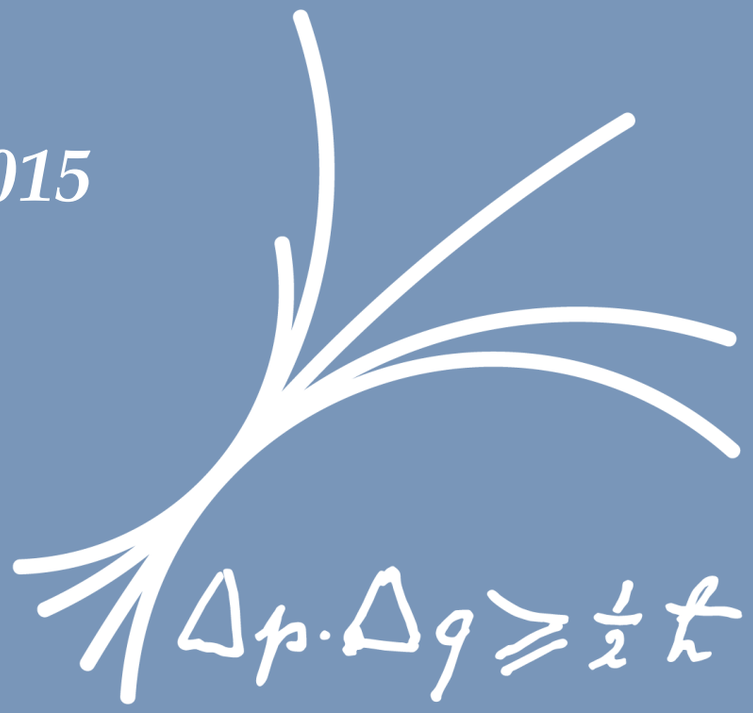
MPP Project Review 2015



Future Detectors: Physics & Detectors at Linear Colliders

Naomi van der Kolk

Future Detectors Group

Close Collaboration with:
Belle/Belle II group
The technical departments

- Group Leader
  Frank Simon
- Post-Docs
  Michal Tesar (until March '15), Naomi van der Kolk
- PhD Students
  Veronica Chobanova (until July '15), Yasmine Israeli (since Oct. '15),
  Miroslav Gabriel, Marco Szalay *funded by Excellence Cluster*
- Master Students
  Philipp Goecke (since March '15), Hendrik Windel (since Nov. '15)
- Bachelor Student/Technical Student
  Hendrik Windel (until Oct. '15)
- Plus several interns

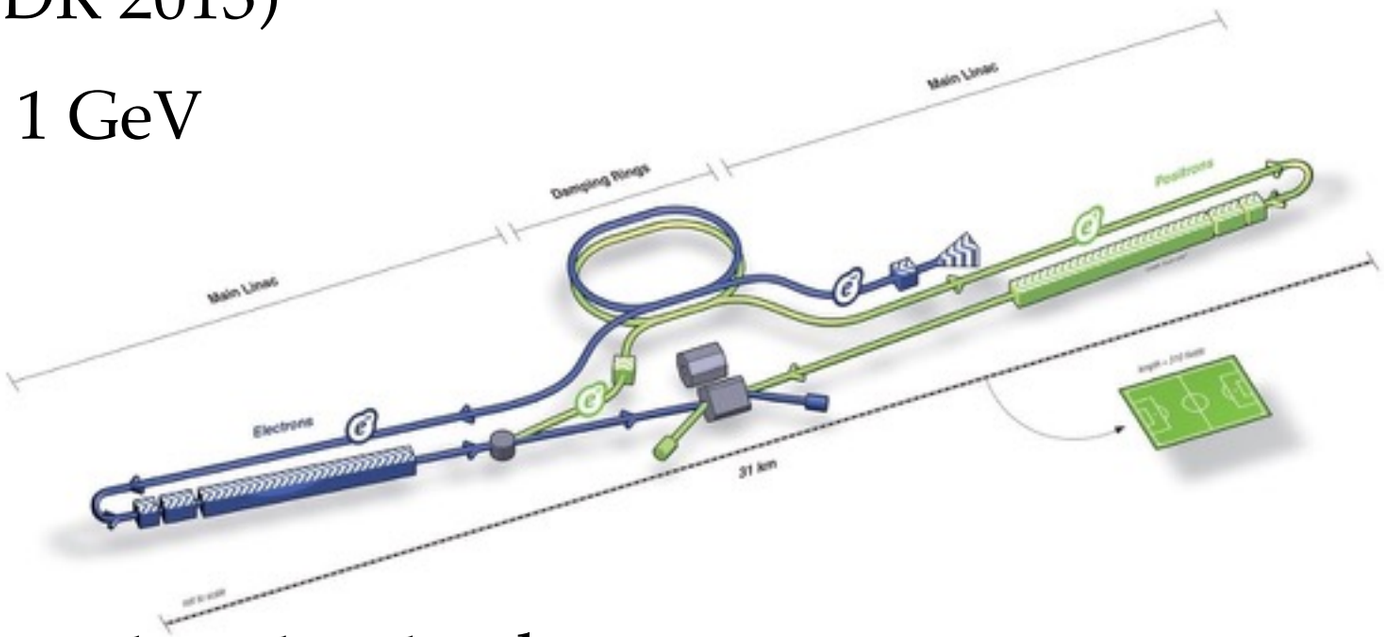
Future Facilities at the Energy Frontier

- The Higgs discovery has completed the Standard model
- Where and how will it break down?

- Explore at high energies and with high precision
  - properties of the Higgs boson
  - properties of the top quark
  - searches for new particles at the TeV scale

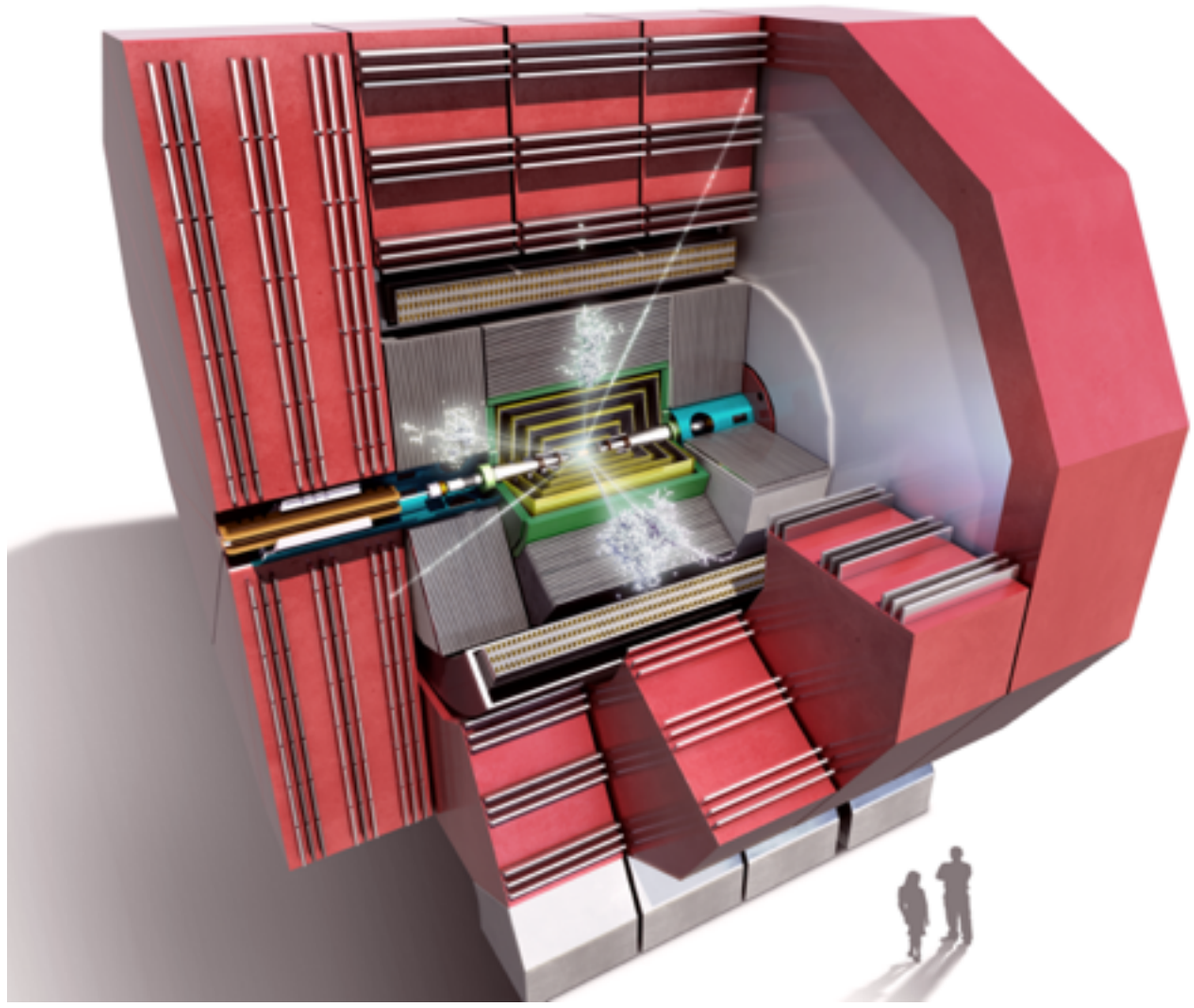
Future e^+e^- Colliders

- Complementary to the LHC: e^+e^- colliders
- The International Linear Collider (ILC) is the most advanced concept for a future energy frontier collider (TDR 2013)
  - Baseline 500 GeV, upgrade to 1 GeV



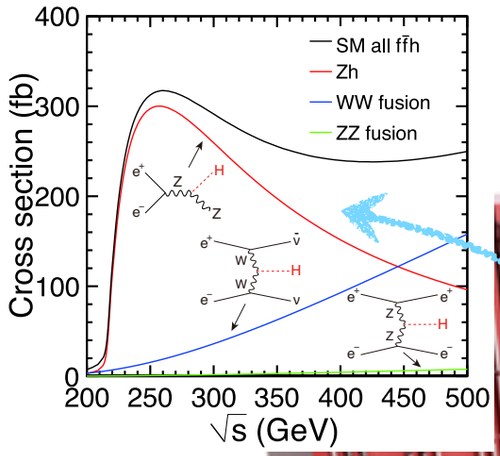
- Japan has expressed interest to host the ILC: a decision has yet to be taken by the government.
- A review has been started by MEXT - evaluation of the physics case and technical issues - expected by spring 2016
- Alternative concept in Europe: Compact LInear Collider (CLIC)
  - Staged operation up to 3 TeV, same physics interests at low energy as ILC

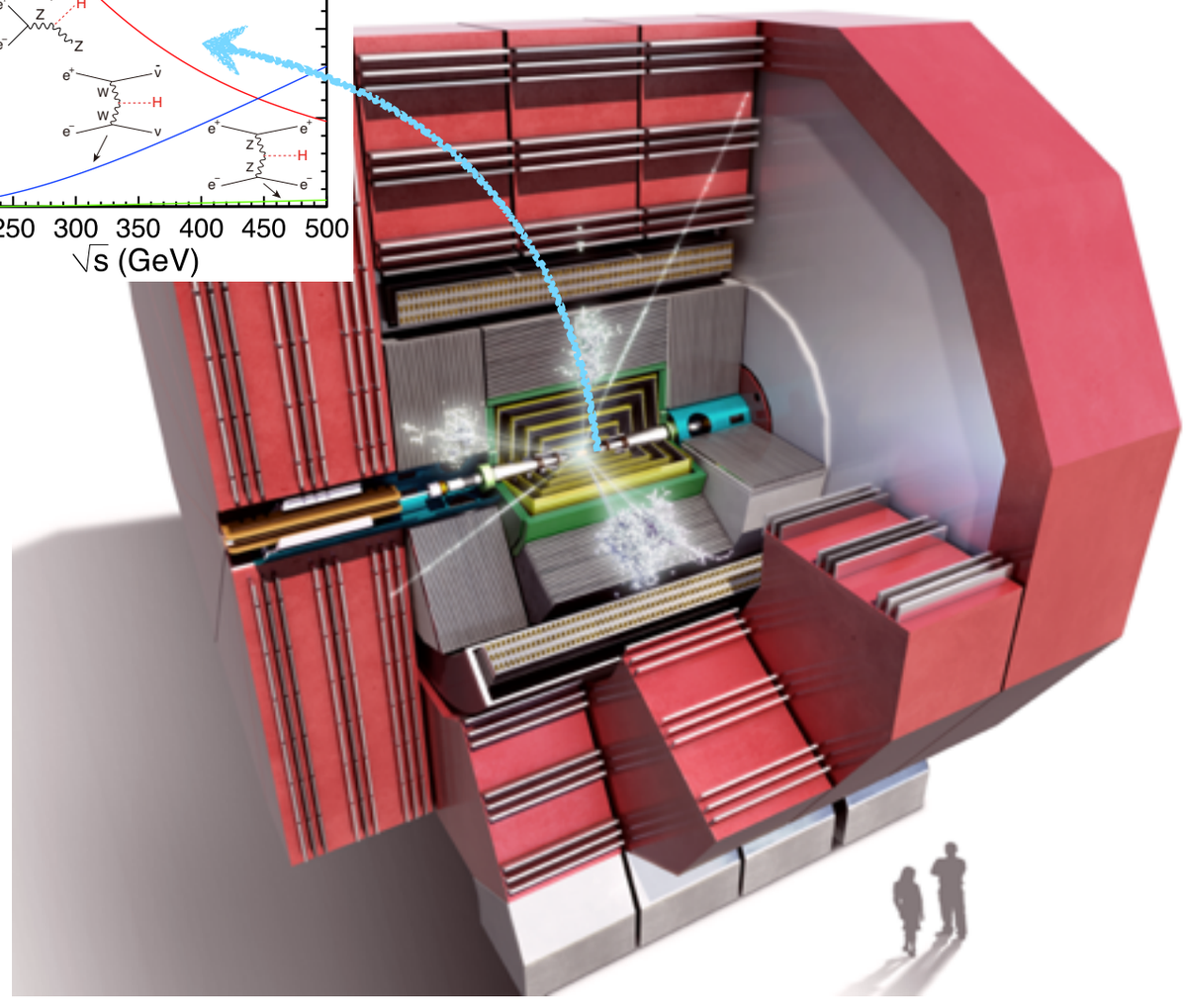
Activities in the Future Detectors Group



Activities in the Future Detectors Group

Physics studies at future Linear Colliders





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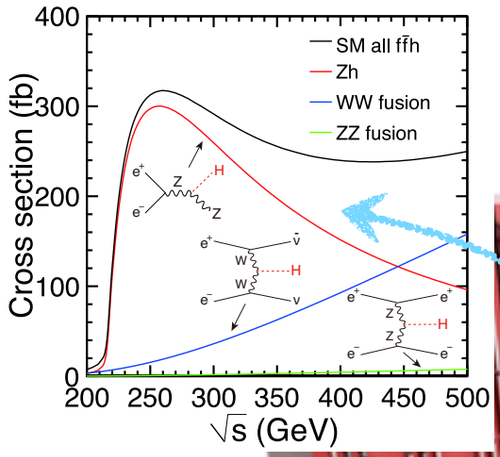
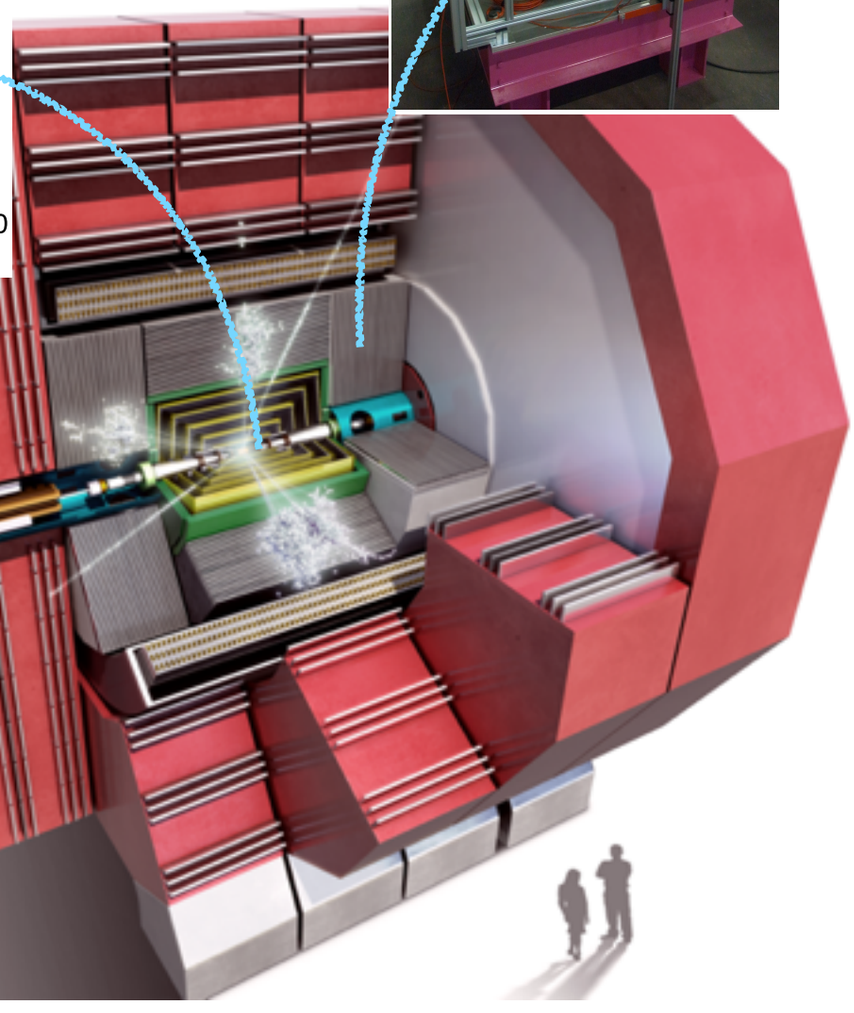
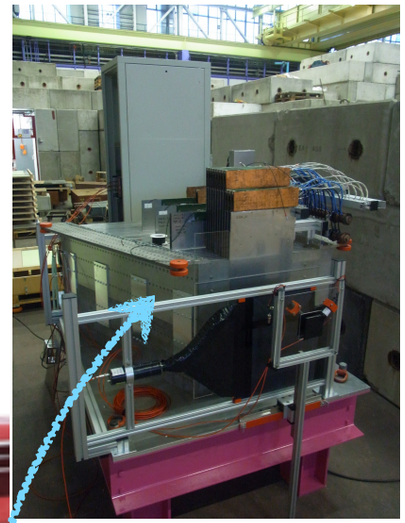


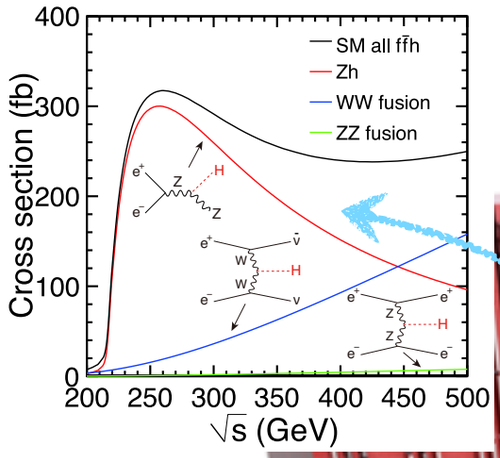


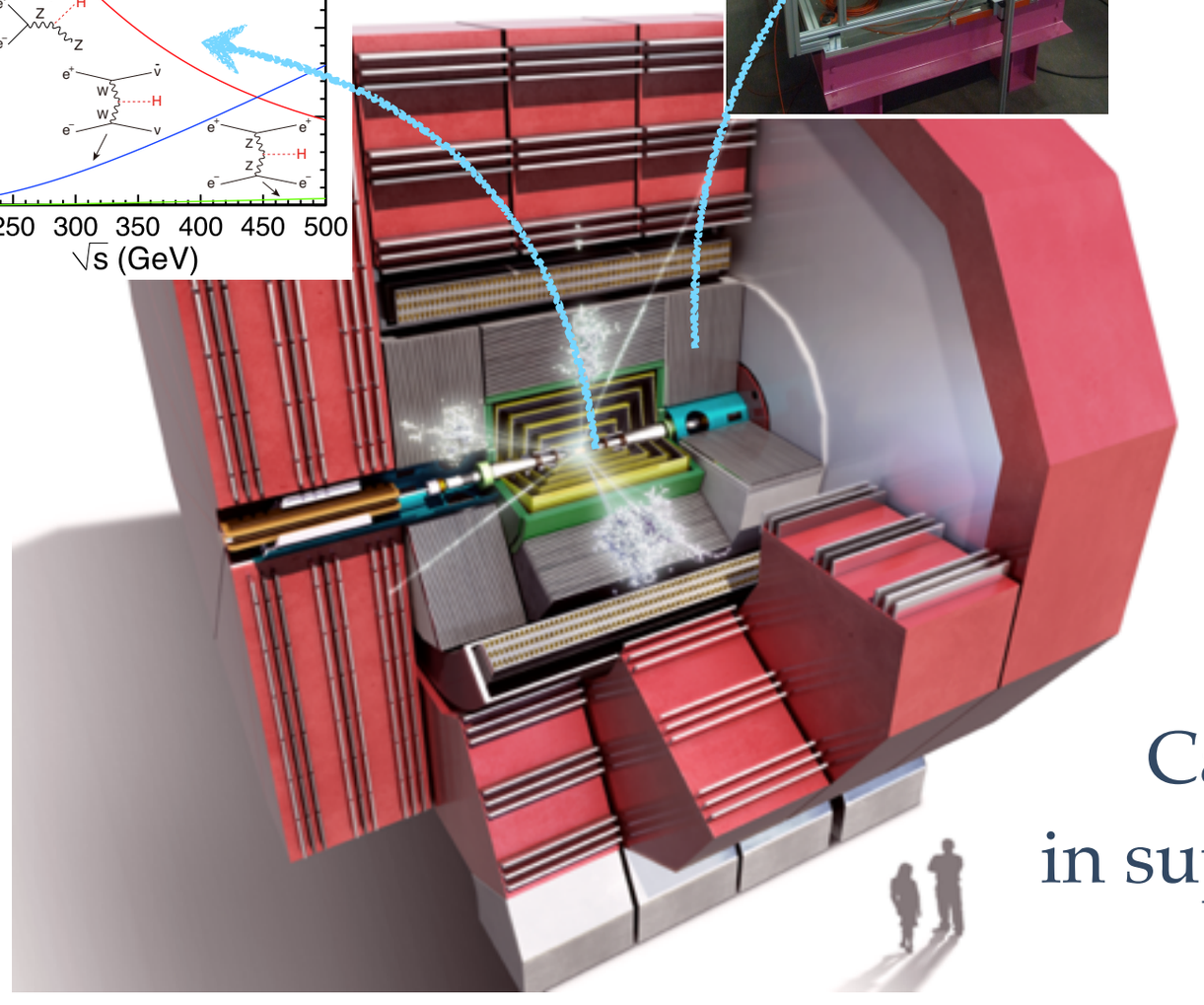


Development of highly granular calorimeters

Activities in the Future Detectors Group

Physics studies at future Linear Colliders





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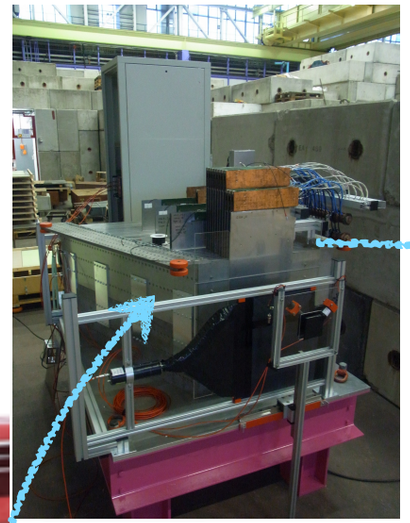


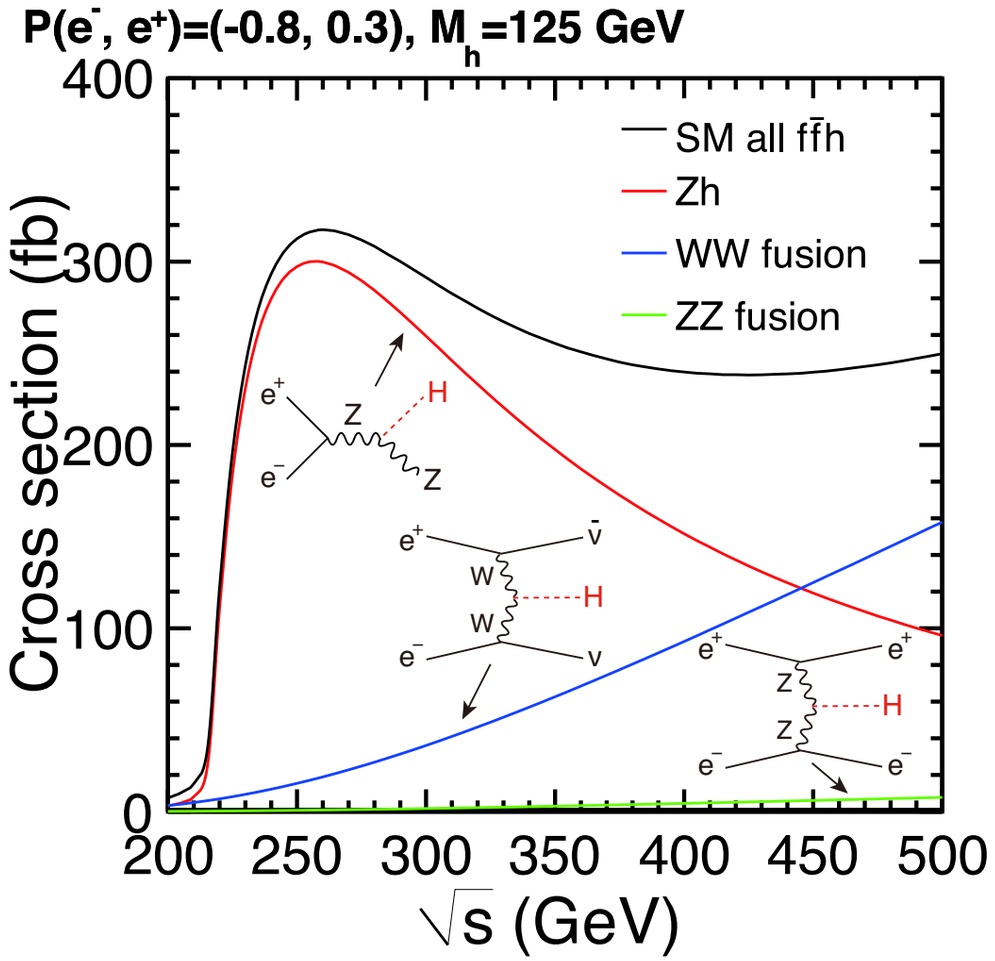
Calorimeter technology in superKEKB commissioning detector: CLAWS

Physics studies for ILC/CLIC: Higgs decay to cc/bb/gg at 350 GeV

- 350 GeV: ZH and WW fusion (VBF) both appreciable cross-sections

- Measure decay fraction $\sigma \times BR$ of H -> bb/cc/gg (for CLIC, equally valid for ILC)

- Difficult analysis, now being finalised



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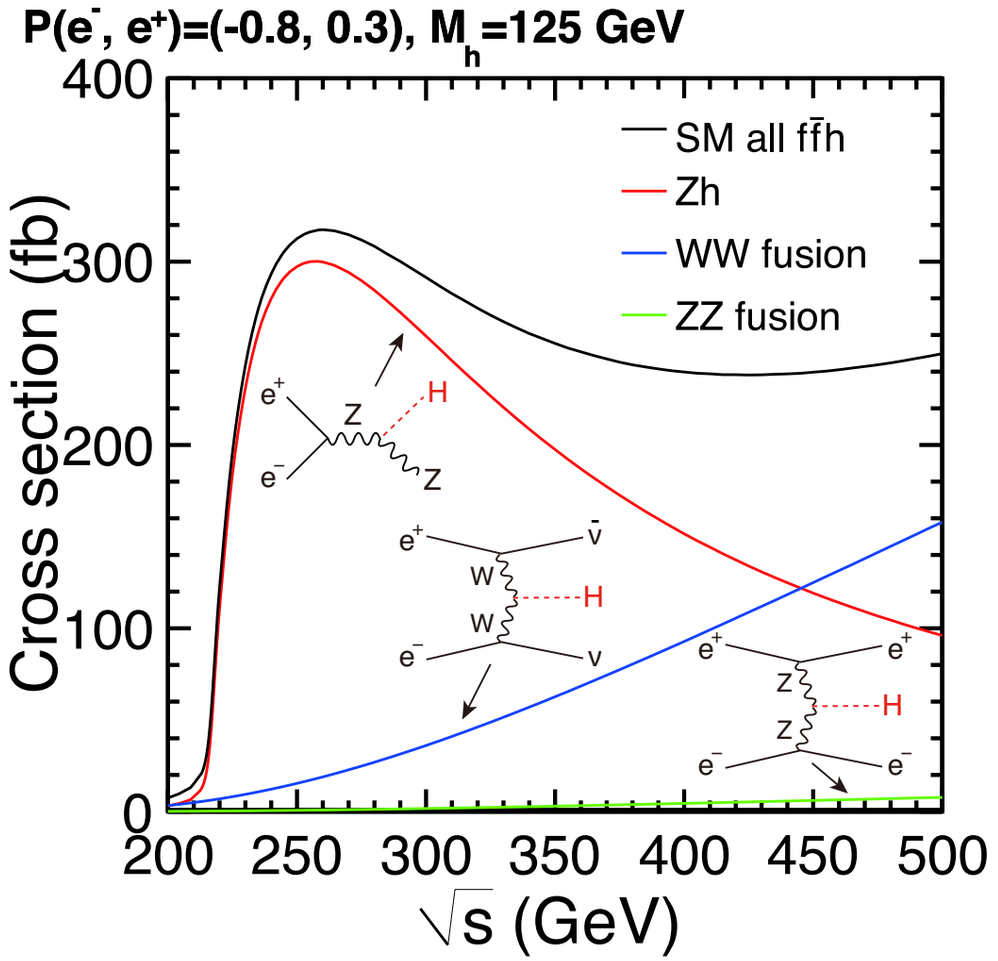

- Event selection and Standard Model background rejection based on multi-variate classifier (Boosted Decision Tree)

- Extracting the decay fraction using a multi-dimensional template fit including flavour tagging and Higgs p_T distribution

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- Extracting the decay fraction using a multi-dimensional template fit including flavour tagging and Higgs p_T distribution

σ x BR fit results:
H->bb (VBF) 1.8%
H->bb (ZH) 0.85%
H->cc 10.7%
H->gg 4.07%

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- Measure decay fraction σ x BR of H -> bb/cc/gg (for CLIC, equally valid for ILC)

- Difficult analysis, now being finalised

- The combined measurement of all Higgs hadronic decay channels allows to extract the Higgs width and its couplings

- Deviations w.r.t. the Standard Model in the couplings point to new physics

σ x BR fit results:

H->bb (VBF) 1.8%

H->bb (ZH) 0.85%

H->cc 10.7%

H->gg 4.07%

Resulting model independent coupling precision:

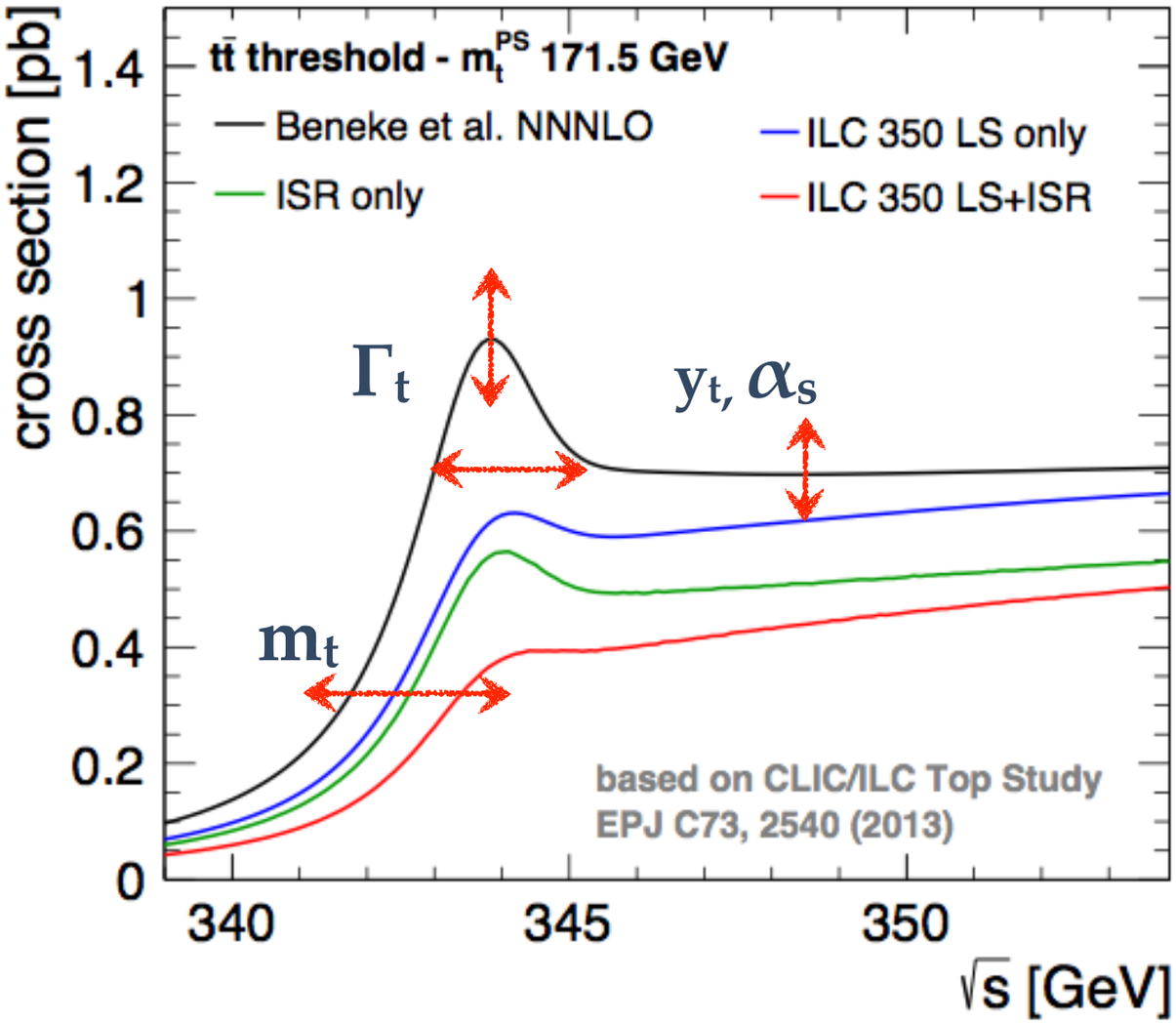
g_{Hbb} 2.8%

g_{Hcc} 6.1%

g_{Hgg} 3.4%

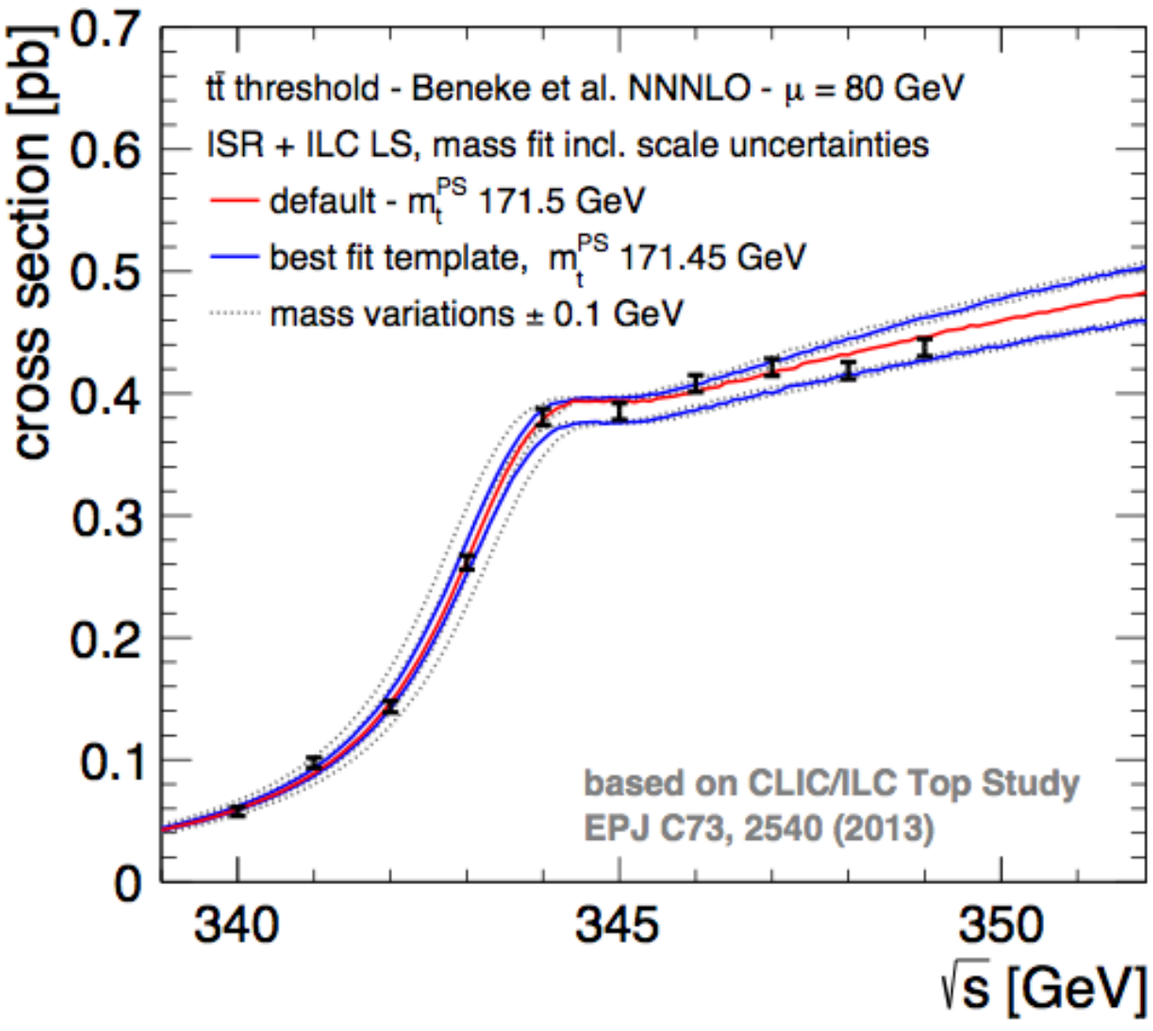
Physics studies for ILC/CLIC: Top mass theory uncertainty

- Top quark physics is a key component of the physics program
- Not yet studied at e^+e^- colliders
- Top mass can be measured with high precision at the ttbar production threshold near 350 GeV
- Production cross-section around the threshold depends on top quark properties and on QCD
- So far: theory uncertainty on top mass estimated ~55 MeV



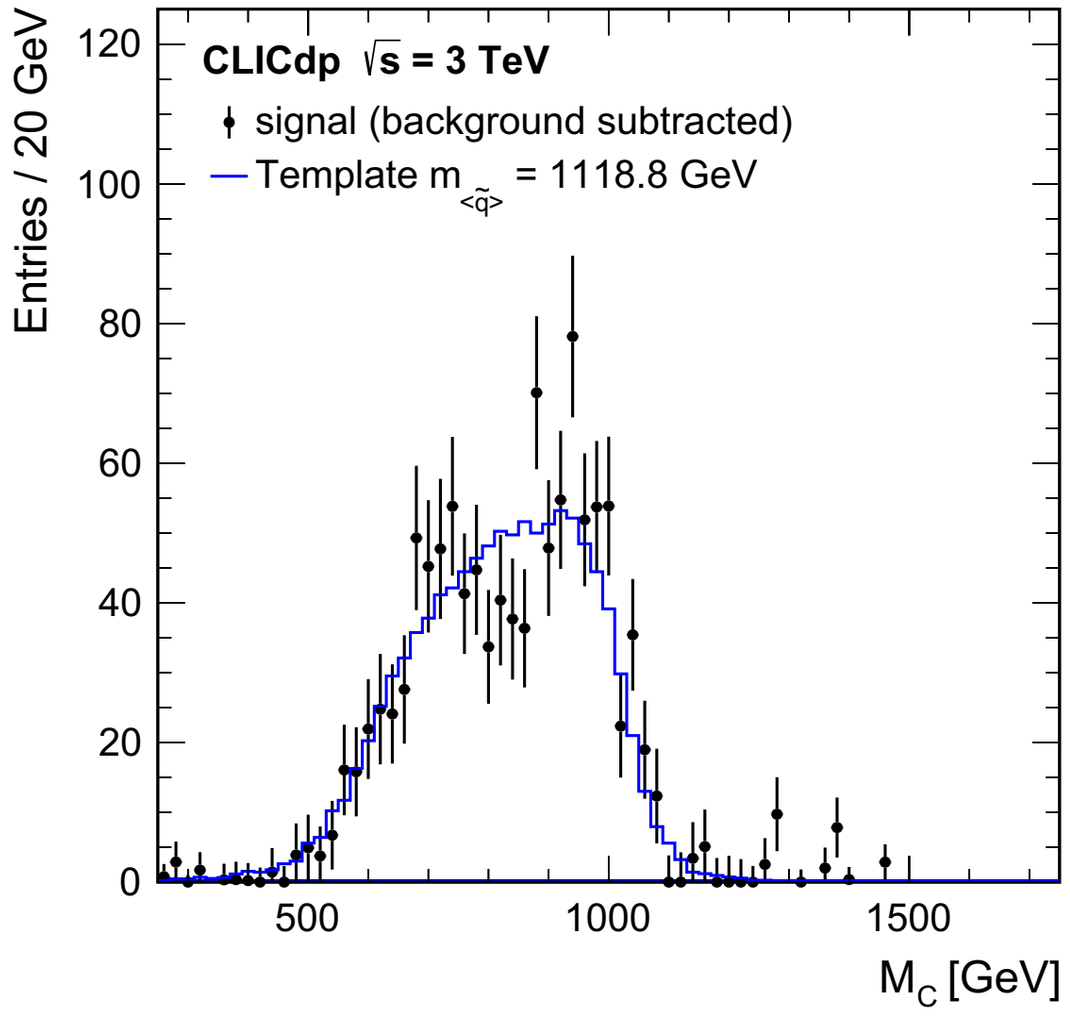
Physics studies for ILC/CLIC: Top mass theory uncertainty

- Re-examine theory uncertainty on the cross-section:
  NNNLO QCD calculations
  available by M. Beneke, J. Piclum et al.
- Substantial variations in cross-section due to QCD scale uncertainties
- Incorporate the scale uncertainties in the mass template fit
- For a threshold scan at ILC:
  45 MeV (syst) from NNNLO
  QCD scale uncertainty,
  32 MeV fit uncertainty
- Expected total uncertainty
  on m_t < 100 MeV for ILC / CLIC
  Now on much firmer ground with realistic theory systematics



Physics studies for ILC/CLIC: Prospect for squark mass measurement

- Mass measurement of TeV-scale light-flavoured right handed squarks for CLIC at 3 TeV
- Signal signature: 2 jets and missing E
- High background (generic signature); multivariate classifiers (BDT)
- Template fit with generator level templates: $\sigma_m/m = 0.58\%$
- Test jet finding algorithms: longitudinally invariant k_t algorithm most robust
- Valuable for any study at e^+e^- colliders involving jets and missing energy



- Analysis published this year: Eur. Phys. J. C75, 379 (2015)

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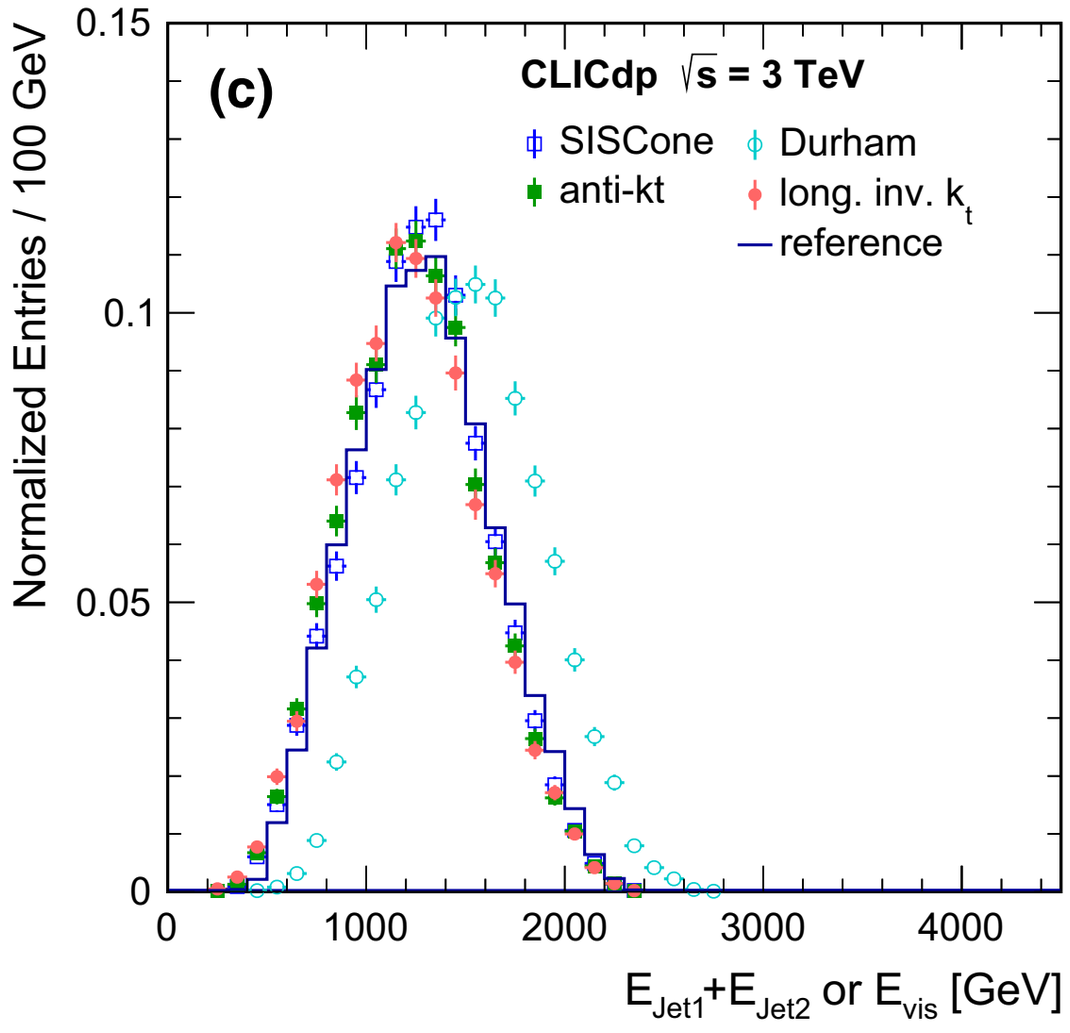

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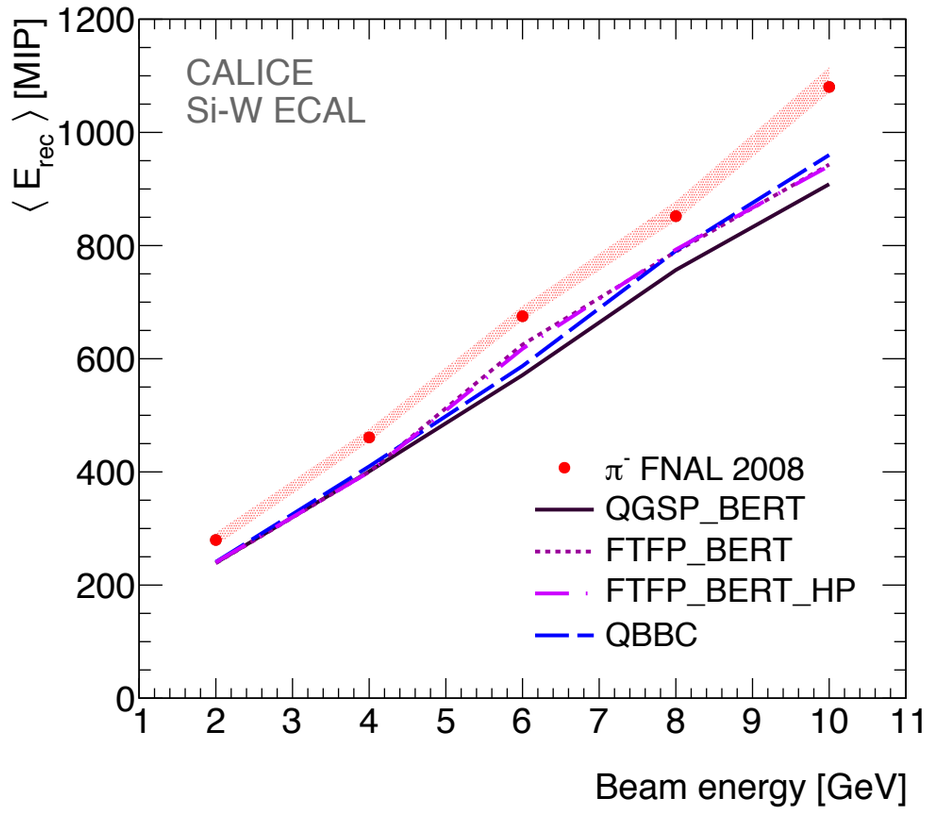
Highly Granular Calorimeters

- For high precision physics at future colliders a high jet energy resolution is needed, this can be achieved when using highly granular calorimeters and Particle Flow Algorithms (PFA)
- Activities in the scope of the CALICE collaboration that develops and tests such calorimeters
  - Spokesperson: Frank Simon (since April ‘15)

Test beam analysis: hadronic showers in Si-W ECAL vs Geant4

- Test beam data taken with CALICE prototypes is ideally suited to test simulation models of hadronic showers
- Detailed analysis of the primary interaction in the SiW-ECAL
- Pion showers at 2 to 10 GeV: MC compared to data
- The data allows to discriminate between Geant4 models on a very fine scale and MC reproduces data within 20% - 5%



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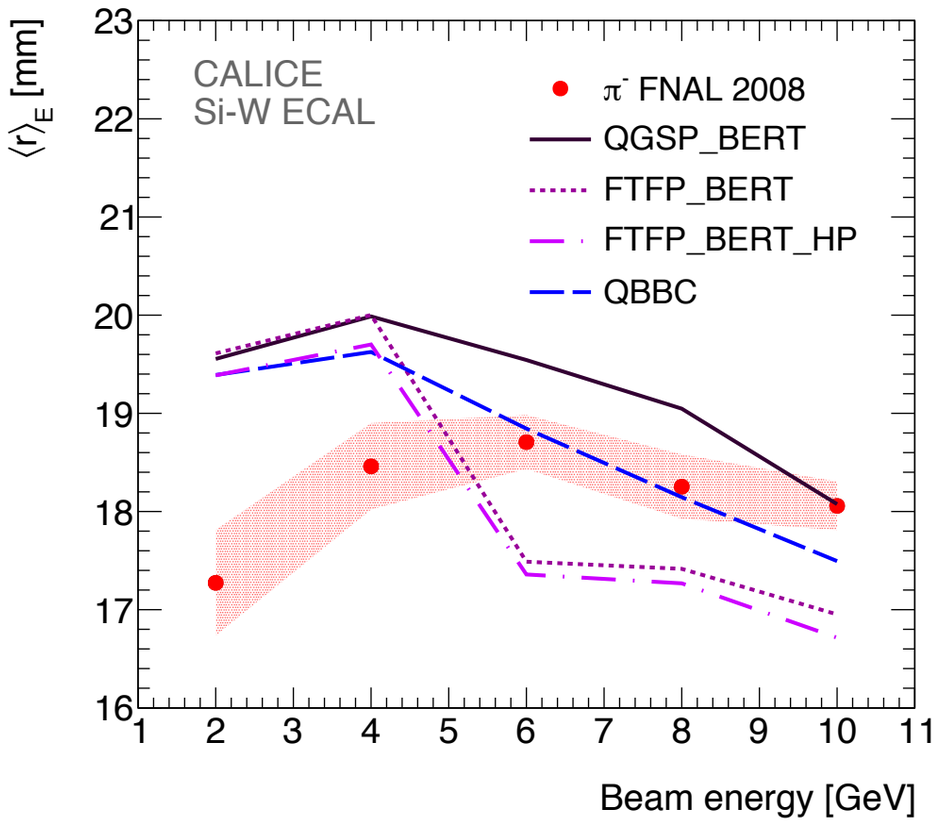

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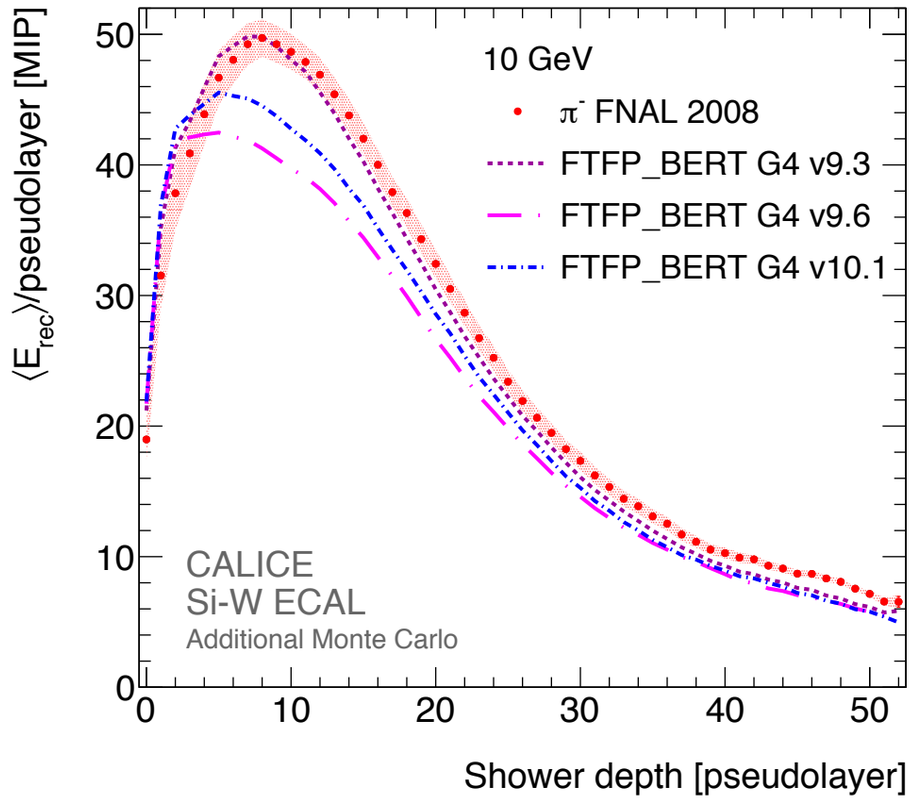

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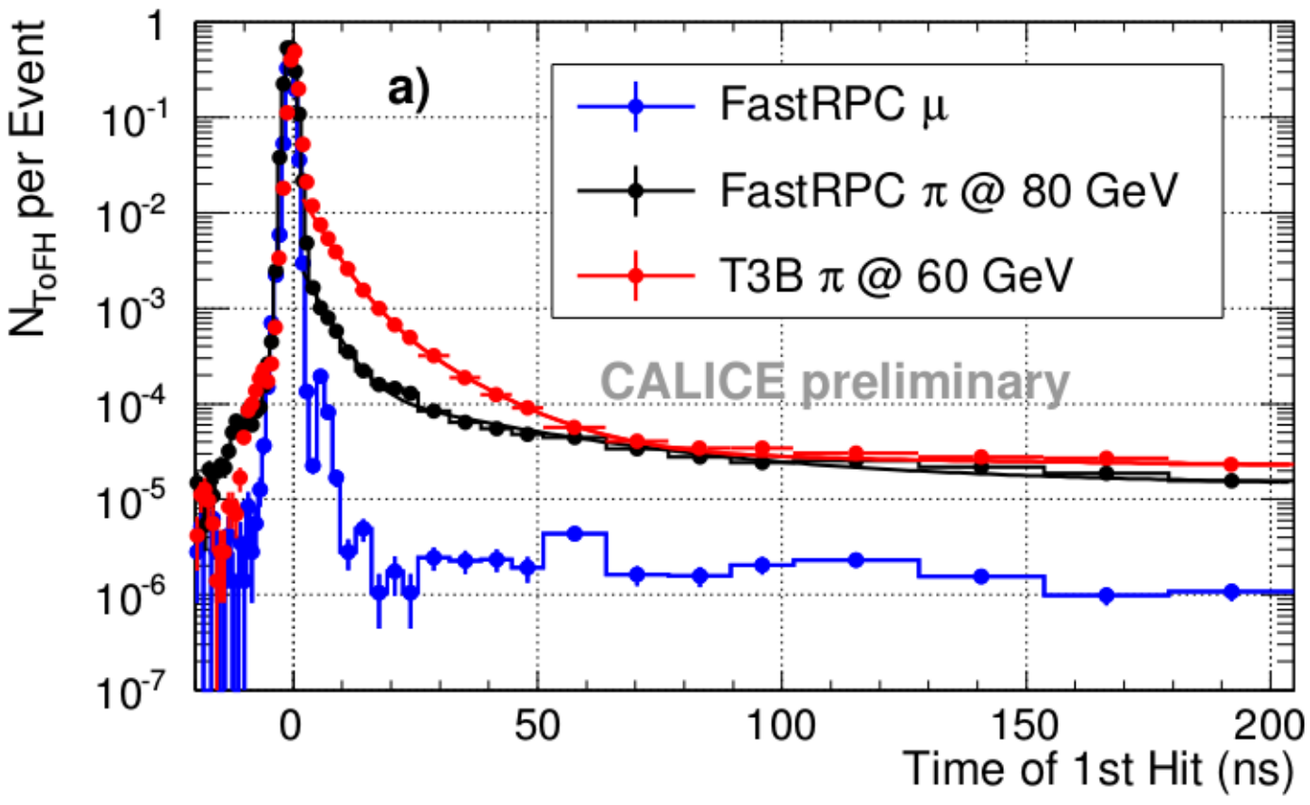
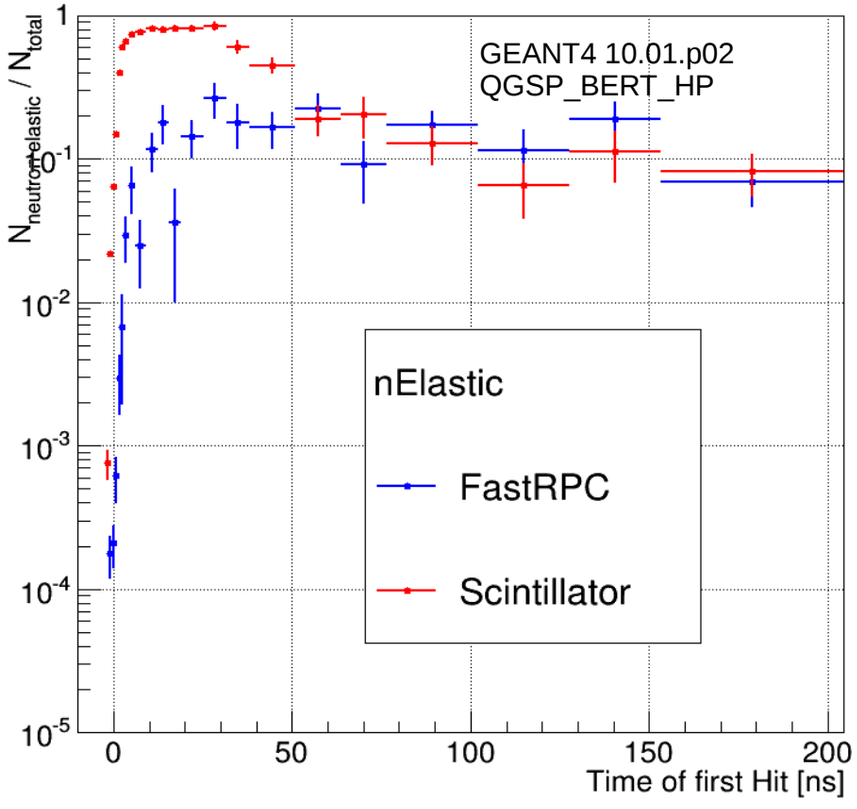
Test beam analysis: Timing in hadronic showers

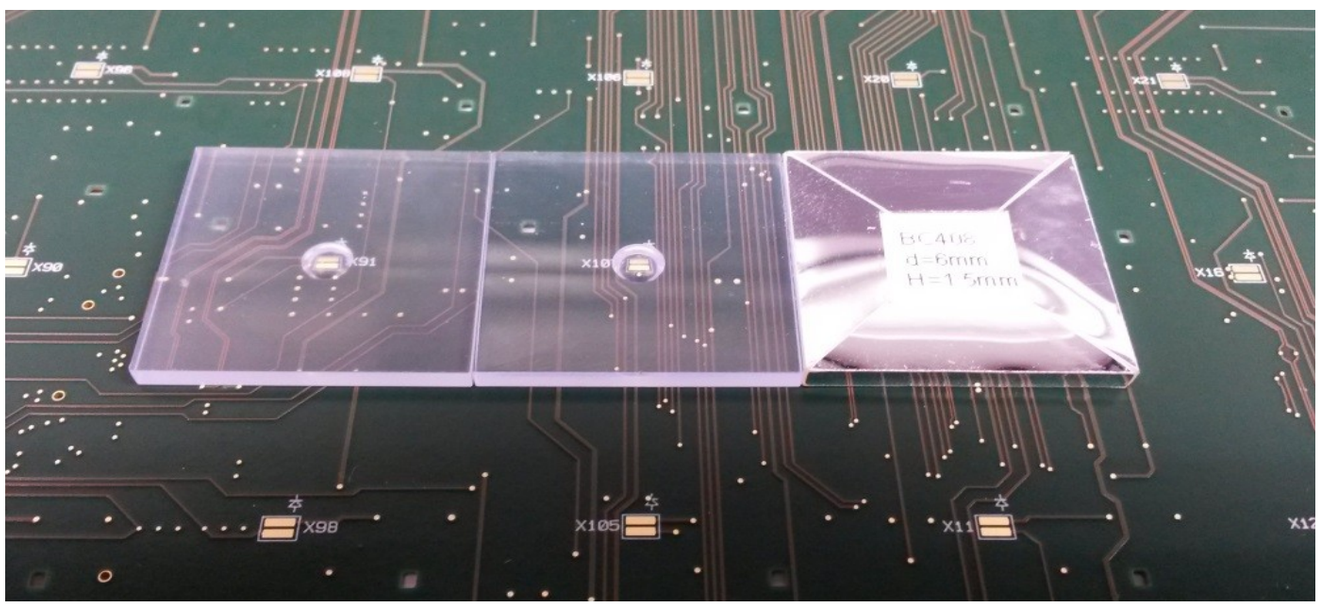
- Previously observed differences in the time of first hit distributions between T3B and FastRPC
- Scintillator vs gas
- Simulations to understand what causes the difference seen
- At short times elastic scattering of neutrons important, at later times neutron capture





Analogue Hadronic Calorimeter

- Scintillator tiles (3x3 cm^2) with SiPM readout, Steel or Tungsten absorber
  - Precision cassettes for the active layers produced in the MPP mechanical workshop
- Construction of an "engineering prototype" in preparation
  - Scalable to the full ILD layout, realistic infrastructure; 30 fully equipped layers, integrated electronics, automatic mass production assembly



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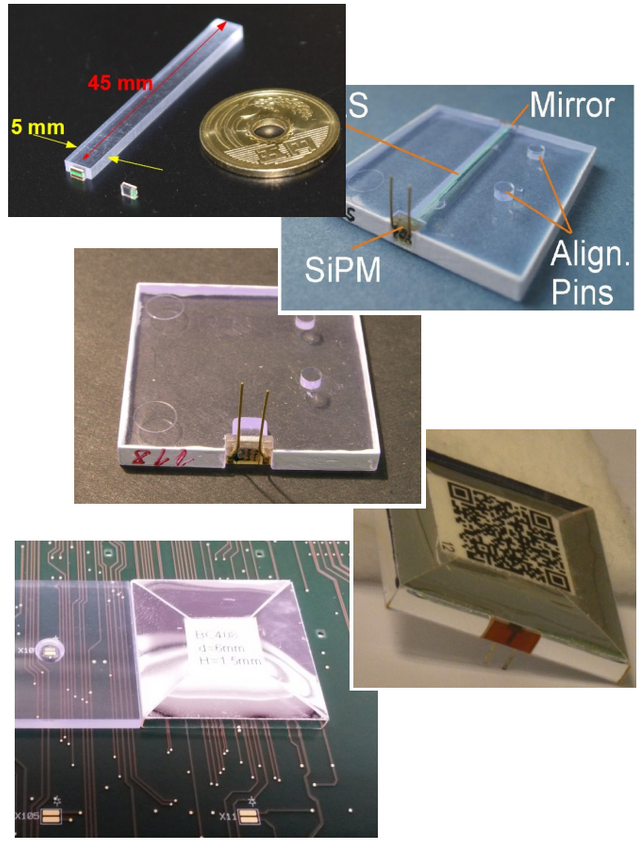
- A 15 layer e.m stack will be constructed in 2016 for electron measurements and power pulsing tests .
  - Absorber structure will be produced in the MPP mechanical workshop
- Experience in test beams with different technologies will give important information to choose 1 tile design and 1 SiPM option

AHCAL test beam at SPS '15

- Two beam test periods this year:
  2 weeks in July and 2 weeks in August
- Gain experience with a variety of tiles and SiPMs
  (different layers with different SiPMs/tiles installed)
- First test beam with 2nd generation electronics
  (giving timing information)
- 10 (11) small layers and 4 big layers with steel
  (tungsten) absorber



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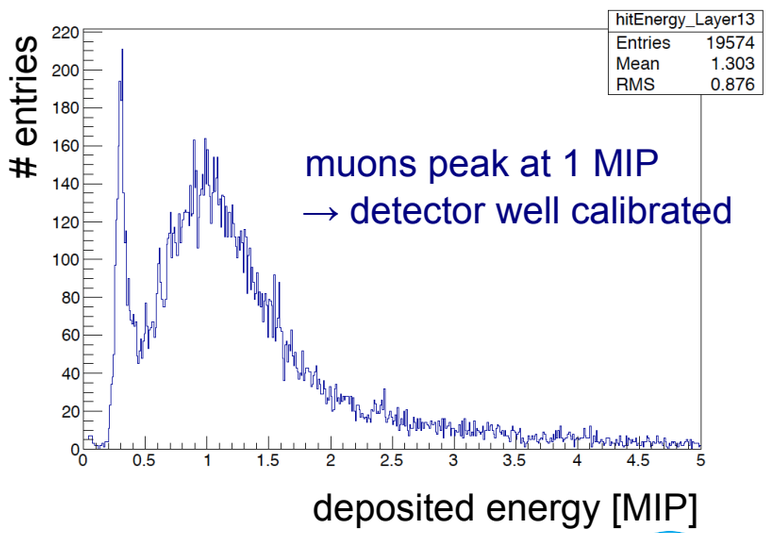
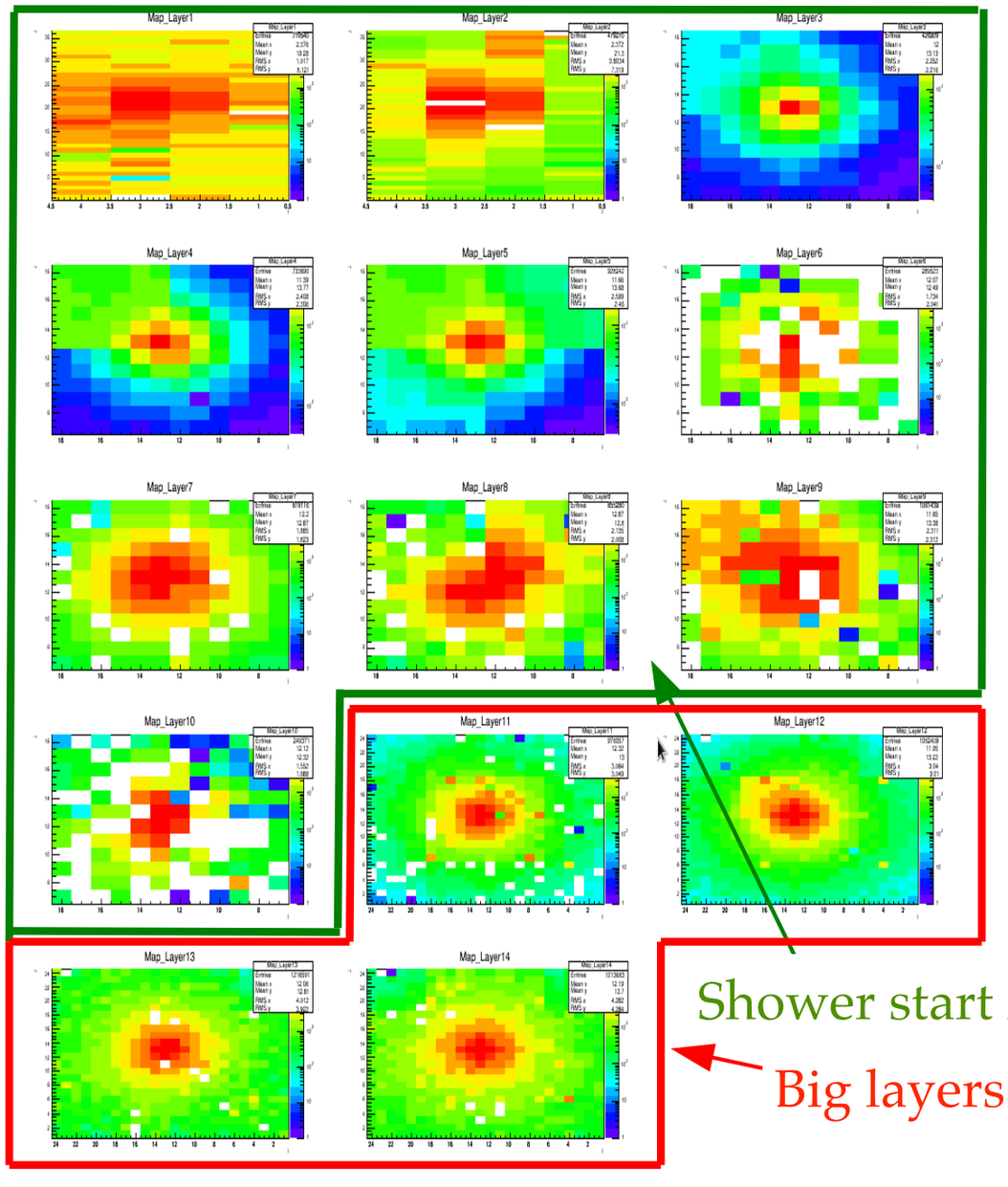
- 10 (11) small layers and 4 big layers with steel (tungsten) absorber
- Succesfull operation
  - DAQ stable, capable of integrating also ECAL
  - Data taken with muons (calibration),
    pions (10 -90 GeV, high stats at 50 GeV),
    electrons (10 - 50 GeV) and positrons at 20 GeV



AHCAL beam test results

Steel

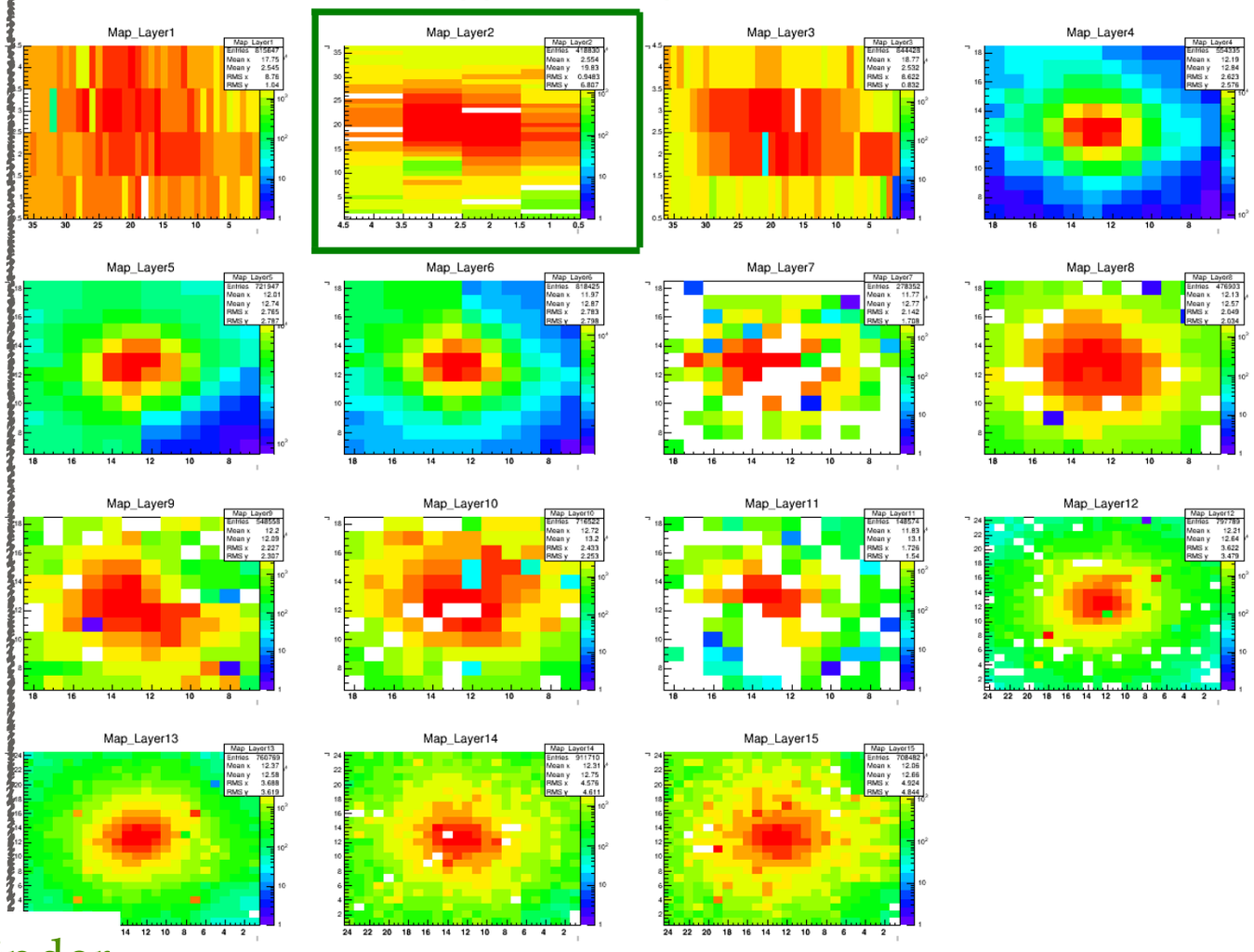


Shower start finder

Big layers

Tungsten

additional EBU with opposite strip orientation



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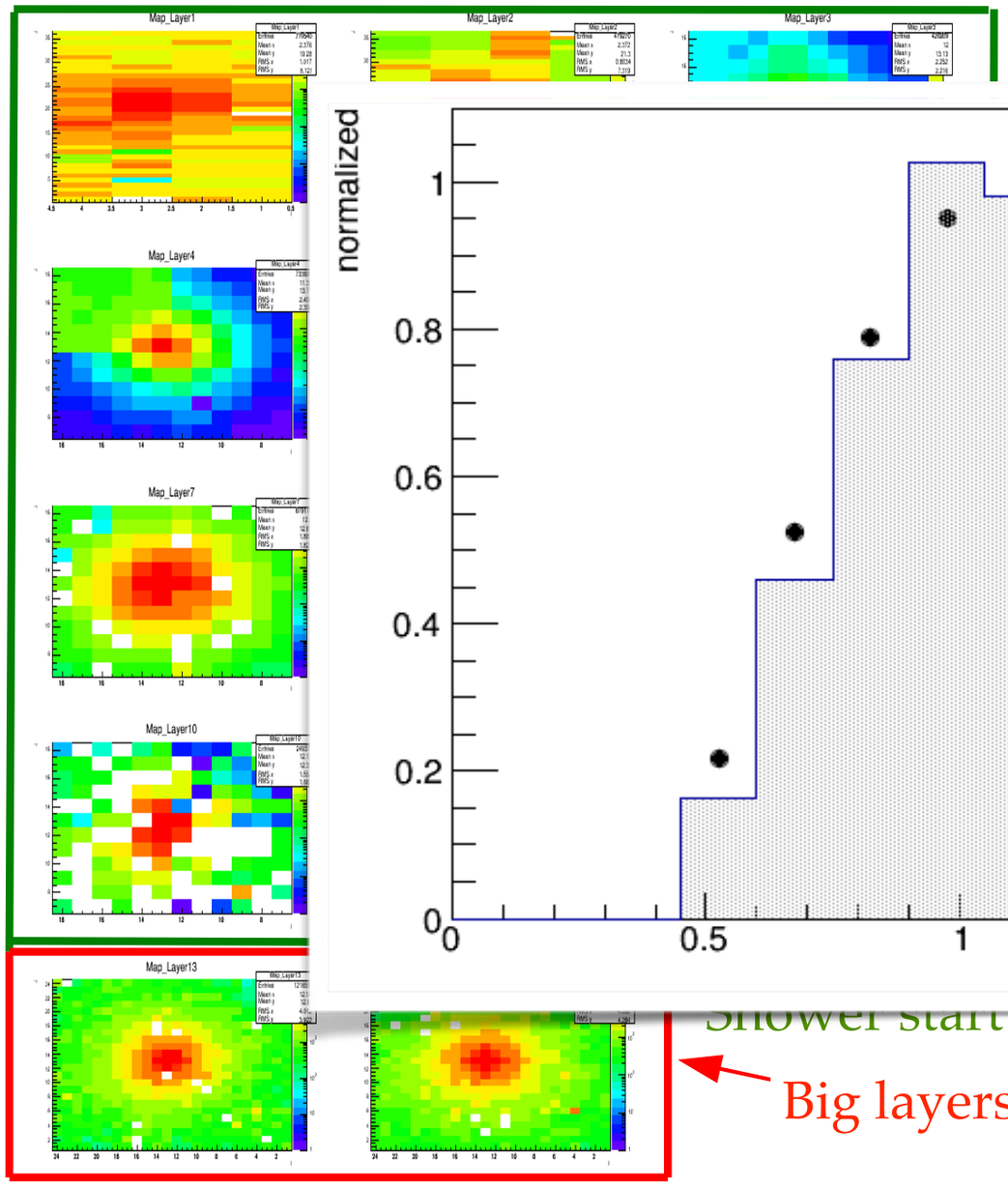

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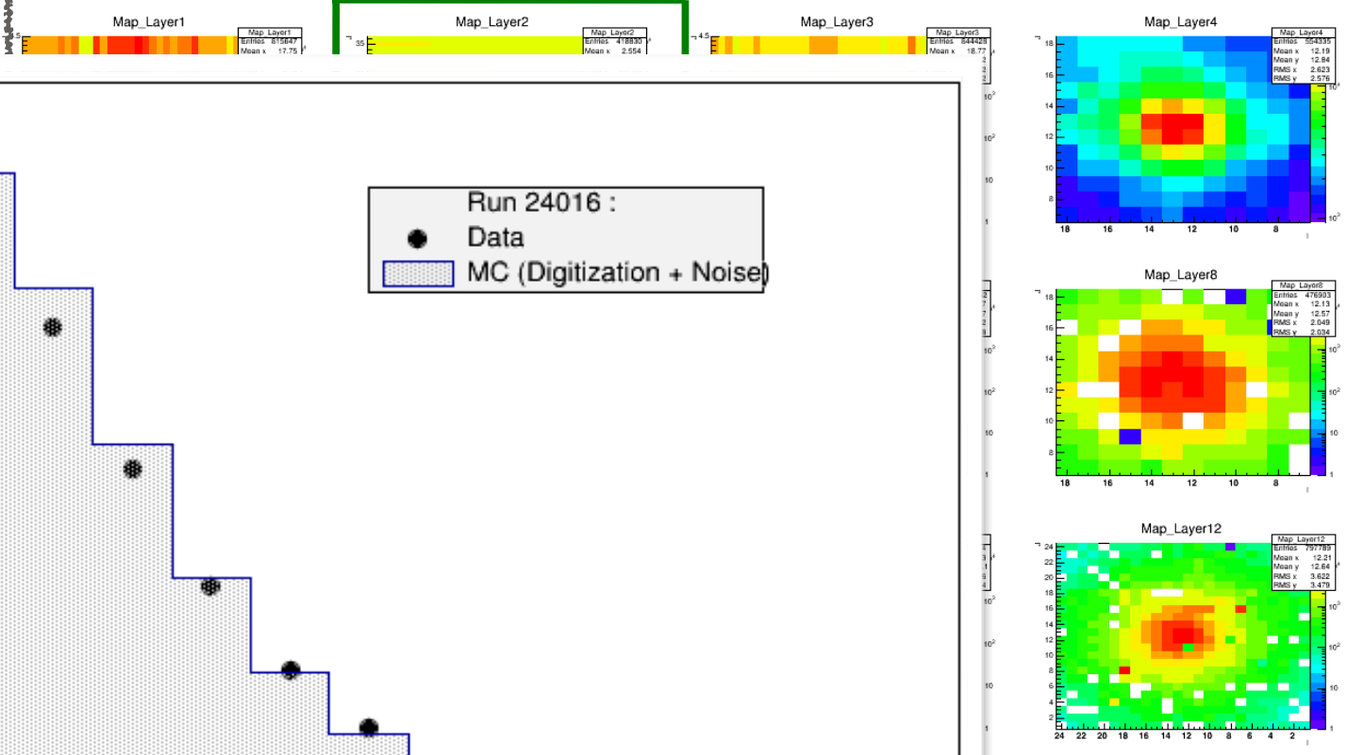
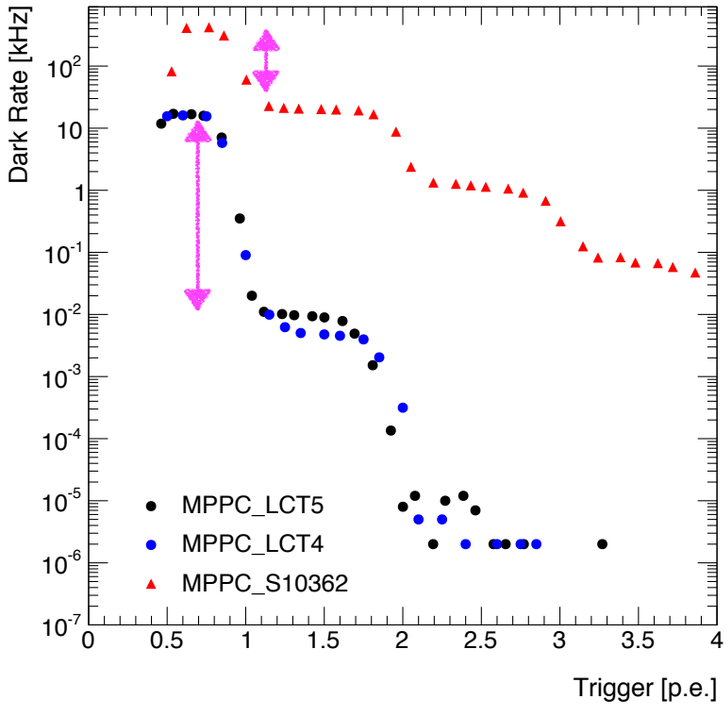


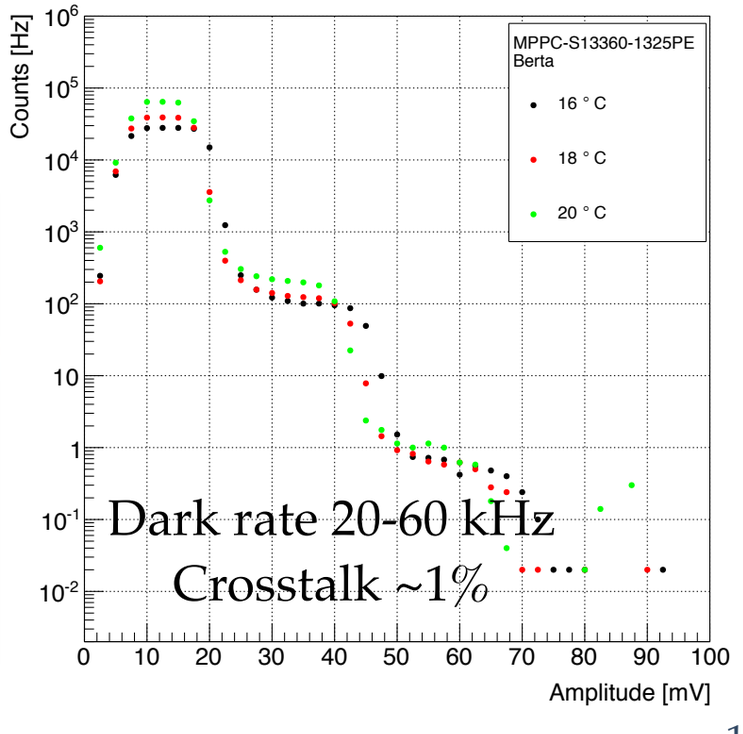
Tile and SiPM studies

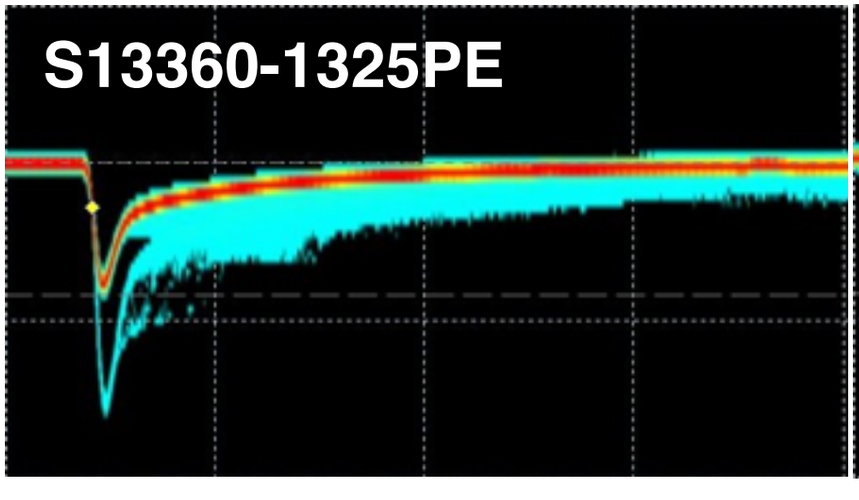
- A test setup to evaluate the homogeneity of scintillator tiles
- This infrastructure will be updated as part of AIDA^{2020} (~3 M€)
  - Higher energy electron source, climate chamber, larger scanning range, low noise SiPMs, new DAQ and analysis package (LabView based)
  - part of Work Package 14 (~100 k€)
    WP coordinators: Frank Simon and Roman Pöschl
- Default scintillator tiles prepared at the MPP plastic workshop
- SiPM amplifier boards prepared at the MPP electronics department

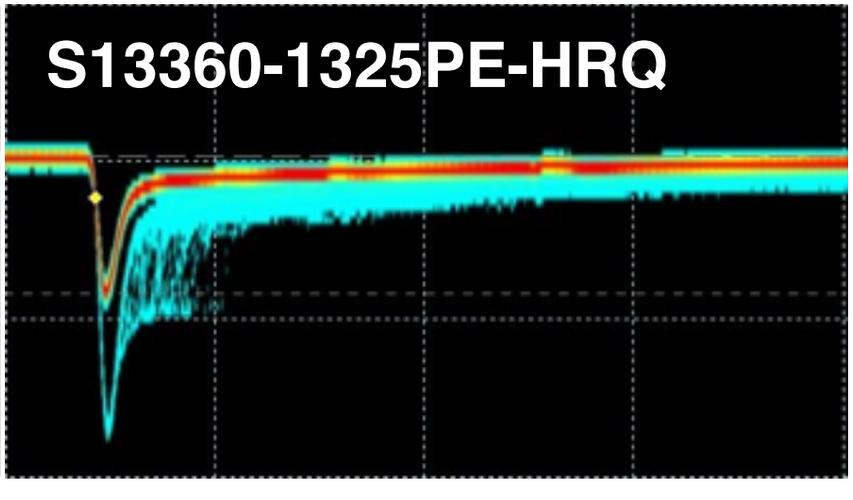
Testing SiPMs

- New generation SiPMs have a lower dark rate and very low inter-pixel crosstalk
- Very promising for AHCAL, CLAWS, upgraded scanning setup



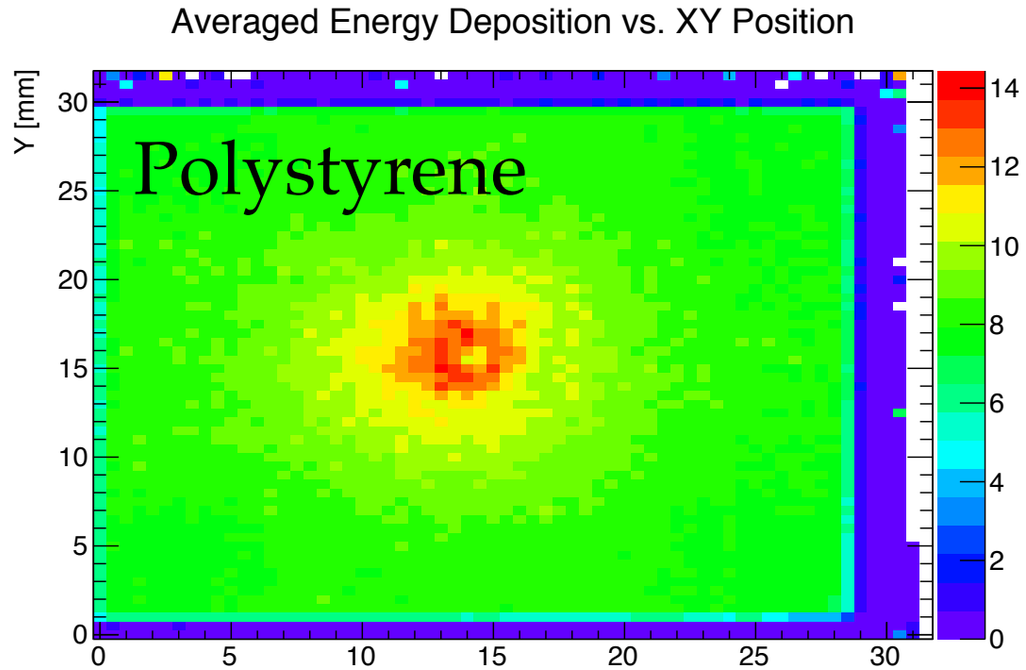


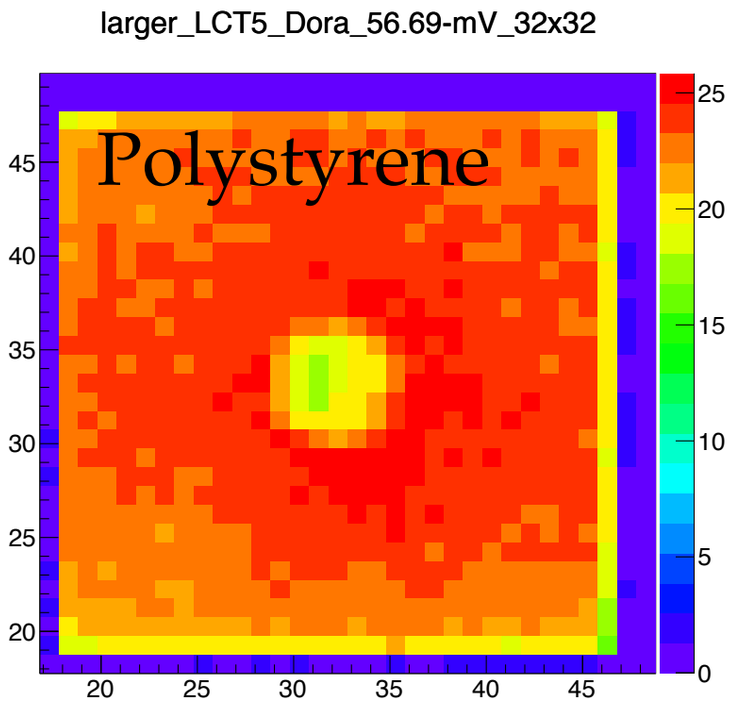


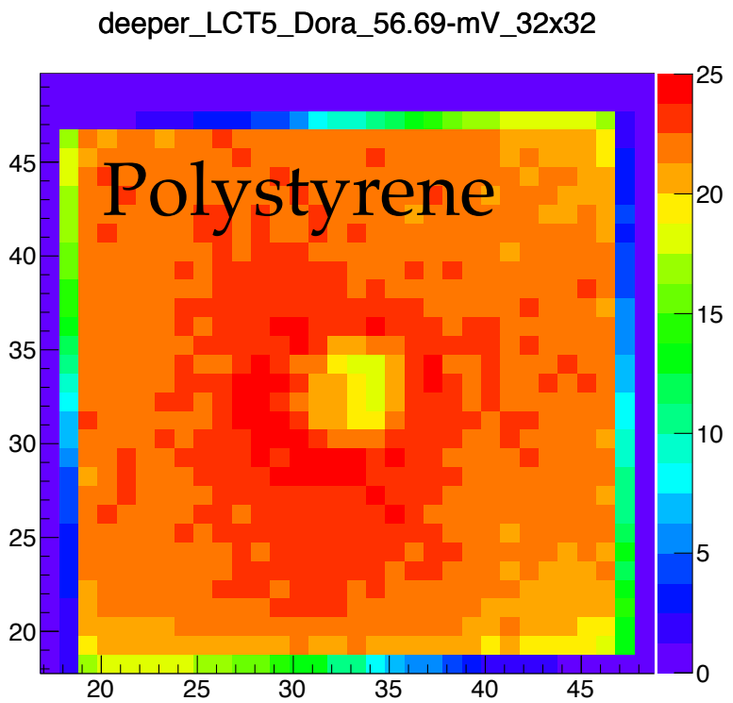


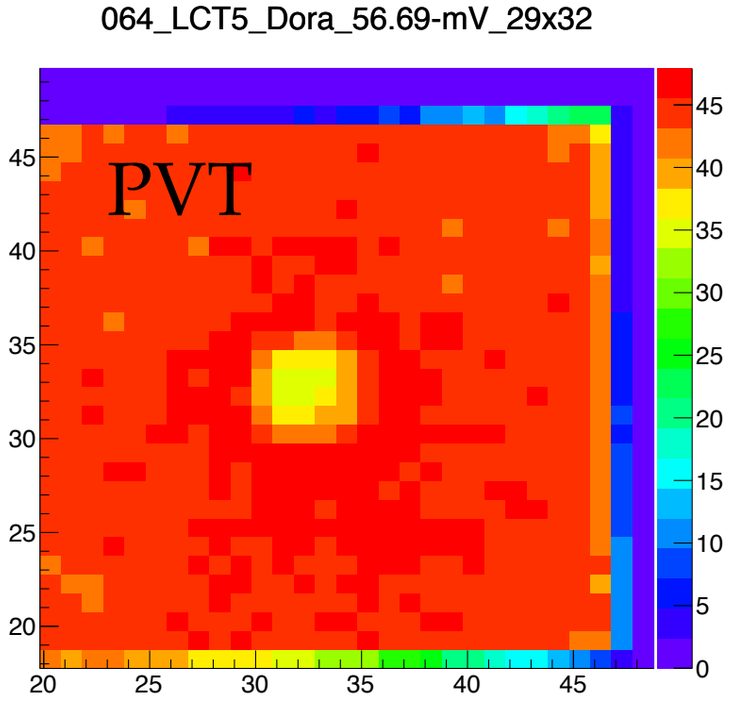
Scintillator uniformity scans

- Testing different tile shapes
- Testing different materials



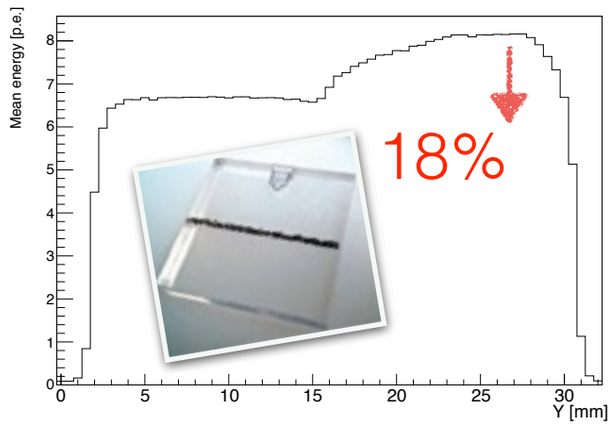


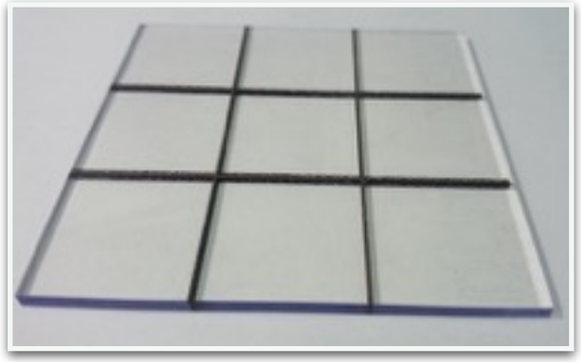


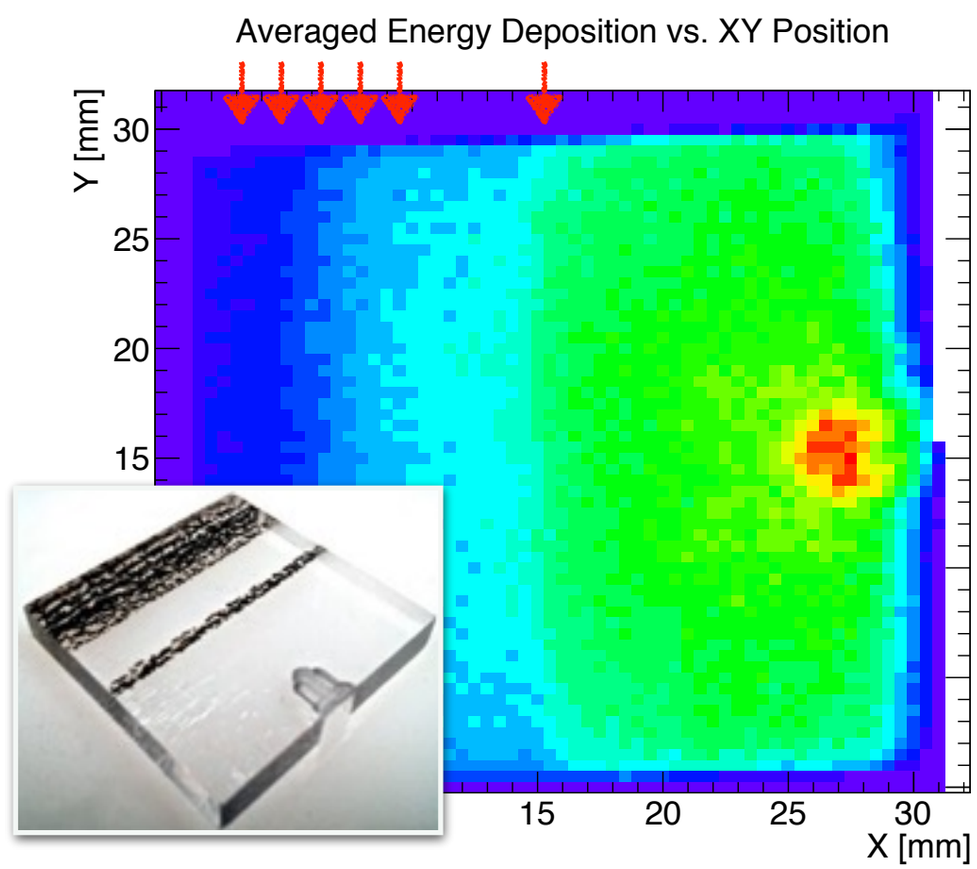


Scintillators for large scale prototype

- Test: optically isolate neighbouring channels in a megatile: subsurface laser engraving -> mechanical stability, mass producible
  - First tests on PVT plastic -> separation not so good
  - New tests on plastics from different suppliers (PVT, polystyrene) Tiles machined at MPP in the plastic workshop
    - so far: surface damaged by lasering process
- Upcoming tests: Injection moulding with alternative scintillator material - potentially cost-effective for large numbers of individual tiles.
  - Material also of interest for Gerda/GeDet: Common study

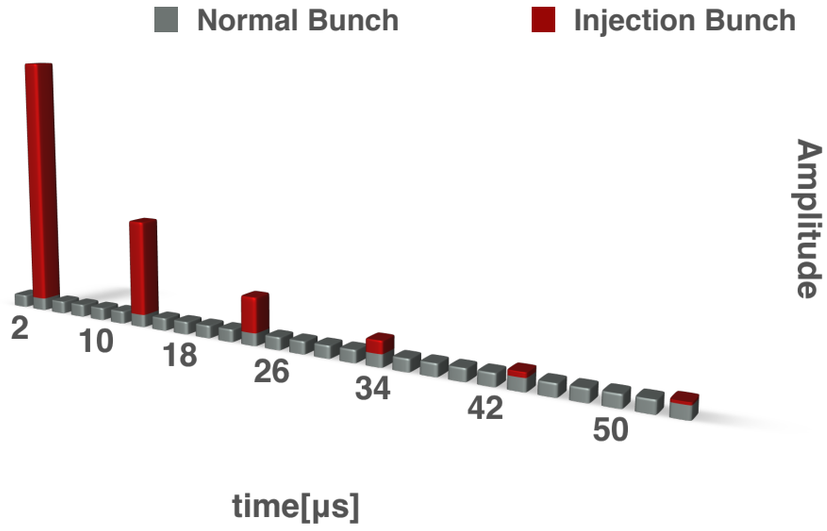




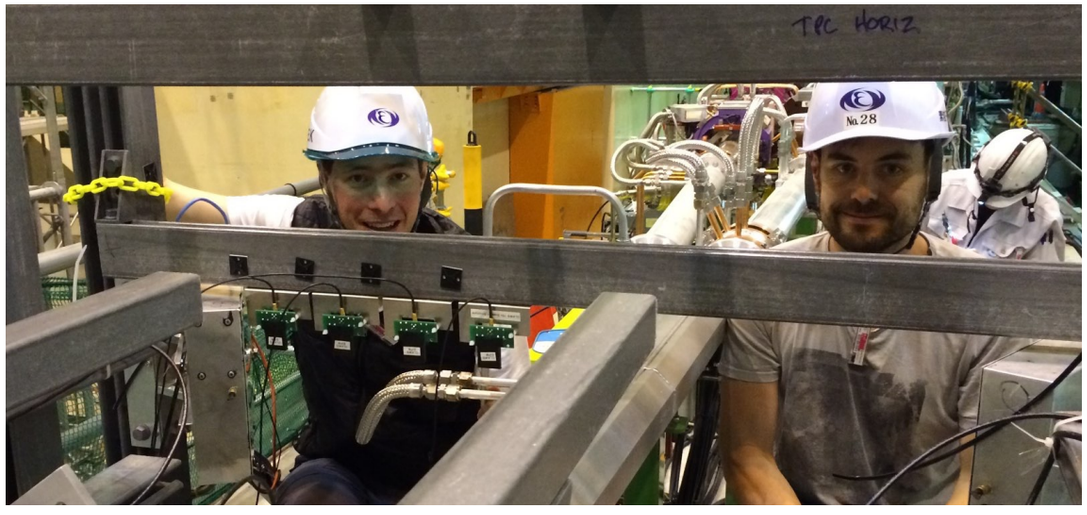


CLAWS

- Collaboration with the Belle II group in the commissioning phase of SuperKEKB and Belle II
  - SuperKEKB Commisioning Detector: BEAST II
  - Measure the beam backgrounds at IP
  - Start of commissioning February 2016
- CLAWS
  Scintillation Light And Waveform Sensors
  - Measure the time dependence of the backgrounds -> injection bunches
  - Fast timing needed and high sampling rate over extended times -> T3B (tiles and SiPMs from CALICE project)
  - Installed in BEAST II at KEK in Sept. ’15
  - DAQ in development



CLAWS



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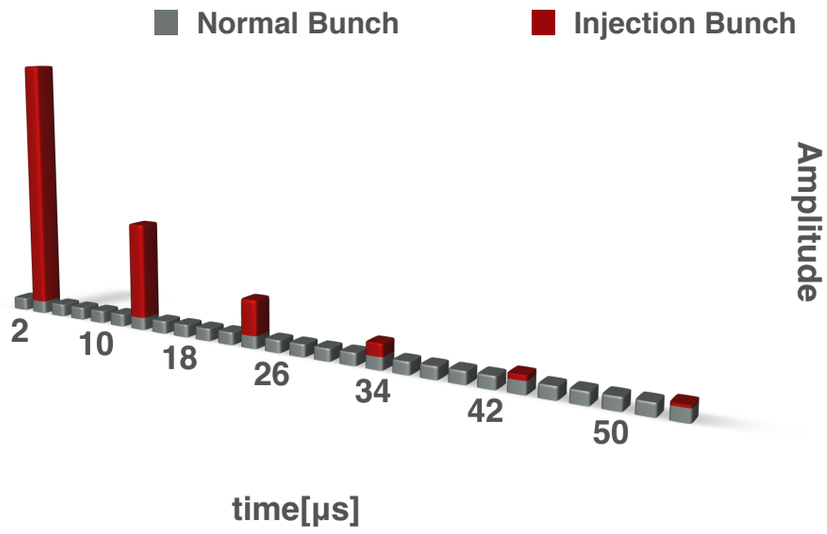

CLAWS

- Developing an upgrade for the first commissioning phase (end of January ‘16)
  - Employ new generation SiPMs: much lower noise and cross talk
  - More radiation hard scintillators
  - New amplifier boards thanks to MPP electronics department

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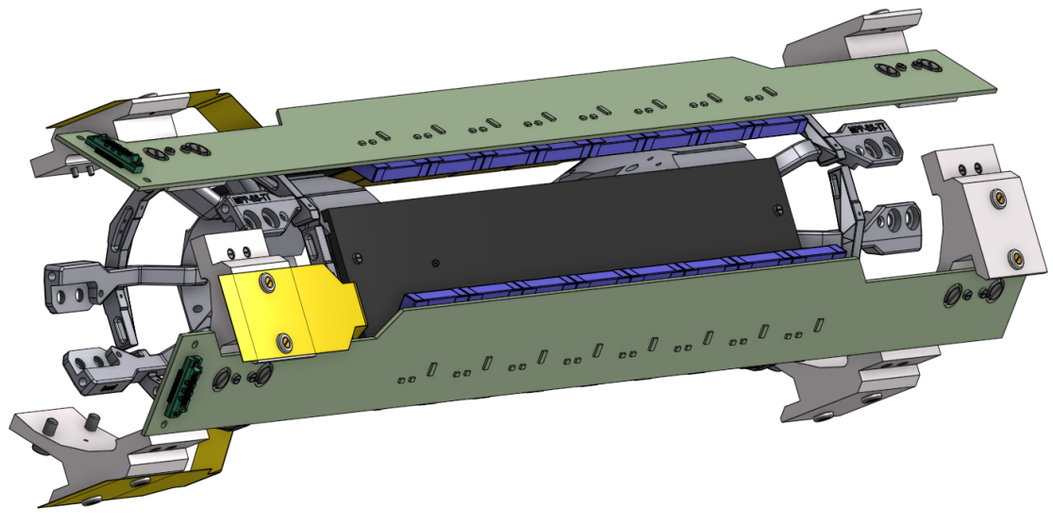
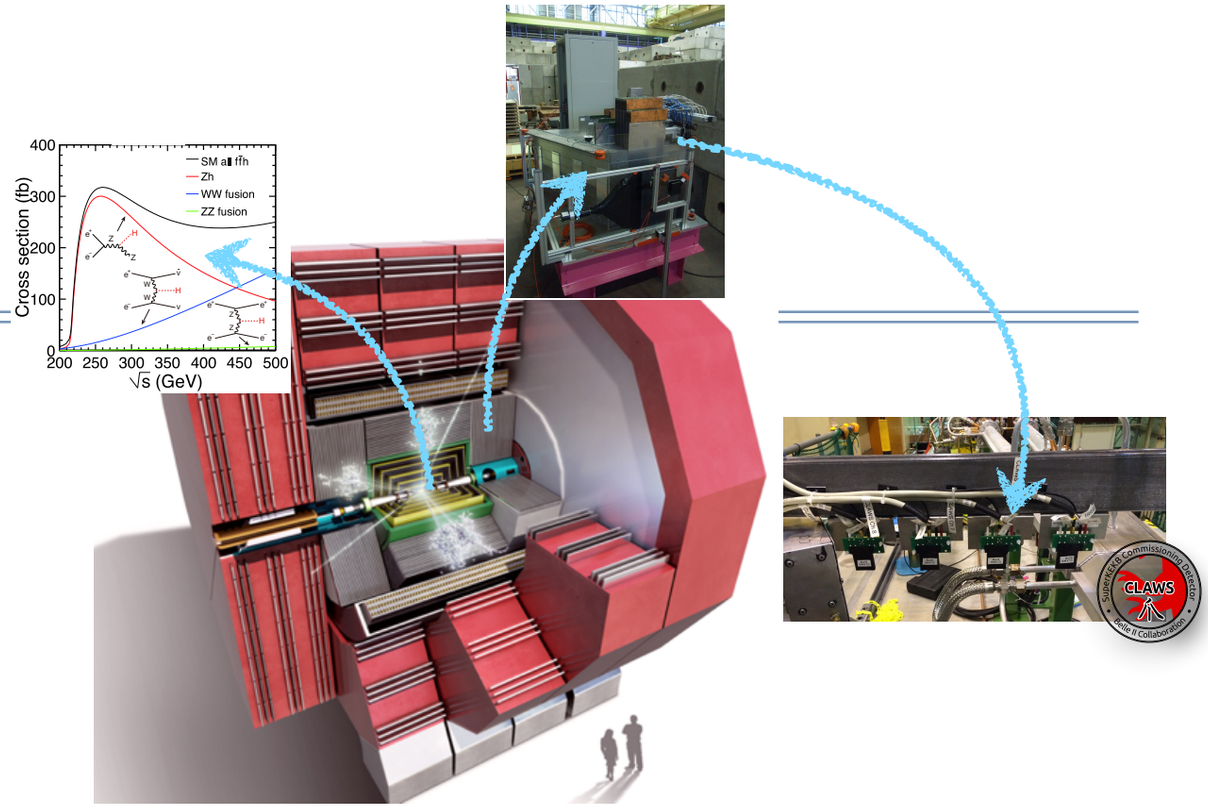
- Developing an upgrade for the first commissioning phase (end of January ‘16)
  - Employ new generation SiPMs: much lower noise and cross talk
  - More radiation hard scintillators
  - New amplifier boards thanks to MPP electronics department
- Phase 2:
  - Measure time dependence of background in the region of the *PXD* of Belle II
  - Similar hardware as for phase 1 upgrade, much closer to the IP
  - Concept exists, details to be worked out



Summary



- Contributions to
  - Physics studies at linear colliders; Higgs, Top, Squarks
  - Calorimeter R&D; construction of prototypes, test beam operation, testing components, tile scanning
  - Commissioning of superKEKB; CLAWS