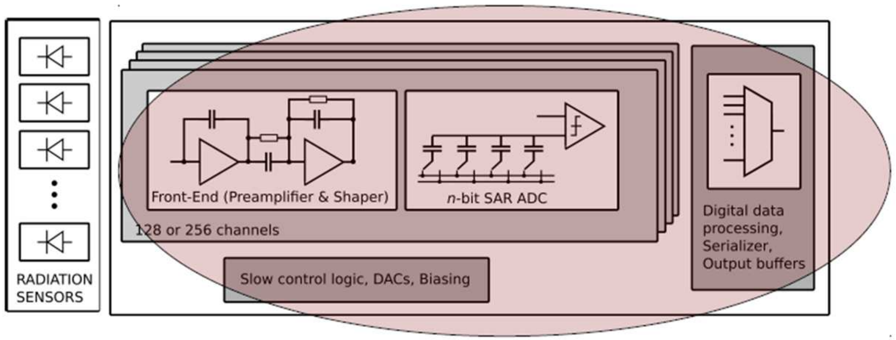
Strips: 16 horizontal, 16 vertical
Behind AHCAL ➔ Most muons



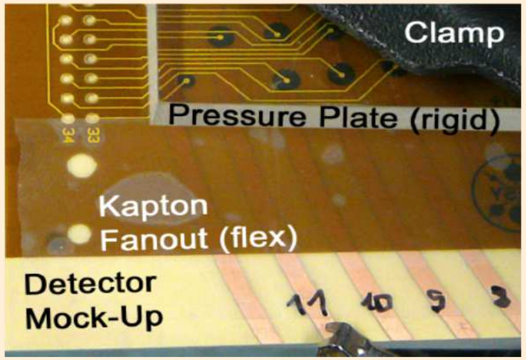
FCAL: BeamCal & LumiCal. Recent developments



Production of highly precise tungsten absorber plates (flatness <50µm) for a compact prototype calorimeter



Submission of a dedicated 16 channel prototype, FE ASIC and ADC on one chip (after successful tests of 8 channel FE and ADC ASIC)



Novel connectivity schemes produce thin sensor planes (small Moliere radius)

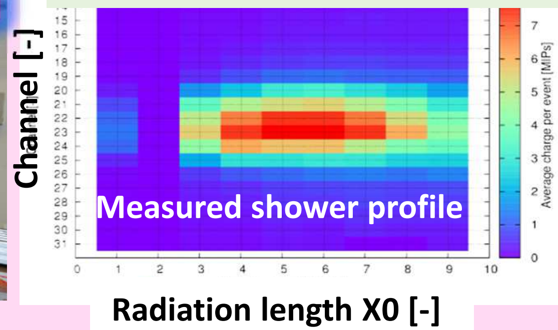
Baseline:

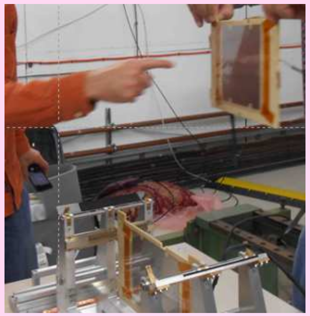
Tungsten sandwich calorimeter with small Moliere radius

Sensors: Silicon (LumiCal), GaAs (BeamCal)

Test beams

Analysis almost completed





Oct. 2015 DESY

1st thin layer prototype (<1mm)

Data analysis just started

PLANS

Thin sensor planes – new connectivity scheme

Dedicated FE & ADC ASICS 130nm technology

Demonstration of power pulsing

Energy & spatial resolution (Luminosity & angular spectrum)

Bias in the angular measurements (systematic uncertainty)