Search for Hidden Particle (SHiP)

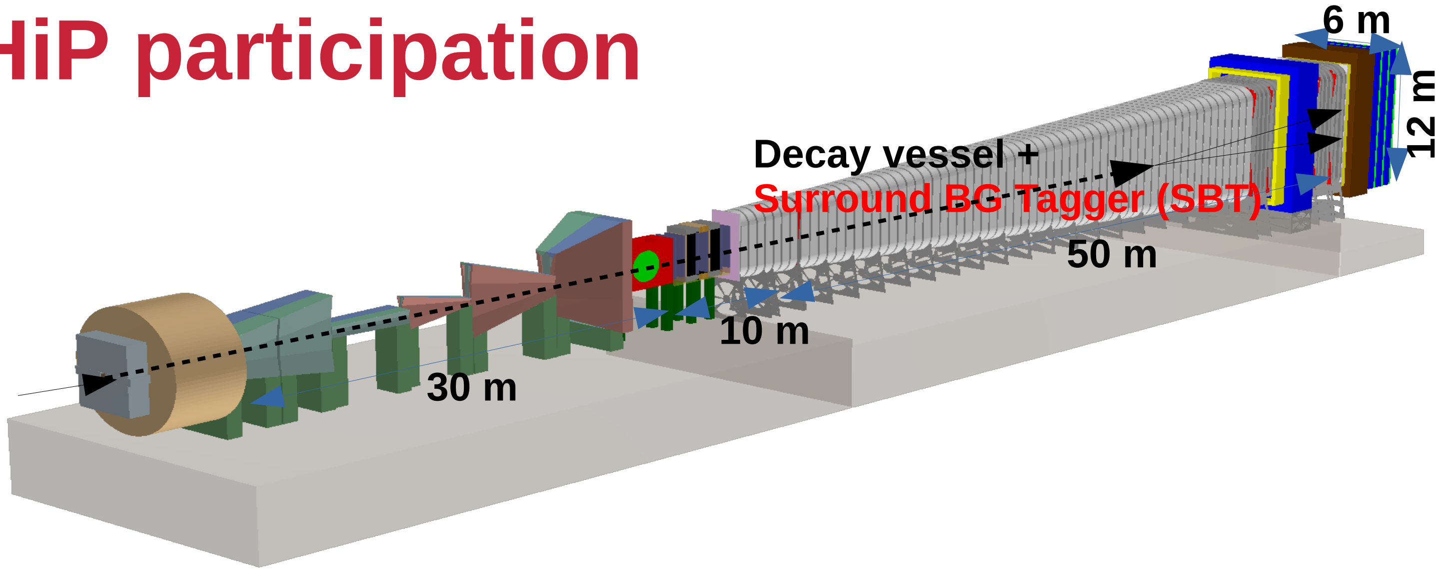
A „Flagship“ of the Physics-Beyond-Collider projects
in the CERN diversity strategy

TDR topics in the area of „Querschnittsthemen“

Heiko Lacker, HU Berlin

12.5.2020

German SHiP participation



- Straw Tracker (SST)
- E.M. SplitCal

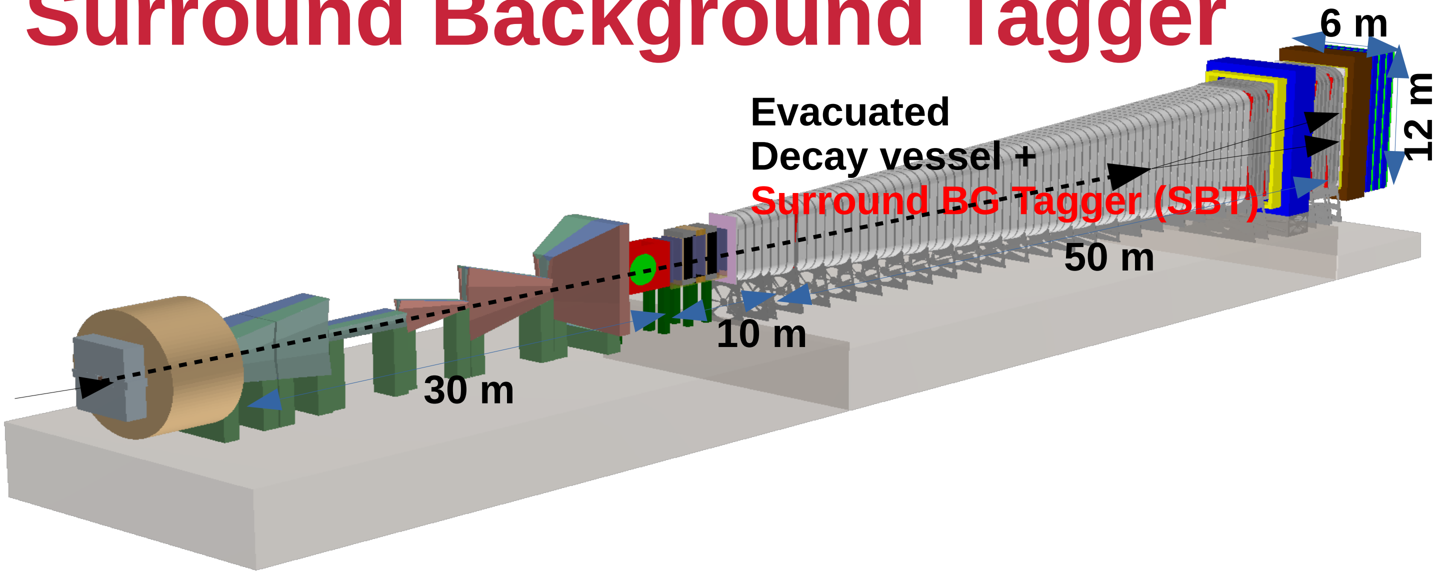
...

	Berlin	Bonn	Freiburg	Hamburg	Jülich (ZEA-2)	Mainz
SBT	Lacker Issever		Schumann Fischer		van Waasen	Wurm
SST				Hagner Haller	van Waasen	
SplitCal						Büscher/ Wanke
μ flux & charm prod.		Cristinziani		Hagner		

SHiP collaboration: 50 (+ 4 associated) institutes + CERN + JINR, 18 countries

Subdetectors with co-convenership from German groups

Surround Background Tagger



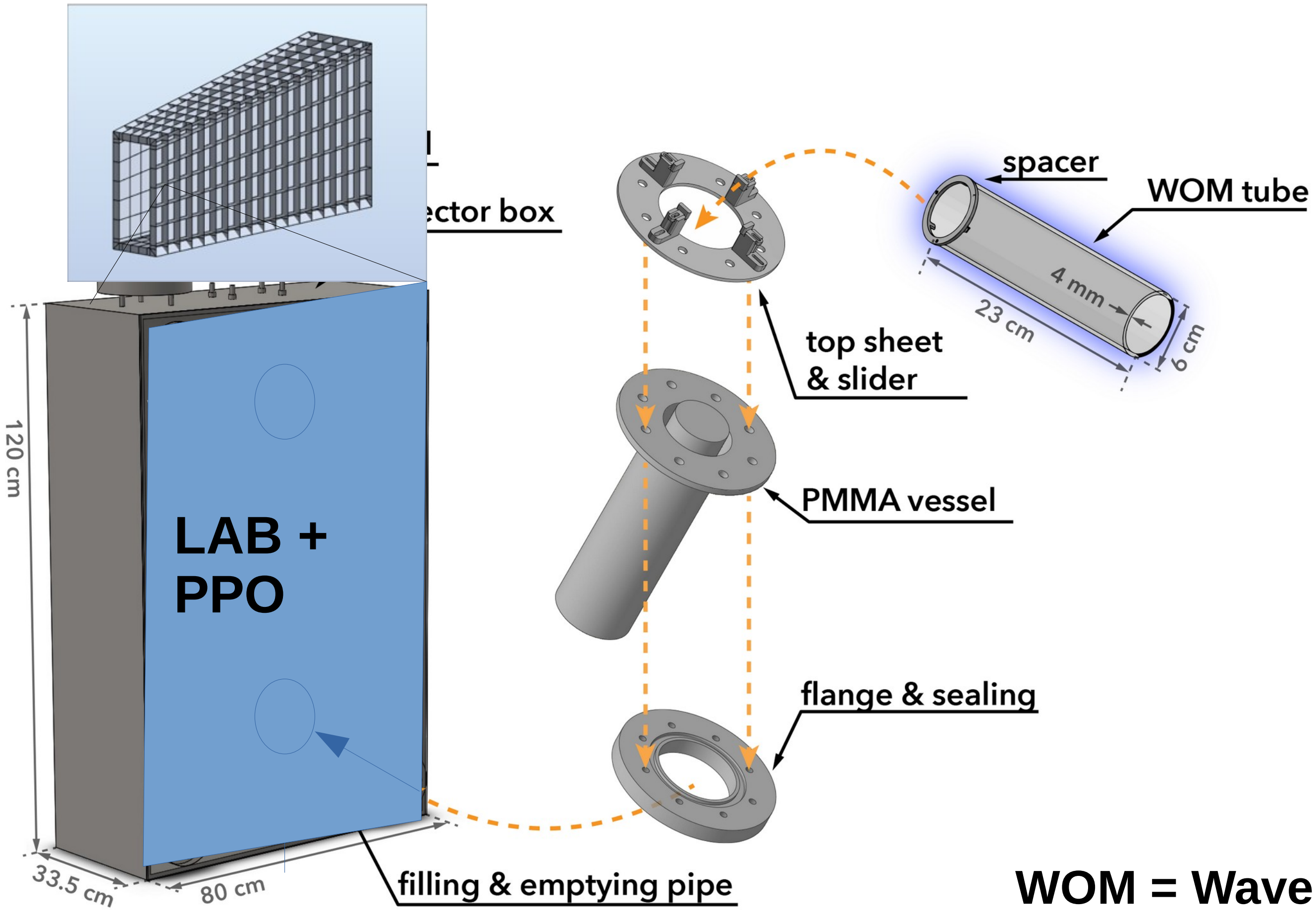
1) Veto: * Detection of charged particles (muons) entering the decay vessel from outside

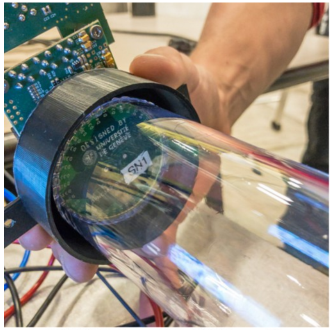
* Detection of ν DIS in decay vessel walls

2) Extend signal efficiency for $N \rightarrow l^{-}\rho^{+} \rightarrow (\pi^{+}\pi^{0})$

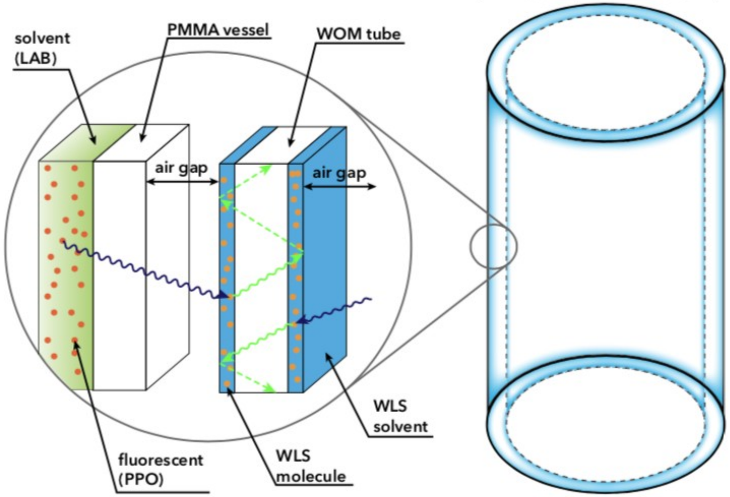
LS-based Surround BG Tagger (SBT)

Optical coupling to 40-SiPM ring array





WOM tube with WLS coating
(PMMA vessel & liquid-scintillator not shown)



WOM = Wavelength-Shifting Optical Module
(first proposed for IceCube extension)

LS-SBT: SHiP-specific and of general interest

* High efficiency (99.9%) and homogeneity over cell area

* High-transparency materials (scintillator, PMMA)

* Alternative WLS; separation btw Cherenkov & scintillation light

* ns Timing & energy share btw WOMs in same/adjacent cells
  → BG suppression
  → spatial resolution
  → particle direction
  → e/γ identification from preshower

* SiPMs: dynamic range; onboard powering and LED calibration; cooling (?)

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* Possible further WOM application beyond SHiP:
  Plastic-scintillator sandwich calo with → small #channels per area
  → reasonable spatial resolution
  → longitudinal shower info

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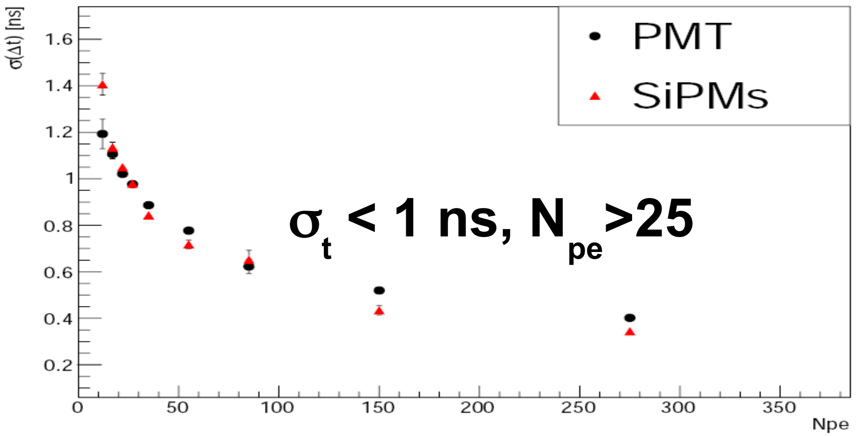
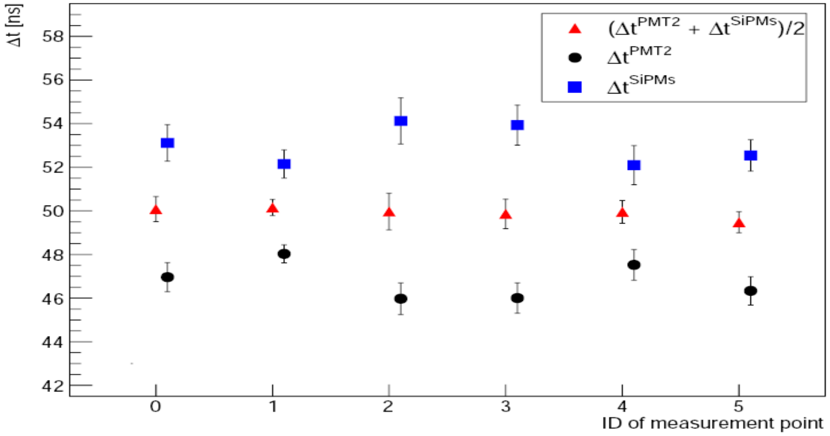
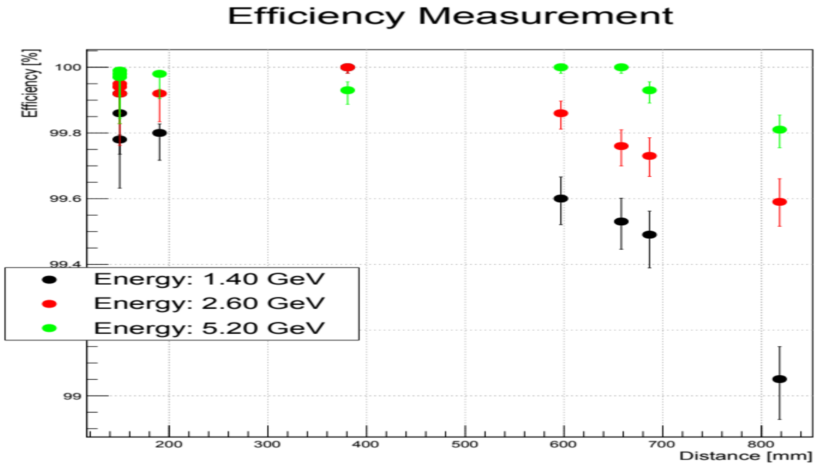
P. Mermod[c], J. Schliwinski[a], L. Shihora[a], P. Venkova[a], M. Wurm[b]

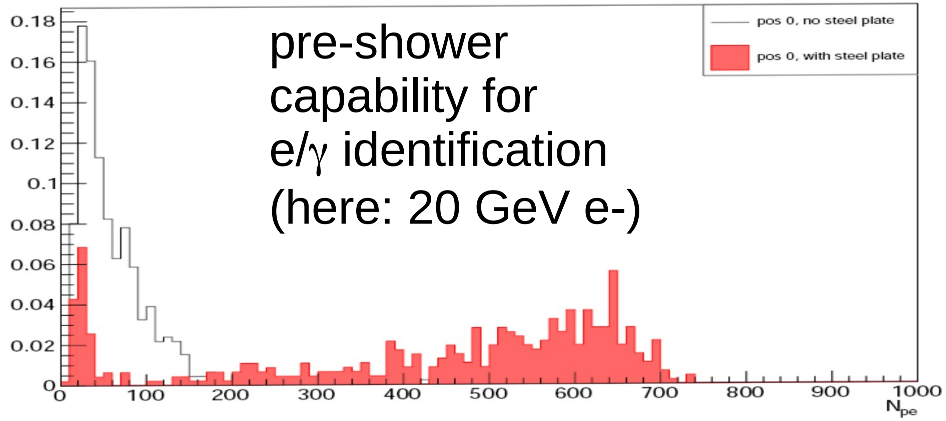
JINST 14 (2019) no.03, P03021, arXiv:1812.06460

Proof-of-principle measurements with a liquid-scintillator detector using wavelength-shifting optical modules

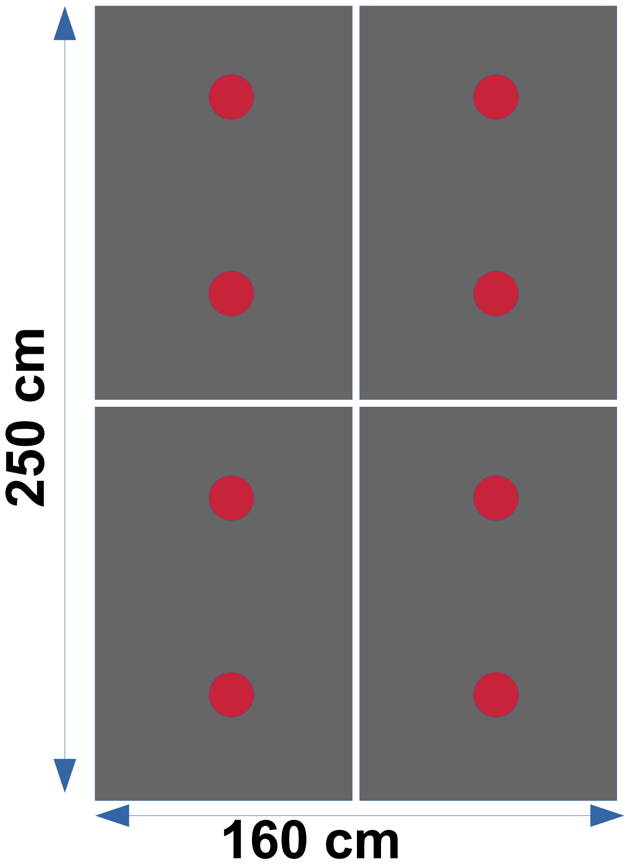








TDR phase: 4-cell demonstrator detector

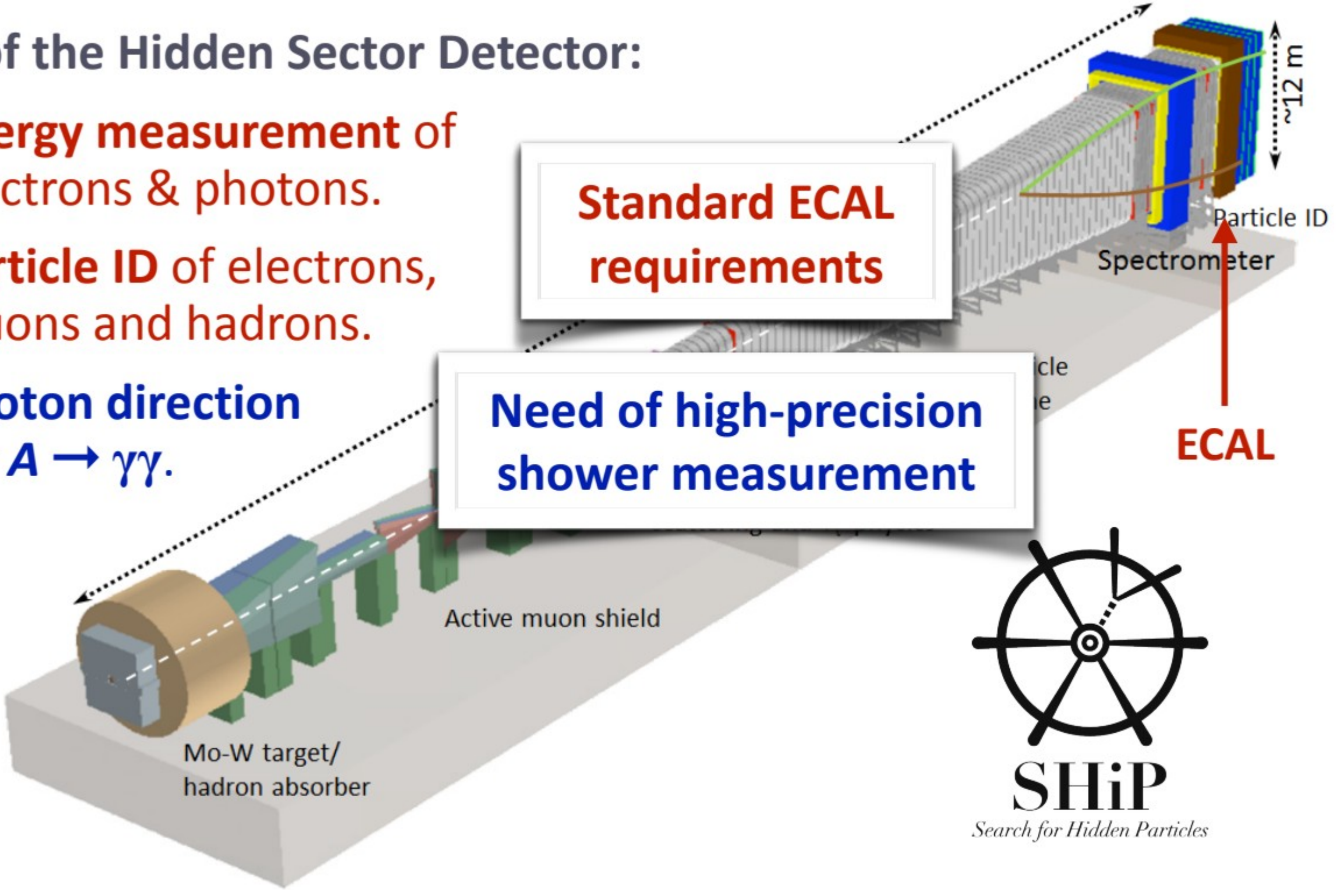


- **Testbeam measurements in 2023**
- **Test version of FE, concentrator electronics, and SiPM PCB w/ powering, LED calibration, (cooling)**
- **WOM design**
- **Demonstrate detector requirements and combine adjacent cell info**
- **Address (decay-vessel) integration questions: reflectivity coating, LS filling and emptying**

The Electromagnetic Calorimeter

ECAL of the Hidden Sector Detector:

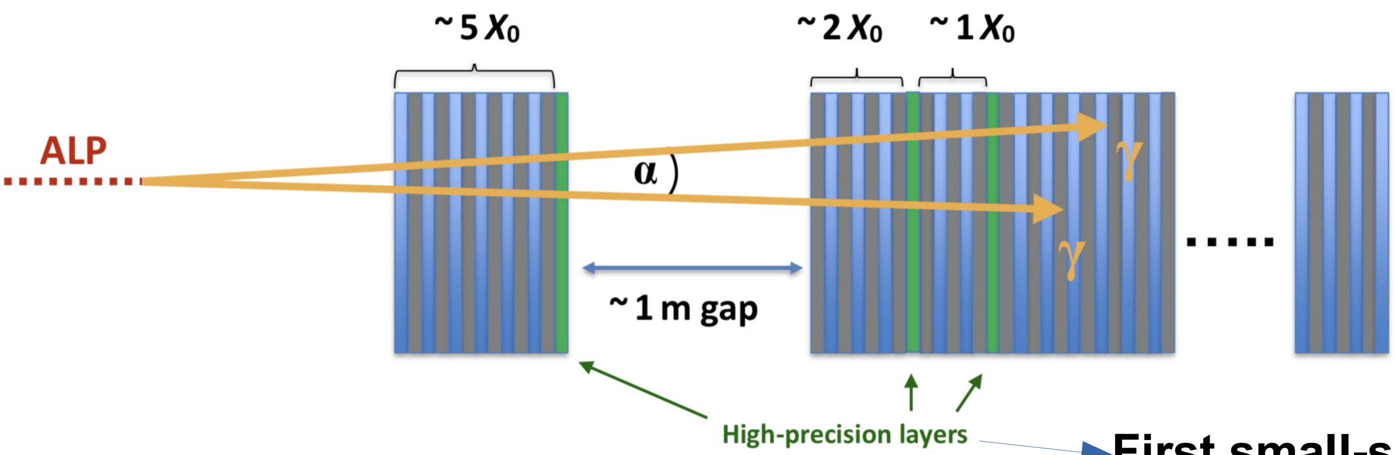
- **Energy measurement** of electrons & photons.
- **Particle ID** of electrons, muons and hadrons.
- **Photon direction** for $A \rightarrow \gamma\gamma$.



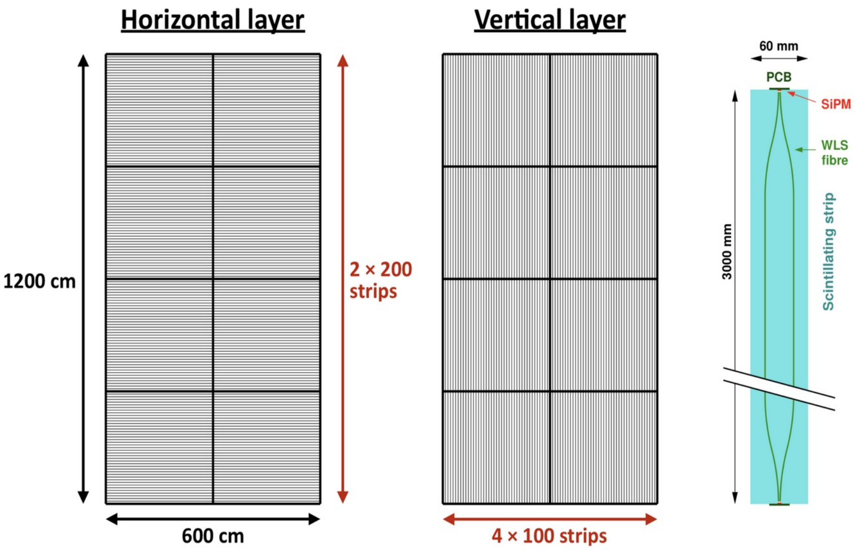
Standard ECAL requirements

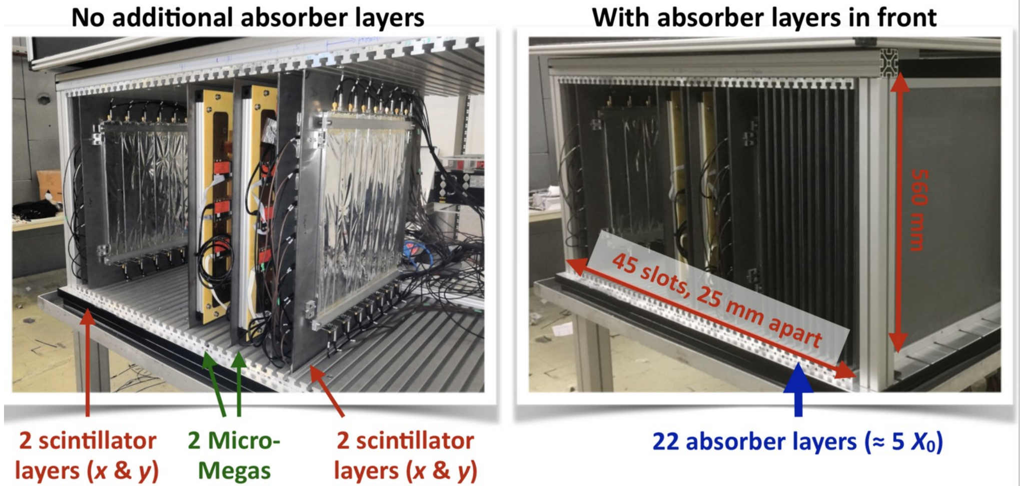
Need of high-precision shower measurement

„SplitCal“ Baseline Design

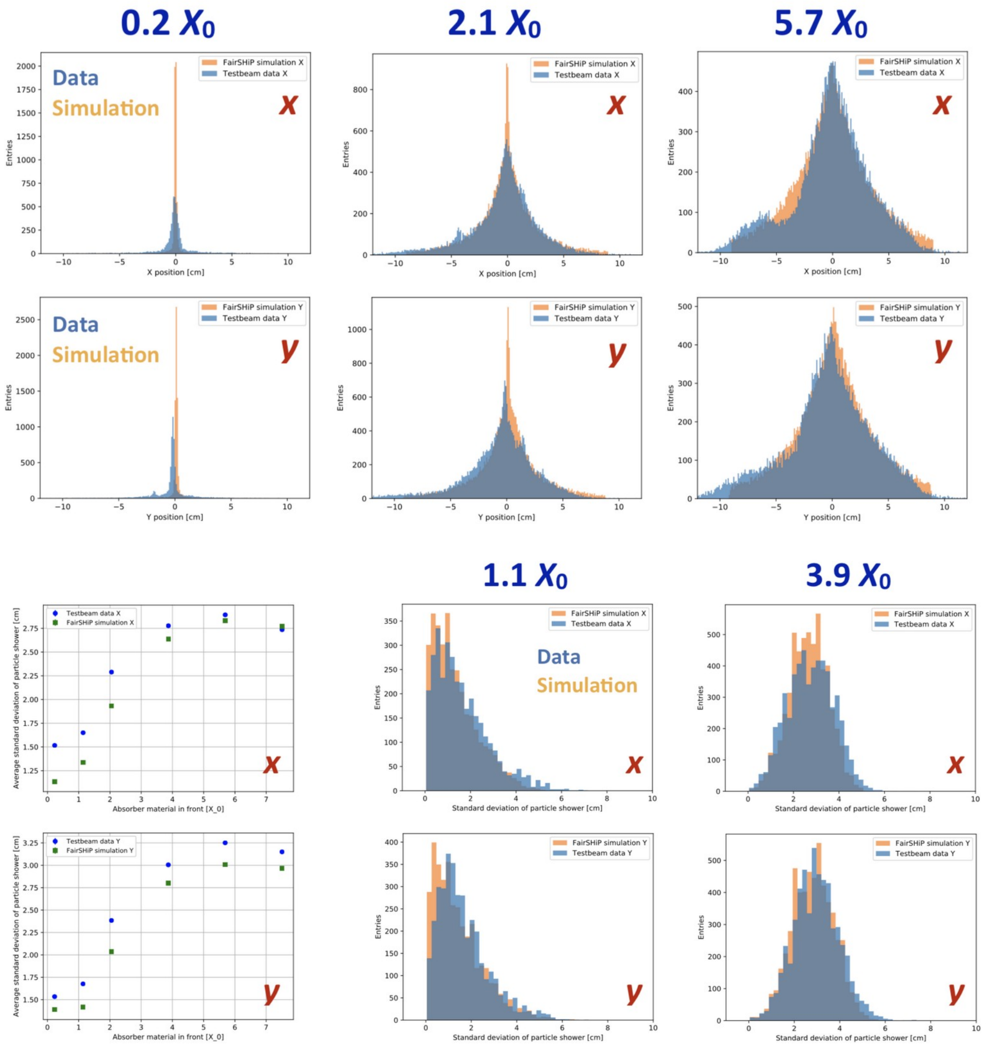


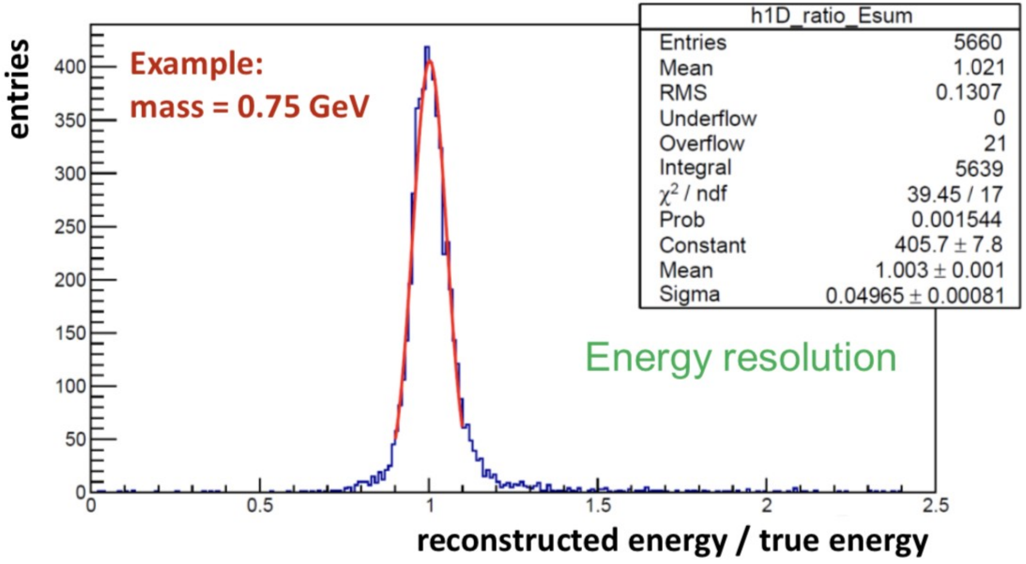
First small-scale prototype w/ ATLAS upgrade MicroMegas





SplitCal: Performance



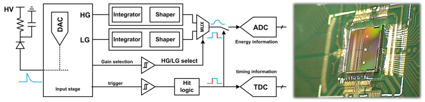


TDR phase

Scintillator SiPM Readout

- **Prototype readout too expensive** (and clumsy) for $\mathcal{O}$(40k) channels.
- **Better: ASICs near SiPMs** for signal collection & digitization.

  Requirements:
  - Large dynamic range (MIPs as well as e.m. showers).
  - SiPM calibration.
  - Multiplexed digital output because of high # of channels.



(Z. Yuan)

KLauS chip from Uni Heidelberg is an option

Main R&D topic at the moment.

Technological prototype

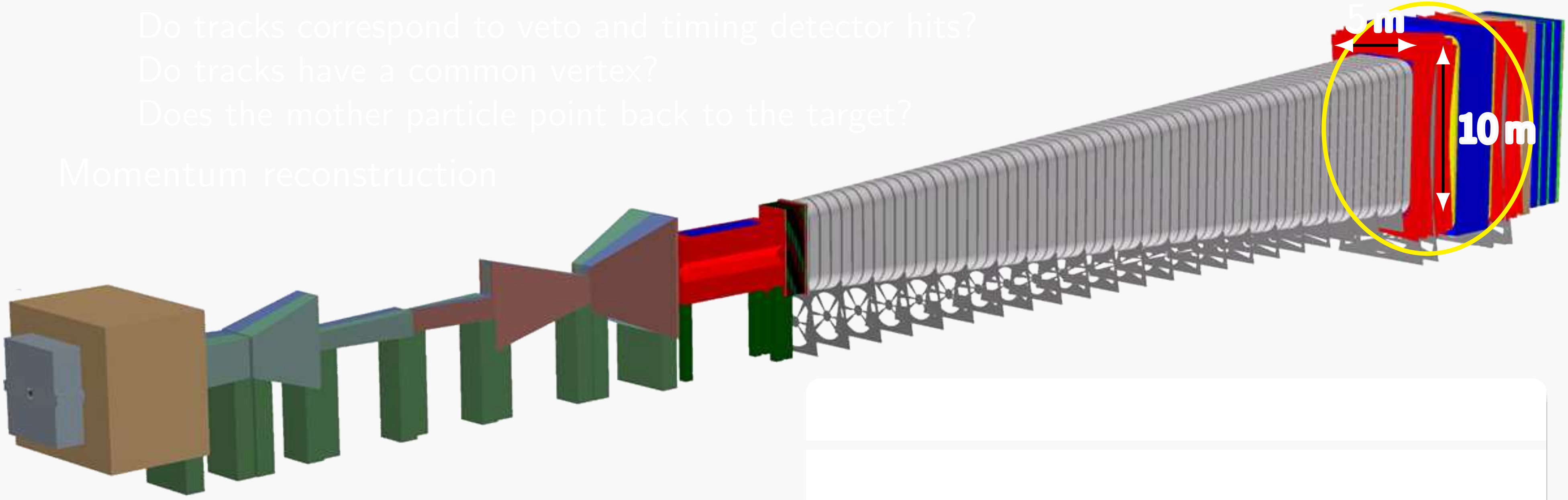
Next step: ***Technological prototype***

- **Involves all required materials and technologies and demonstrates the feasibility and functionality.**
- **Front face of about 1.5 m x 1.5 m.**
- **10 scintillating layers** (5 *x*, 5 *y*) and **2 high-precision layers.**
- **500 SiPM channels** and **25200 MicroMegas channels.**
- **Close to final Readout** with ASICs.
- **Mechanical integration.**

To be built for the TDR

Spectrometer Straw Tracker (SST)

- Reconstruct tracks of charged particles
  - Do tracks correspond to veto and timing detector hits?
  - Do tracks have a common vertex?
  - Does the mother particle point back to the target?
- Momentum reconstruction



Straw Tubes

Suitable technique

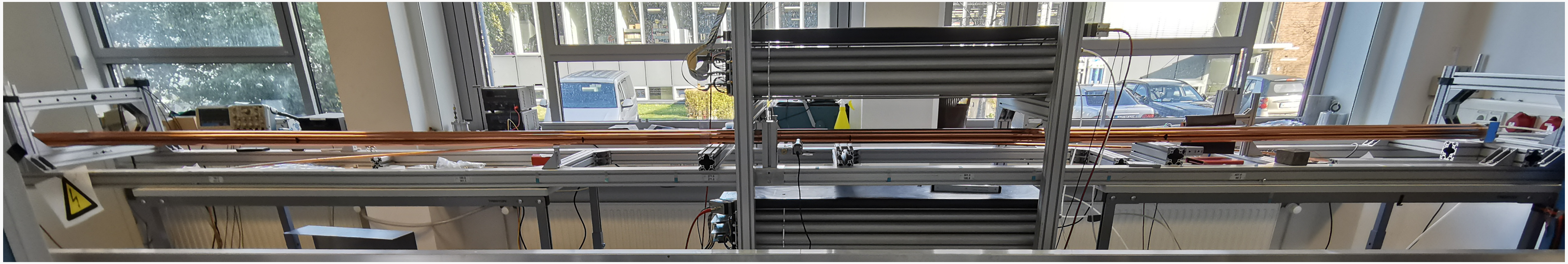
Wall thickness	36 μm
Coating	Au (20 nm), Cu (50 nm)
Diameter	2 cm
Length	5 m

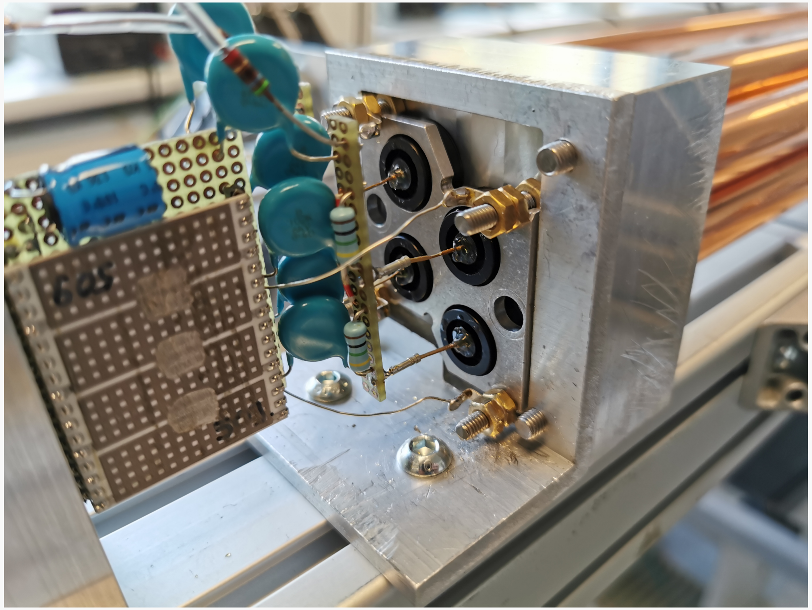
Operated with Ar/CO_2 @1 bar

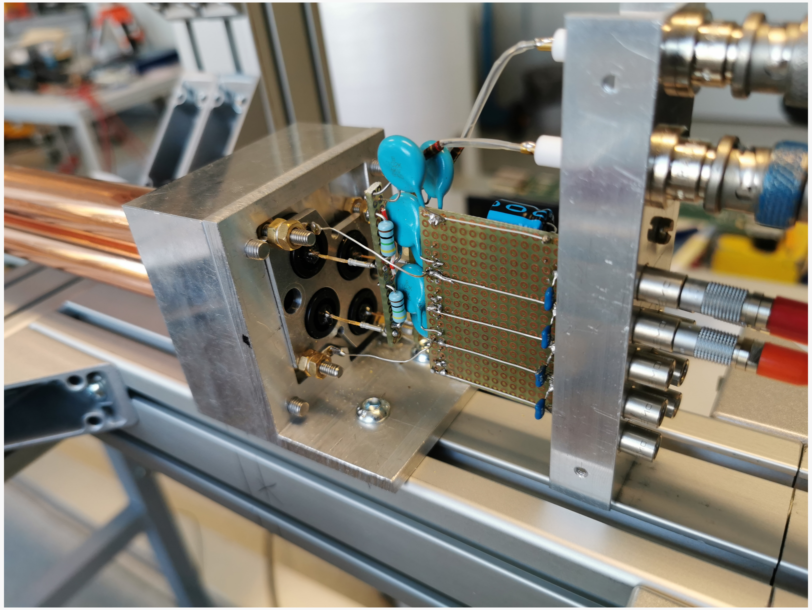
Shorter tube tested in 2017 testbeam: CERN-SHiP-INT-2019-005

But adding more challenges . . .

Prototype with Four Tubes







Summary and Outlook

- Technology well suited but mechanics challenging
- Vivid R&D ongoing
- Alternative designs under study
  - converge to one design for TDR
- Working prototype @UHH
  - Concept based on well established technology from NA62 and OPERA
  - First ever working 5 m long prototype now operating in our lab
  - Concept documented in CERN-SHiP-INT-2019-006
  - Next step: design of a 64 strawtube module
- Rough design for a frame exists (more a proof of concept) → further work needed

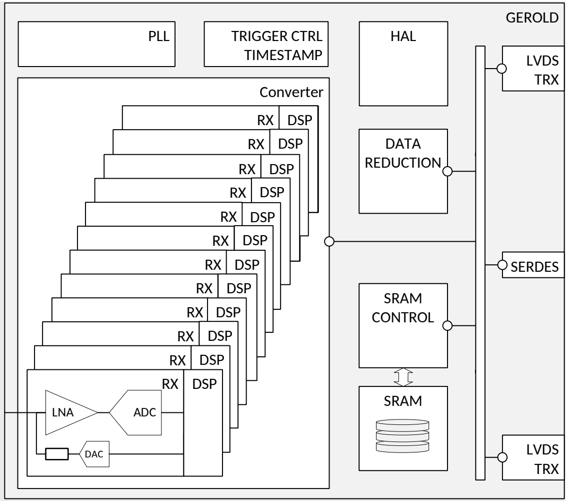
COMMON FEE: GEROLD IC AS A FRONT-END IN DETECTOR READOUT CHAIN - BENEFITS

small area (cost reduction during mass production, reliability)

- less material budget (PCB, cables, etc.)
- less total power consumption, less cables
- smaller footprint → less cooling

programmability/high functionality/scalability (cost reduction, reliability)

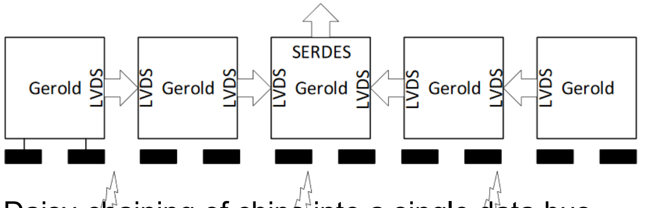
- more data analysis on chip → data reduction → less cables for data transfer
- for next stages of DAQ (e. g. concentrators) less processing power required
- feature extraction (ToT, charge, clustering) at early stages of signal processing, error correction … – reliability, data reduction, less material budget for cables, etc.
- generic readout for future detectors – a single platform with easy reconfigurability



multi-channel, programmable front end w/ A/D functionality, digital data processing, high speed communication

physics benefits (ease of use, rich functionality, reliability)

- more possibility for online data processing & data analysis close to detector sensors
- better feature extraction due to multi-channel architecture: e. g. data clustering
- single chip for different sub-detectors & experiments, generic readout for future detectors
- radiation tolerant



Daisy-chaining of chips into a single data bus allows for saving on cable costs and ease interconnection complexity

application schedule

- detector development takes 5-10 years from initial idea to start of production
- often still no time to develop new architecture, often only reuse of concepts
- GEROLD can be used to build a reference system with core functionality

→ Development of the RX chain is possible in less than 2 years from idea to mass production of the components if it is building on a flexible, highly integrated Chip!

SHiP TDR phase (2021-24): Rich program with connected topics and possible links to other R&D activities to define one or several applications in „Querschnittsthemen“

	Large area	SiPMs	Scint.	Common FE/ Concentrator	Timing	Directional/ spatial info	Shower profile	Tracker	Triggerless Readout
SBT	x	x	Liquid	x	x	x			x
SST	x			x				x	x
SplitCal	x	x	Plastic		x	„Pointing“	x	x	x
WOM-based Calo	x	x	Plastic (Liquid)	x	x	x	x		(x)