New Ideas on Detector Technology for the ILC Experiments

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on behalf of the ILC International Development Team Detector and Physics Group

30th International Symposium on Lepton Photon Interactions (LP2021)
Online, Manchester, UK, Jan. 10-14, 2022

Many forms of Linear Collider Detector R&D efforts:

Scintillator ECAL

RPC DHCAL

LCTPC

CLICPix

KPIX

SDHCAL

SOI

RPC Muon

TPAC

Dual Readout

GEM DHCAL

Silicon ECAL (ILD)

VIP

Silicon ECAL (SiD)

Scintillator HCAL

CMOS MAPS

DEPFET

ChronoPixel

FCAL

FPCCD

- **Large collaborations: CALICE, LCTPC, FCAL**
- **Collection of many efforts such as vertex R&Ds**
- **Individual group R&D activities**
- **Efforts currently not directly included in the concept groups (ILD, SiD, CLICdp), which may become important for ILC in the future**

Linear Collider Collaboration Detector R&D Liaison Report

Final release (Feb. 2021) at the end of the mandate of the LCC Physics & Detectors Exec. Board:

LINEAR COLLIDER COLLABORATION

DOI 10.5281/zenodo.4496000

Detector R&D Report

FINAL VERSION

doi:10.5281/zenodo.3749461

Editors

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LINEAR COLLIDER COLLABORATION
Designing the world's next great particle accelerator

https://doi.org/10.5281/zenodo.3749461

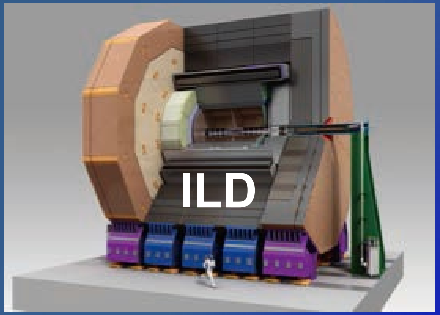
- "Publicize" particular technology and to provide an update of the recent R&D efforts (through ~ 2020)
- Provides a "snapshot" for a given technology, without information on manpower needs and financial resources to reach project milestones
- Provides an entry point for new groups in order to help them learn about the current landscape of ILC R&Ds
- No specific choices are made / keep various options for technologies to realise the individual sub-detectors → advantage that technologies can be further advanced until the project is approved.

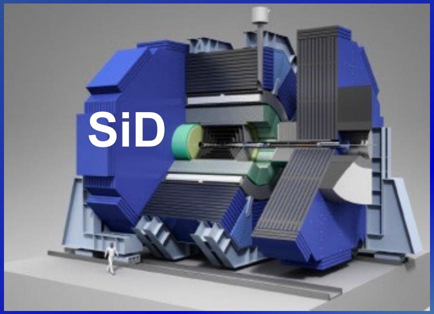
Some « New ideas » (not included into the R&D Liaison Report) are presented in this talk from ILCX2021:

https://agenda.linearcollider.org/event/9211/

Furthermore — and as important — this keeps a broad community of R&D groups at universities and labs involved and increases the chance to arrive at the best technically possible solution when ILC has to be built.

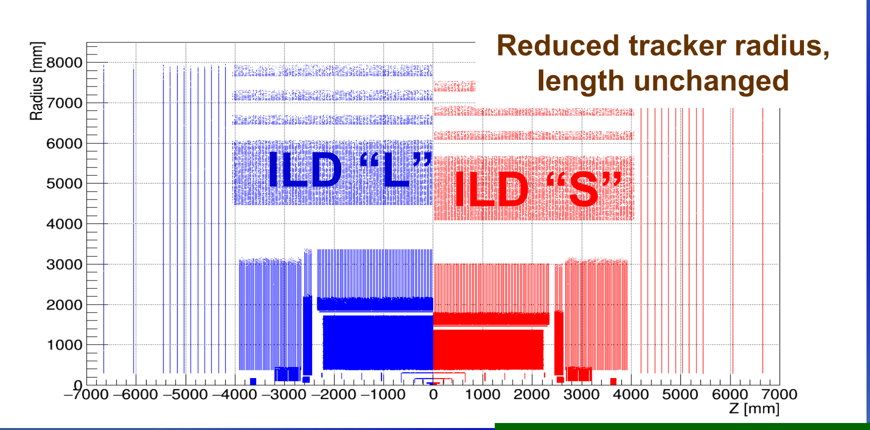
ILC Detector Concept Groups: ILD and SiD

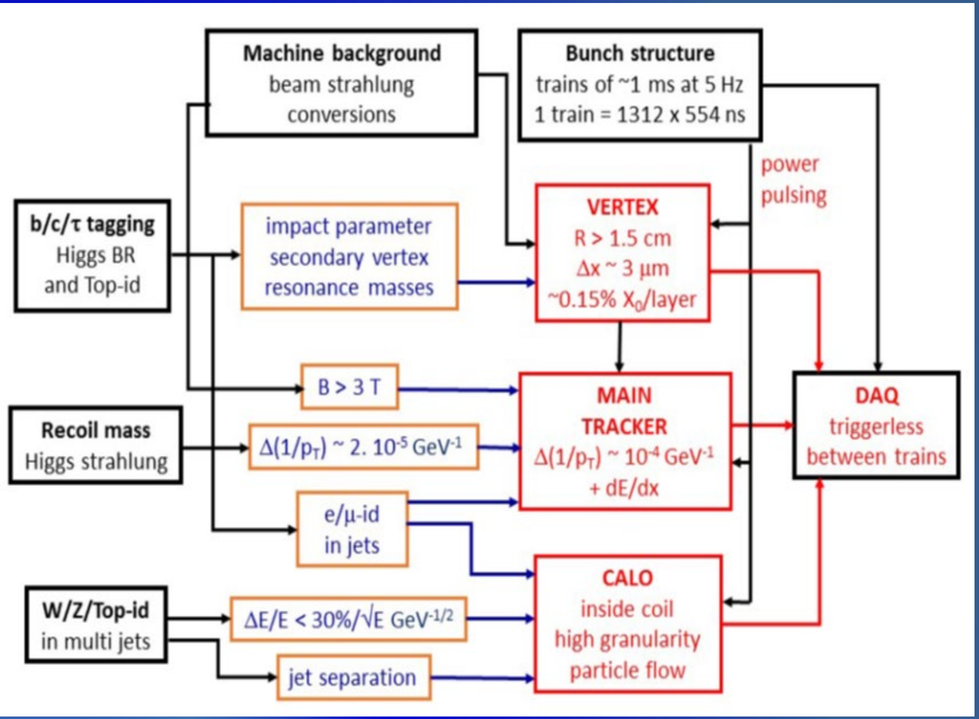




- ✓ **ILD: International Large Detector**
- ✓ **SiD: Silicon Detector**

ILD Re-optimisation: Large (L) & small (S) options





ILD ("L" & "S") — ILD Interim Design Report: arXiv: 2003.01116	SiD — SiD Design Update: arXiv: 2110.09965
Both optimized for PFA Performance: ~ $B \cdot R_{ECAL,inner}^2$ (two-track separation @ ECAL)	
B = 3.5 T / 4 T	**B = 5 T**
$R_{ECAL,inner}$ = 1.8 / 1.46 m	**$R_{ECAL,inner}$ = 1.27 m**
Si + TPC tracking **Outer radius: 1.77 / 1.43 m**	**Silicon Tracking only** **Outer radius: 1.22 m**

ILD vs SiD Tracking: Two Complementary Approaches

ILD: Silicon + Gaseous Tracking

VERTEXING:

- long barrel of 3 double layers of Si-pixels

  $0.3\%\ X_0$ / layer, $\sigma_{sp} \lesssim 3\ \mu m$

TRACKING:

- Intermediate Si-tracker (SIT, SET, FTD)
  - SIT/FTD: silicon pixel sensors (e.g. CMOS)
  - SET: silicon strip sensors
- Time Projection Chamber with MPGDs
  - High hit redundancy (200 hits / track)
    - → 3D tracking / pattern recognition;
    - → dE/dx information for PID

SiD: All-Silicon Tracking

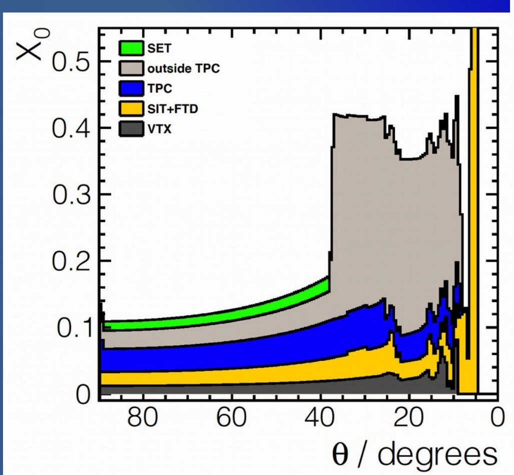
- short barrel of 5 single layers of Si-pixels

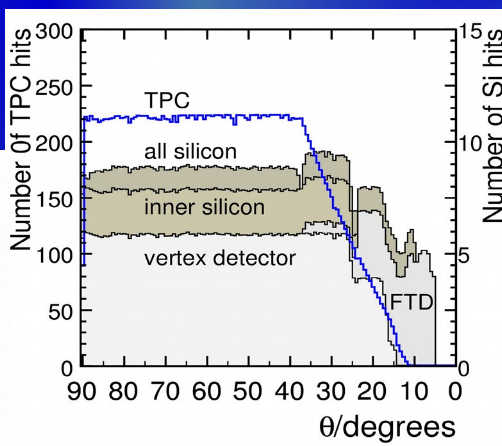
  $0.15\%\ X_0$ / layer, $\sigma_{sp} \lesssim$ 3-5 μm

- 5 layers Silicon-strip tracker
  (25um strips, 50 um readout pitch)

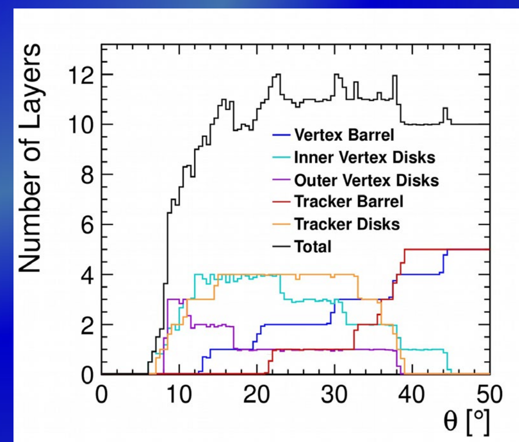
- Fewer highly precise hits (max. 12)
- Robustness, single bunch time stamping

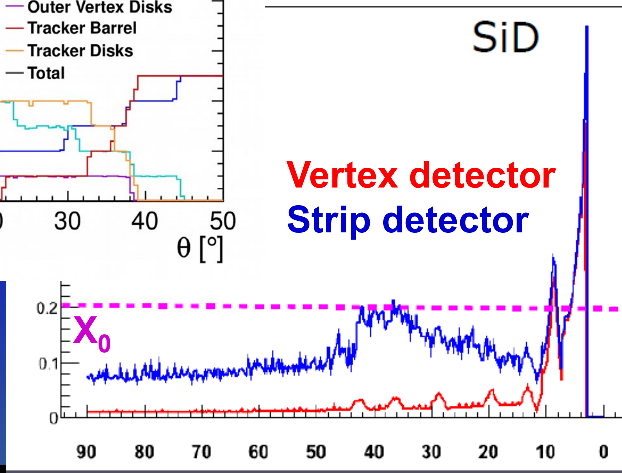
ILD:





SiD:





Still a lot of opportunities in ILD/SiD optimization : physics goals, software developments and technology options

Vertex Technologies for Linear Collider: State-of-the-Art

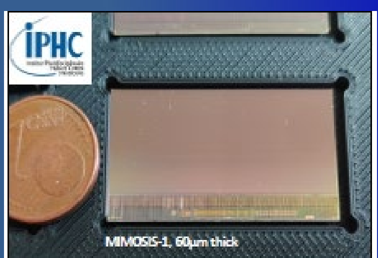
- **Exploiting the ILC low duty cycle 0(10^{-3}): triggerless readout, power-pulsing**
- **Readout strategies:**
  → continuous during the train with power cycling → mechanic. stress from Lorentz forces in B-field
  → delayed after the train → either ~5µm pitch for occupancy or in-pixel time-stamping

Physics driven requirements — **Running constraints** — **Sensor specifications**

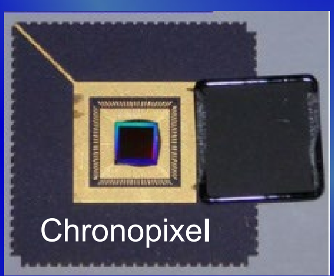
$\sigma_{s.p.}$ 2.8um → Small pixel ~16 µm
Material budget 0.15% X_0/layer → Thinning to 50 µm
→ Air cooling → low power 50 mW/cm^2
r of Inner most layer 16mm → beam-related background → fast readout ~1 µs
→ radiation damage → radiation tolerance
≤3.4 Mrad/ year
≤$6.2\times10^{12} n_{eq}/(cm^2\,year)$

Technology	FPCCD	DEPFET	SOI	CMOS	iLGAD
Added value (example)	Very granular	Low material budget	2 tier process (high density µcircuits)	Industry evolution	PID

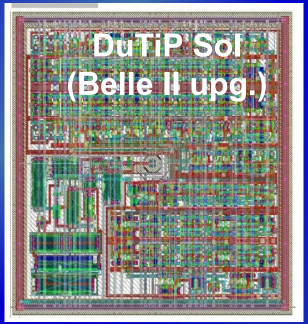
CMOS (CPS): continuous readout, stiching (STAR, ALICE)

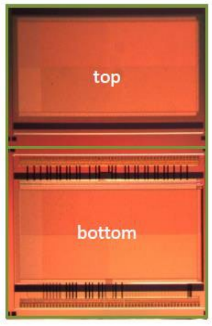


Chronopixel: delayed readout, monolithic CMOS, 50 um thick



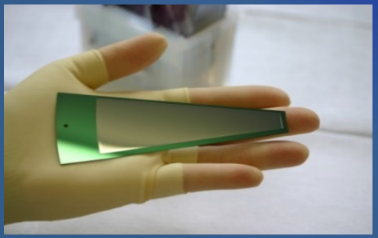
SOI: delayed / continuous readout; suited for 3D integration



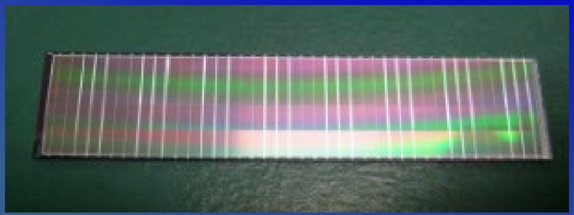


SoI-based 3D integration: rely on high-density in-pixel circuitry, with double-tier "3D" in CMOS TJ 180nm process

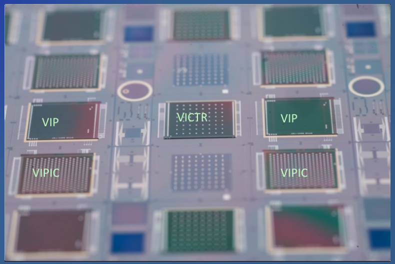
DEPFET: continuous readout, 75 / 50 um thick (Belle II)



Fine pixel CCD: delayed readout, 5 um pitch, 50 um thickness



3D Integration (in-pixel data processing, on-hold): MWR in 2010, VIP(ILC)



Vertex Technologies for Linear Collider: CMOS Evolution

A. Besson @ILCX2021

	ULTIMATE STAR-PXL	ALPIDE ALICE-ITS	MIMOSIS CBM-MVD	PSIRA proposal ILD-VXD
Data taking	2014-2016	>2021-2022	>2021	>2030
Technology	AMS-opto 0.35 μm	**0.18 μm**	0.18 μm	0.18 μm (conservative) < 0.18 μm ?
	4M	HR, V_{bias} ~-6V Deep P-well	HR, Deep P-well	?
Architecture	Rolling shutter + sparsification + binary output	**Asynchronous r.o. In pixel discri.**	Asynchronous r.o. In pixel discri.	Asynchronous r.o. (conservative)
Pitch (μm^2) / Sp. Res.	20.7 x 20.7 / 3.7	27 x 29 / 5	22 x 33 / <5	~ 22 / ~ 4
Time resolution (μs)	~185	**5-10**	5	**1 – 4**
Data Flow		~10^6 part/cm²/s Peak data rate ~ 0.9 Gbits/s	peak hit rate @ 7 x 10^5 /mm²/s **>2 Gbits/s output (20 inside chip)**	~375 Gbits/s (instantaneous) ~1166Mbits / s (average)
Radiation	O(50 kRad)/year	2×10^{12} n_{eq}/cm² 300 kRad	3×10^{13} n_{eq}/cm²/yr & 3 MRad/yr	O(100 kRad)/year & O(1×10^{11} n_{eq}(1MeV)) /yr
Power (mW/cm²)	< 150 mW/cm²	**< 35 mW/cm²**	< 200 mW/cm²	~ 50-100 mW/cm² + Power Pulsing
Surface	2 layers, 400 sensors, 360×10^6 pixels 0.15 m²	7 layers, 25×10^3 sensors **> 10 m²**	4 stations Fixed target	3 double layers 10^3 sensors (4cm²) 10^9 pixels ~0.33 m²
Mat. Budget	~ 0.39 % X_0 (1st layer)	~ 0.3% X_0 / layer		~ 0.15-0.2 % X_0 / layer
Remarks	1st CPS in colliding exp.	(with CERN)	Vacuum operation Elastic buffer	Evolving requirements

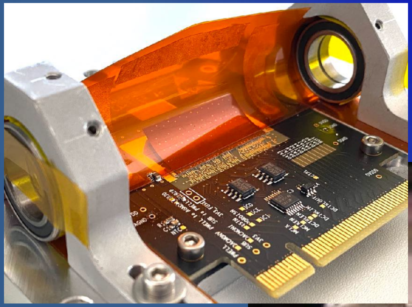
Today, most ILC R&D is focused on sensor designs
→ Sensor's contribution to the total X_0 is 15-30% (majority cables + cooling + support)

ILC Challenges (beam bkg., cooling, material budget) needs to be addressed by emerging R&D's:

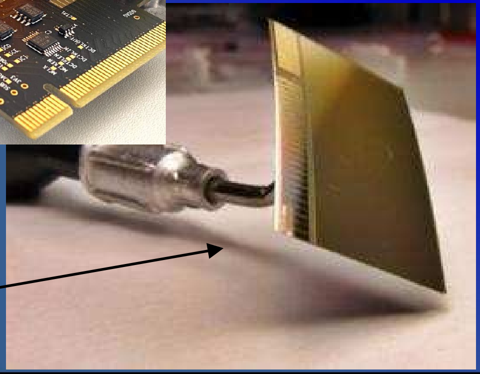
- ✓ Beam related (beamstrahlung) bkg. suppression → time stamping towards a few 100 ns (bunch-tagging)
- ✓ Further intergration & X_0 reduction → reduce impact of mechanical supports, services, overlap of modules/ladders (e.g. Mu3e /ALICE studies on Kapton support structures, bent sensors)

ALICE-ITS3 upgrade drives the R&D:

180 nm CMOS technology: VALIDATED



ALPIDE@ ALICE ITS-3 (bending 50 um sensor)

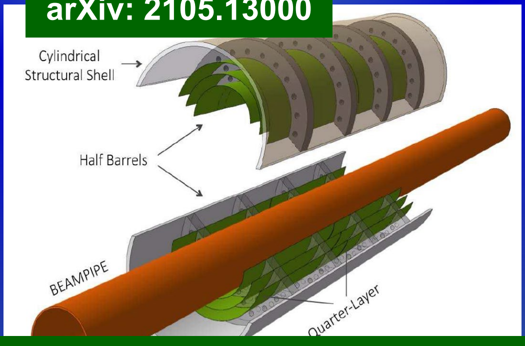


MIMOSIS @ CBM-MVD

Bending thin Si-layers (MAPS):

Truly cylindrical, supportless CPS for ALICE-ITS3 upgrade (65 nm)

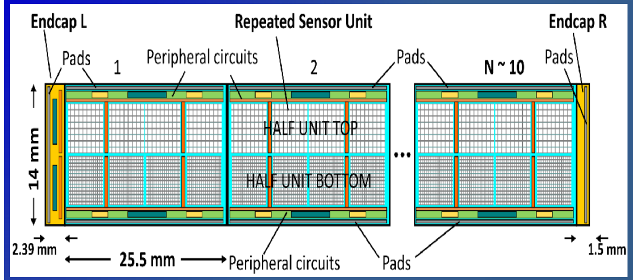
arXiv: 2105.13000



https://indico.cern.ch/event/1071914/

Industrial stitching & large surfaces for low-mass detect.:

using several reticles from the same wafer (possible with both 180 and 65 nm)



➢ submission (ER1, Q1 2022): stitching exploration

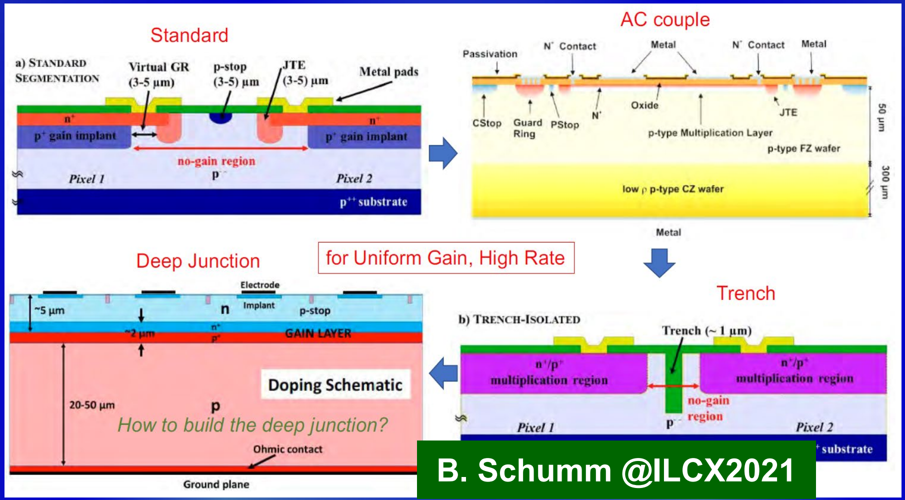
Silicon Tracking Conceptual Studies for ILC

Not much dedicated development work recently on Silicon tracking technologies

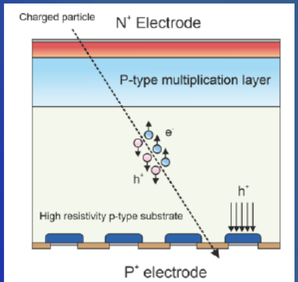
→ Baseline solution: silicon-microstrip tracker; also some enabling technologies (e.g. based on LGAD concept)

Timing Detectors open up 4D (and 5D) tracking → ATLAS/CMS upgrades include several m^2 of LGADs:

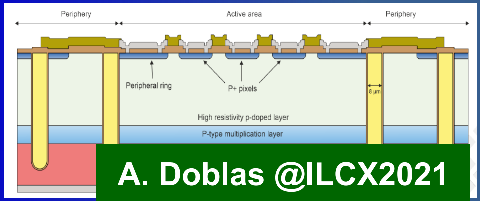
- ✓ Large area detectors
- ✓ High-precision tracking → a few um per layer
- ✓ High-precision timing → tens of ps per layer
- ✓ Optimal geometrical acc. (large fill-factor).
- ✓ Low material (50 µm thickness per plane).



iLGAD:

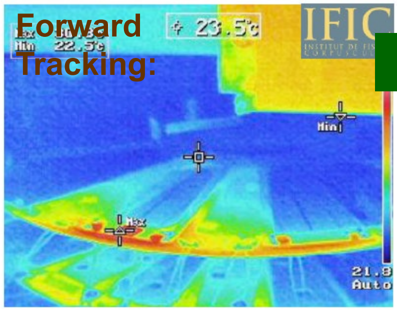


Trench iLGAD:



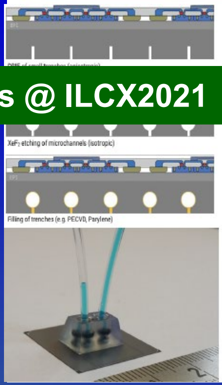
Readout ASICs (power dissipation) may limit the intrinsic sensor performance

→ power pulsing to reduce energy consumprion or the use of microchannnels to complement air cooling



Thermal management optimization strongly linked with supporting structure desing

M. Vos @ ILCX2021



A pattern of small trenches (3 x 10 µm) is etched on the backside of the pixel detector

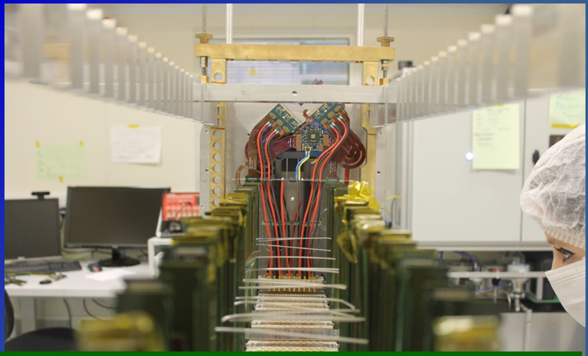
Microchannels are etched isotropically with XeF2.

A thin film of parylene (5 µm) seals the microchannels. It is finally cured by a thermal cycle.

M. Boscardin et al., NIM A, 2013
L. Andricek et al., JINST 11 (2016) P06018
C. Lipp, MSc Thesis, EPFL, 2017
I. Berdalovic et al., JINST 13 (2018) C01023

***Working MALTA CMOS sensor with integrated µ-channels*:**

Ultra-light microchannel cooiling:

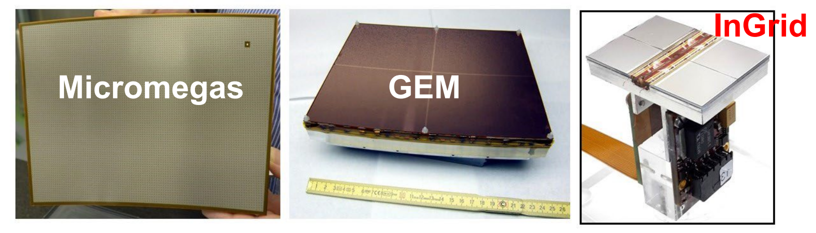


LHCb VELO: P. Collins @ILCX2021; arXiv: 2112.12763

Gaseous Tracking: TPC with MPGD-based Readout

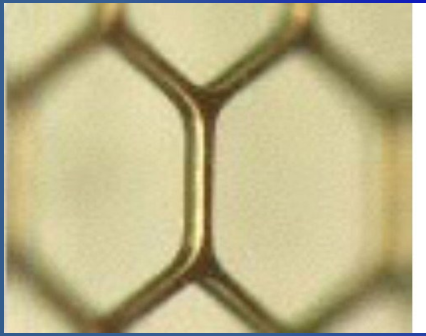
Three MPGD options are foreseen for the ILC-TPC:

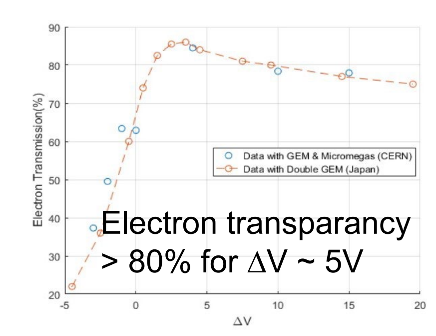
→ Wet-etched / Laser-etched GEMs
→ Resistive Micromegas with dispersive anode
→ GEM + CMOS ASICs, « GridPix » concept
(integrated Micromegas grid with Timepix chip)



ILC: gating scheme, based on large-aperture GEM

→ Machine-induced background and ions from gas amplific.
→ Exploit ILC bunch structure (gate opens 50 us before the first bunch and closes 50 us after the last bunch)

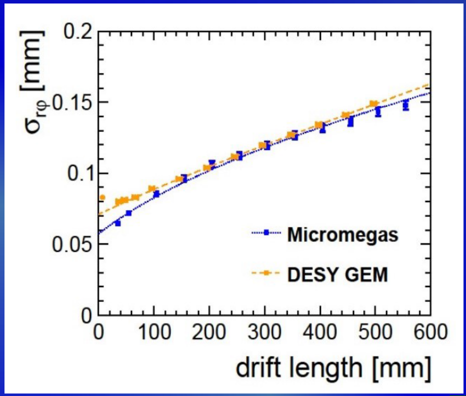


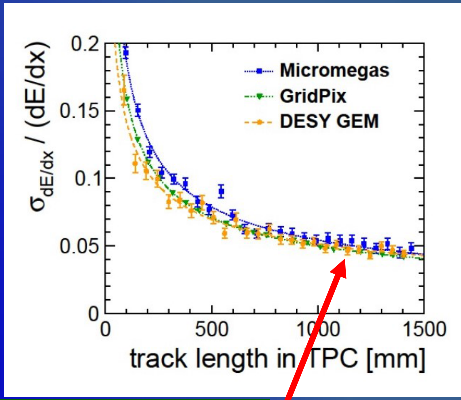


CHALLENGES / FUTURE PLANS:

✓ Common modules with a final design (with gating)
✓ Optimization of cooling & material budget
✓ GridPix development and production

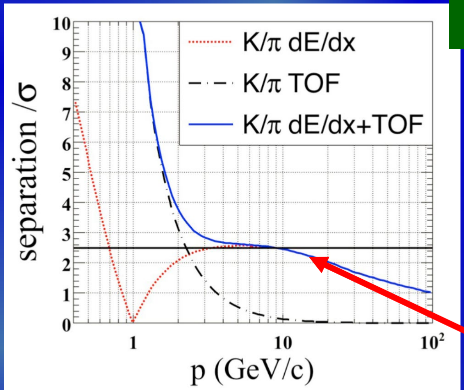
Spatial resolution of σ_T ~ 100 um and dE/dx res. < 5% have been reached with GEM, MM and InGrid)



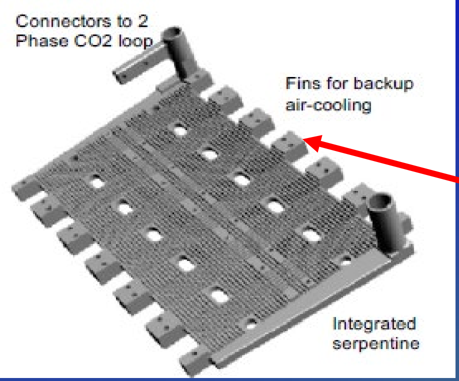


arXiv: 2003.01116

dE/dx ~ <4 % can be achieved with Gridpix (cluster-counting)



Added value of TIME information for ILC: dE/dx combined with ToF (SiW-ECAL) for K-PID



3D-printed monolithic cooling plate for a TPC using 2-phase CO_2

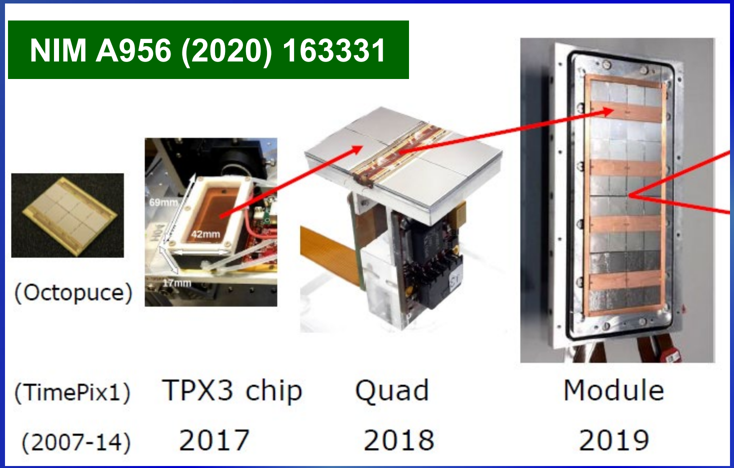
P. Colas @ ILCX2021

Gaseous Tracking: Towards Pixel ("GridPix") TPC

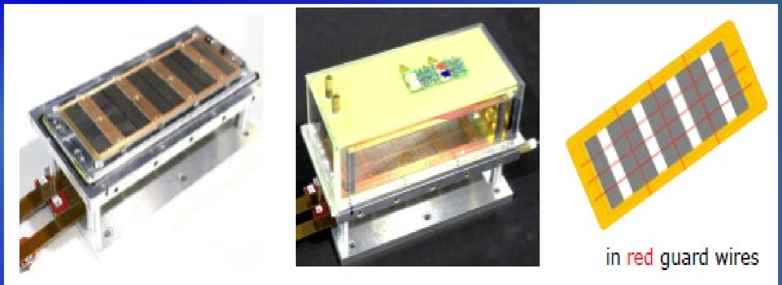
To readout ILC TPC with GridPixes: ~120 chips/ mod.; 240 mod./endcap (10 m²) → ~50000 GridPixes

Quad board (Timepix3) as a building block → 8-quad detector with a field cage

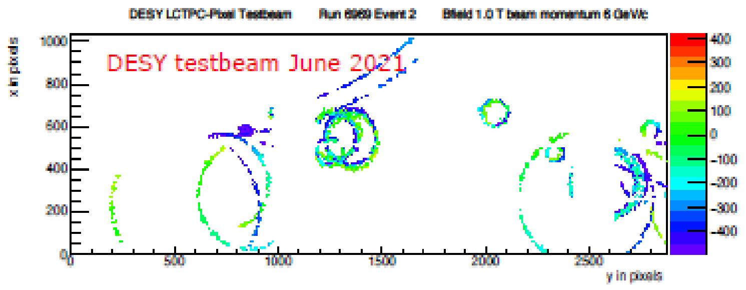
A PIXEL TPC IS REALISTIC!



J. Kaminski @ ILCX2021

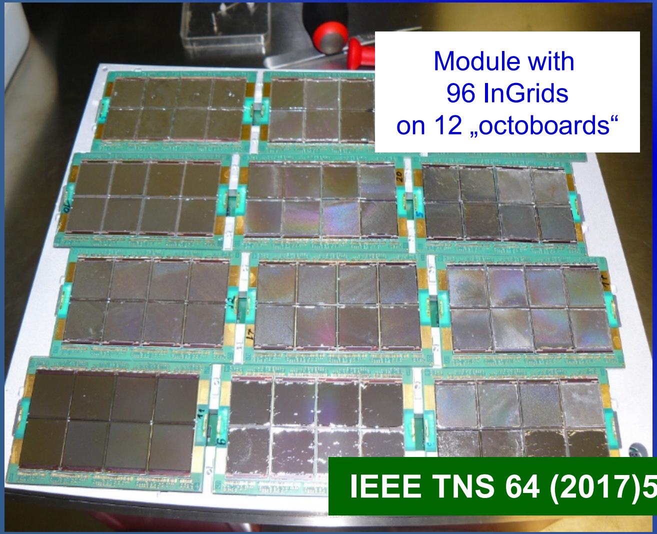


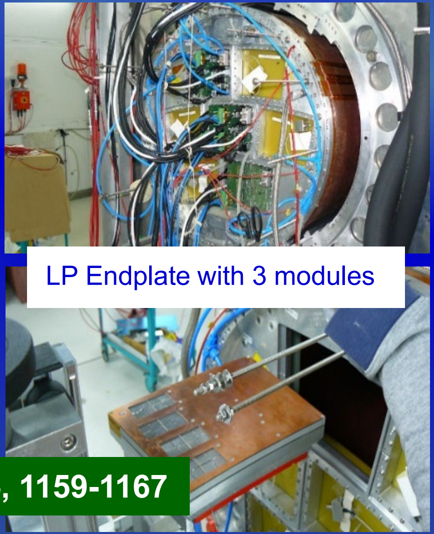
DESY Test-Beam in 2021:



3 modules for Large TPC @ DESY: 1 x 96 and 2 x 32 GridPixs

320 cm² active area, 10,5 M. channels, new SRS Readout system





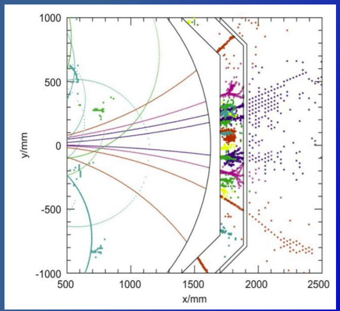
Physics properties of pixel TPC:

- Improved dE/dx by cluster counting
- Improved meas.of low angle tracks
- Excellent double track seperation
- Lower occupancy @ high rates
- Fully digital read out (TOT)

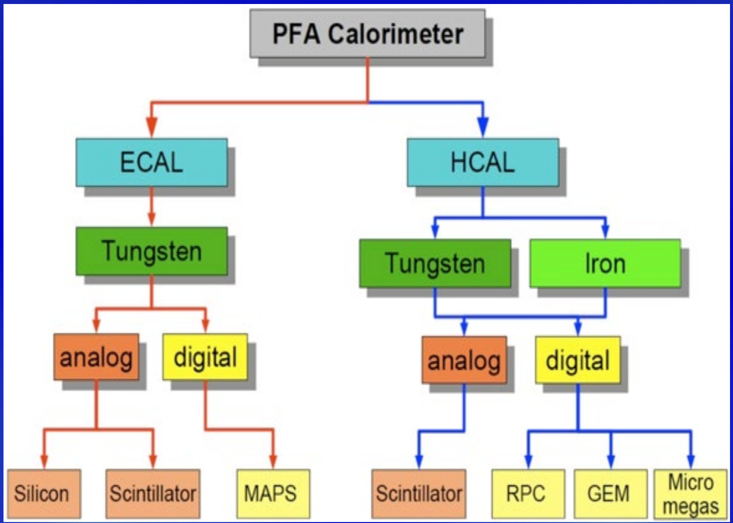
Particle Flow Calorimeters: CALICE Collaboration

Development and study of finely segmented / imaging calorimeters: initially focused on the ILC, now widening to include developments of all imaging calorimeters, e.g. CMS HGCAL for Phase II):

Imaging Calorimetry → high granularity (in 4D), efficient software (PFA).



Issues: overlap between showers, complicated topology, sep. "physics event" from beam-induced bkg.



Mixture of matured concepts and advanced ideas:

MATURED (CALICE):

- **SiW-ECAL**
- **SciW-ECAL**
- **AHCAL**
- **DHCAL (sDHCAL)**

→ (Almost) ready for large-scale prototype
→ Prepare for quick realization of 4-5 years to real detector

Example: **ILD detector for ILC**, proposing **CALICE** collaboration tech.

	ECAL option	ECAL option	HCAL option	HCAL option
Active layer	silicon	scint+SiPM	scint+SiPM	glass RPC
Absorber	tungsten	tungsten	steel	steel
Cell size (cm×cm)	0.5×0.5	0.5×4.5	3×3	1×1
# layers	30	30	48	48
Readout	analog	analog	analog	Semi-dig (2 bits)
Depth # (X_0/Λ_{int})	24 X_0	24 X_0	5.5 Λ_{int}	5.5 Λ_{int}
# channels [10^6]	100	10	8	70
Total surface	2500	2500	7000	7000

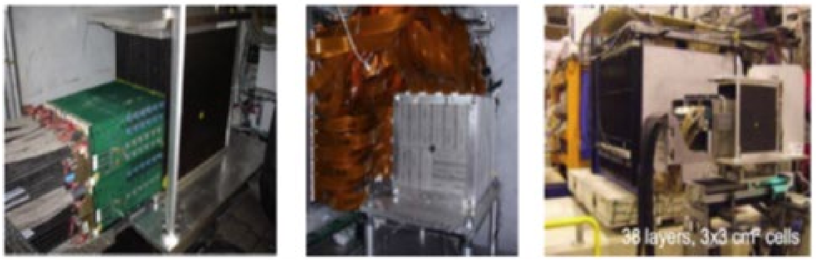
ADVANCED (beyond CALICE):

- **MAPS ECAL**
- **Dual-readout ECAL**
- **LGAD ECAL (CALICE)**

→ Evaluate additional physics impact to ILC experiment
→ Needs intensive R&D effort to realize as real detector

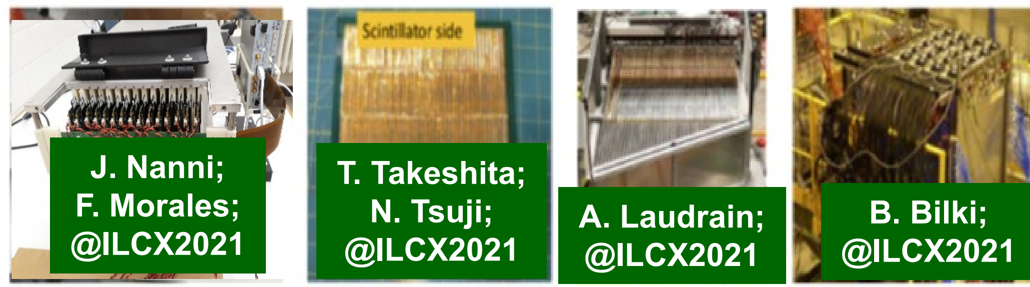
Particle Flow Calorimeters: CALICE Collaboration

Si-W ECAL | Sc-W ECAL | Sc-Fe(W) AHCAL | GRPC-Fe DHCAL



← Proof-of-principle with first generation physics prototypes (2003-2012)

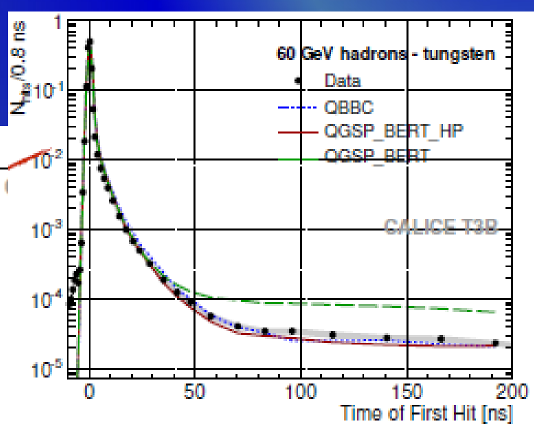
Si-W ECAL | Sc-W ECAL | Sc-Fe AHCAL | GRPC-Fe SDHCAL

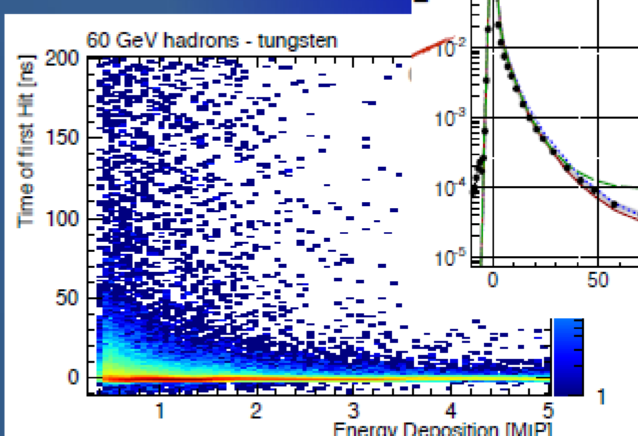


Scalability tests with 2nd generation (>2010) technological prototypes (power pulsing, compact mechanical design, embedded electronics, assembly, calibration approaches) →

- **Timing measurement for shower development (from 4D to 5D):**
  Today's CALICE prototypes (SiW ECAL, AHCAL) provides unprecedented granularity and cell-by-cell ns-level timing for validation hadronic models on different readout technologies (gas, silicon, schint.)

JINST9 (2014) P07022





→ improve GEANT simulation models

ILC AHCAL & CMS HGCAL common test-beam

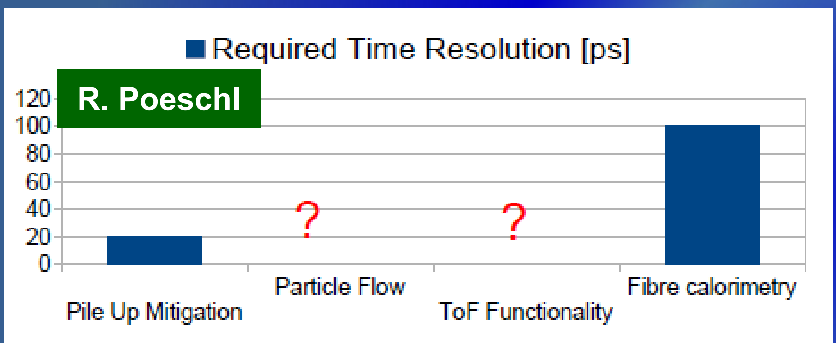
CMS HGCAL has measured **evoluton of hadronic showers in the time domain** with ~80ps accuracy (50ps TDC binning)

Imaging Calorimeters: The 5th Dimension ?

Impact of 5D calorimetry (x,y,z, energy, time) needs to be evaluated more deeply to undertand optimal time acc.

What are the real goals (physics wise)?

- Mitigation of pile-up (basically all high rates)
- Support for full 5D PFA → unchartered territory
- Calorimeters with ToF functionality in first layers?
- Longitudinally unsegmented fibre calorimeters



✓ **Trade-off between power consumption and timing capabilities (maybe higher noise level)**

✓ **Timing in calorimeters / energetic showers?**

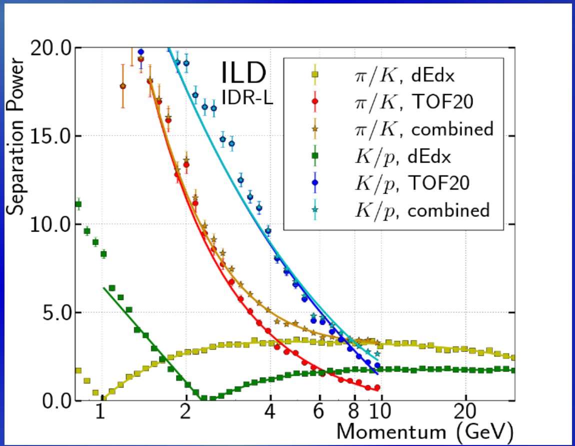
→ intelligent reconstruction using O(100) hits & NN can improve "poor" single cell timing

→ can help to distinguish particle types: usable for flavour tagging (b/c/s), long-lived searches (decaying to neutrals) , enhance $\sigma(E)$ / E

Replace (part of) ECAL with LGAD for O(10 ps) timing measurement

T. Suehara @ILCX2021

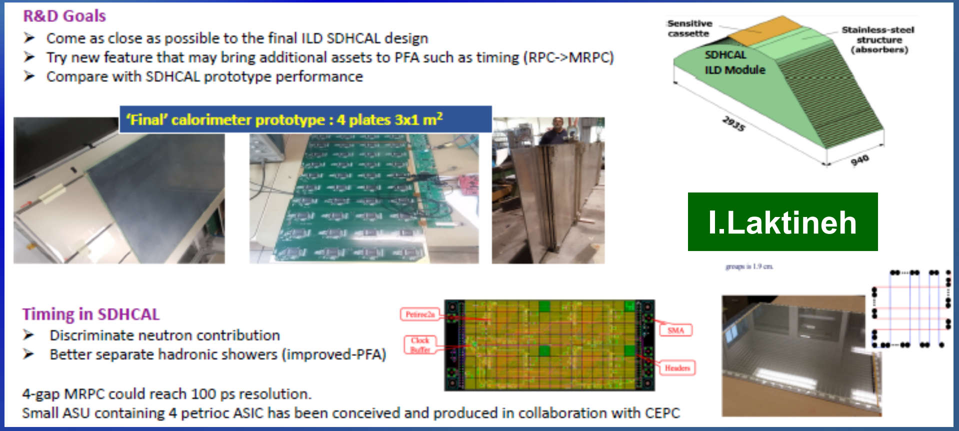
20 ps TOF per hit can separate π/k/p up to 5-10 GeV



Timing resolution Is affected by noise

Sensor	Amp. th.	Time reso.
S8664-50K (inverse)	20 mV	123 psec
	40 mV	63 psec
S2385 (normal)	20 mV	178 psec
	40 mV	89 psec

sDHCAL R&D: improved timing with replacement of RPC with MRPC → O(20-100) ps



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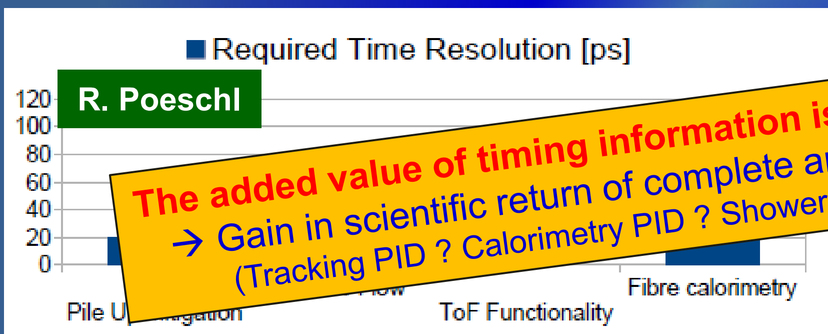
R. Poeschl



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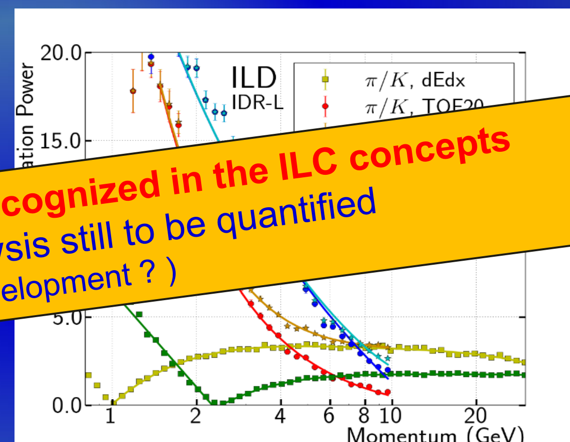
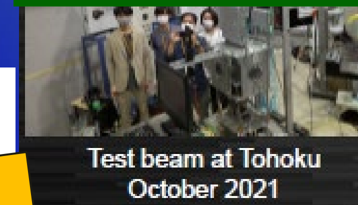


T. Suehara @ILCX2021



Test beam at Tohoku October 2021

Timing resolution Is affected by noise

Sensor	Amp. th.	Time reso.
S8664-50K (inverse)	20 mV	123 psec
	40 mV	63 psec
S2385 (normal)	20 mV	178 psec
	40 mV	89 psec

The added value of timing information is recognized in the ILC concepts
→ Gain in scientific return of complete analysis still to be quantified
(Tracking PID ? Calorimetry PID ? Shower development ?)

✓ **Trade-off between power consumption and timing capabilities (maybe higher noise level)**

✓ **Timing in calorimeters / energetic showers?**

→ intelligent reconstruction using O(100) hits & NN can improve "poor" single cell timing

→ can help to distinguish particle types: usable for flavour tagging (b/c/s), long-lived searches (decaying to neutrals) , enhance σ(E) / E

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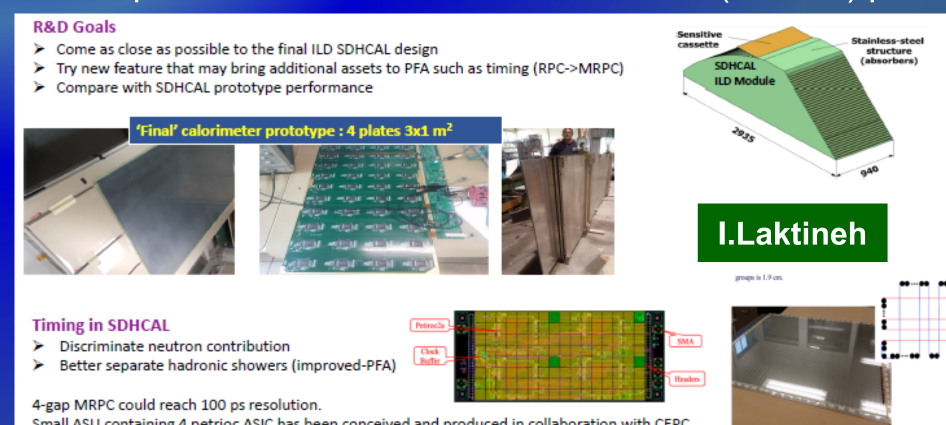
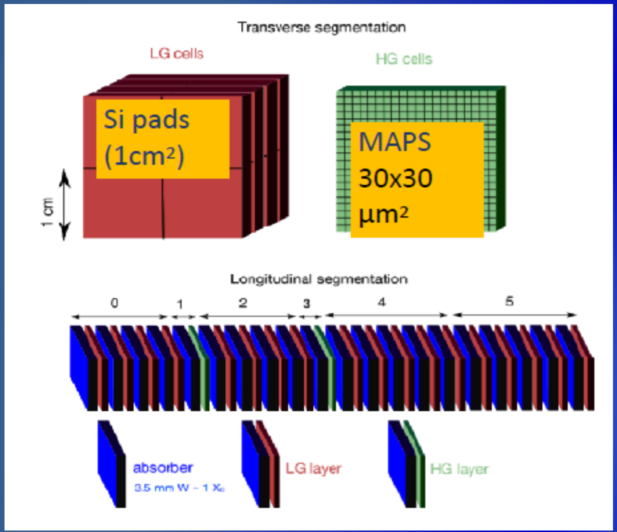


New Trends: Ultra-High Granularity (MAPS ECAL)

CMOS Sensors for calorimetry → Synergies between LC Detector R&D and ALICE FoCAL

ALICE FoCAL: 24 layer MIMOSA CMOS sensor calorimeter Si-W stack



Forward electromagnetic and **hadronic calorimeters;**

- ✓ FoCal-E: high-granularity Si-W sampling calorimeter → direct γ, $\pi 0$
- ✓ FoCal-H: Pb-Sc sampling calorimeter for photon isolation and jets

Digital ECAL prototype:

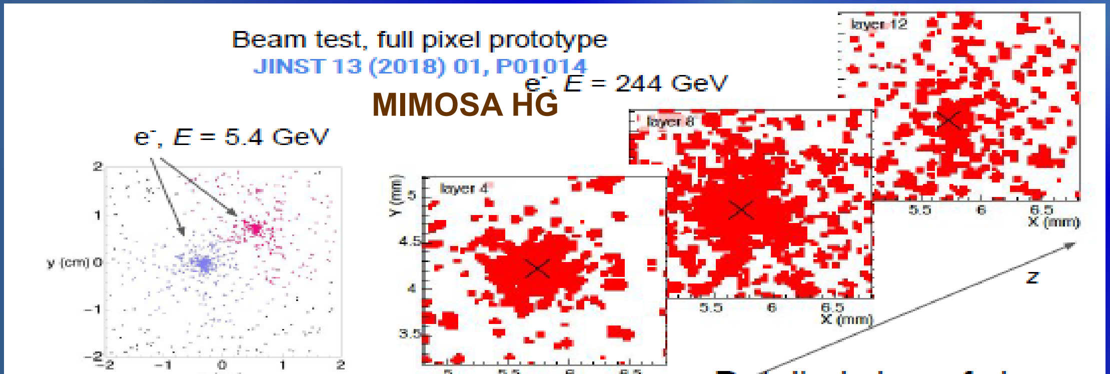
- number of pixels above threshol ~ deposited energy
- Monolithic Active Pixel Sensors (MAPS) PHASE2/MIMOSA23 wit a pixel size: 30x30 µm2
- 24 layers of 4 sensors each: activ area 4x4 cm2 , 39 M pixels
- 3 mm W absorber for 0.97 X0 pe layer R_M ~ 11 mm

FoCAL: assuming ≈ $1m^2$ detector surface

A. Rossi @ ICHEP2020

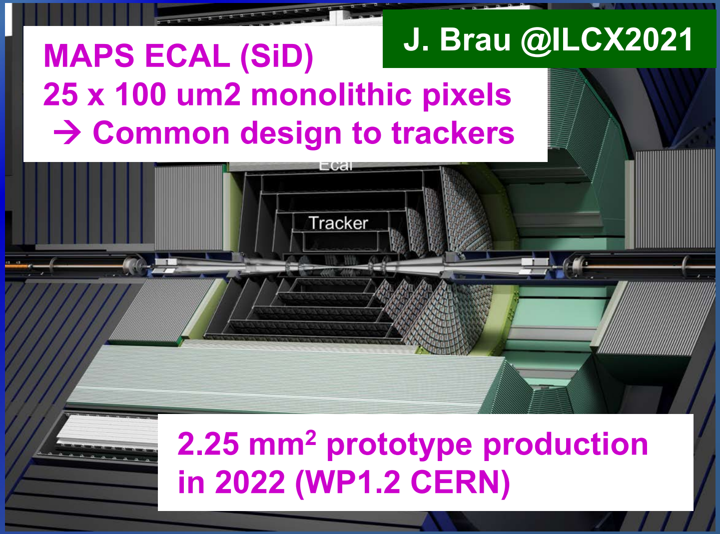
	LG	HG
pixel/pad size	≈ 1 cm^2	**≈ 30x30 μm^2**
total # pixels/pads	≈ 2.5 x 10^5	**≈ 2.5 x 10^9**
readout channels	≈ 5 x 10^4	**≈ 2 x 10^6**

Could be a unique tool to improve shower simulation …



Detailed view of shower profile → high-resolution -shower separation

T. Peitzmann, PH Detector Seminar, 25/10/2019
P. Allport, PH Detector Seminar, 10/09/2020
A. De Haas, JINST13 (2018) P01014



J. Brau @ILCX2021

MAPS ECAL (SiD)
25 x 100 um2 monolithic pixels
→ Common design to trackers

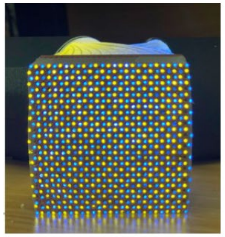
2.25 mm^2 prototype production in 2022 (WP1.2 CERN)

New Ideas: Dual-Readout Calorimetry + High Granularity

Fast signals for relativistic (EM) component

Slow signals for non-relativistic (hadronic)

Building Blocks:



SiPM for much better separation of Ch. & Sci. light

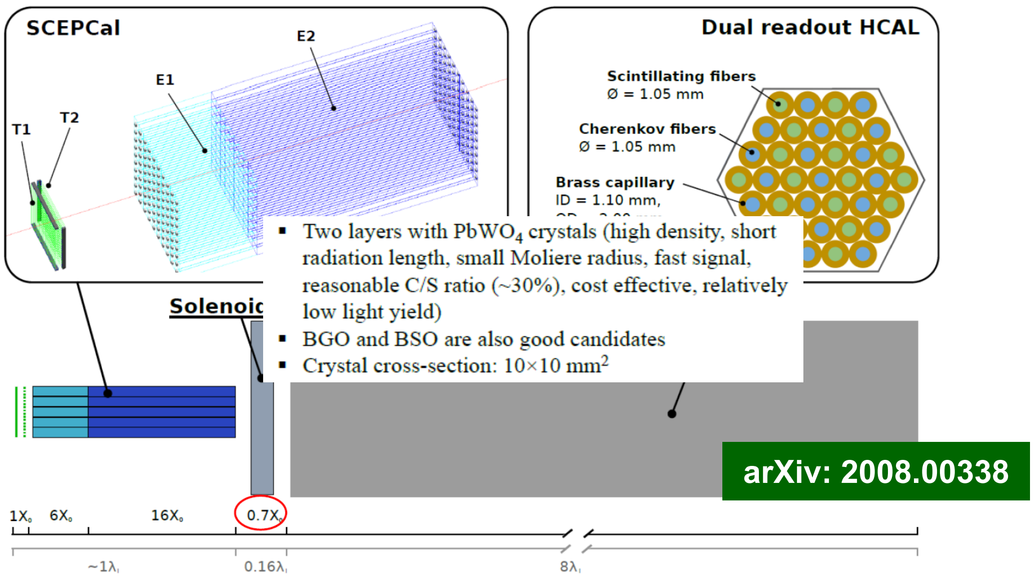
Dual readout to capture Electromagnetic and hadronic components of shower

Extensive R&D by the DREAM/RD52/IDEA collaborations
(Rev. Mod. Phys. 90, 025002, 2018): an old idea in 4th ILC concept
→ Recent technological progress (SiPM, 3D-printed absorber material) enables highly granular DREAM calorimetry

✓ **Dual-readout (DRO) crystal ECAL:** **J. Zhu @ILCX2021**

A Segmented DRO Crystal ECAL with a DRO Fiber HCAL

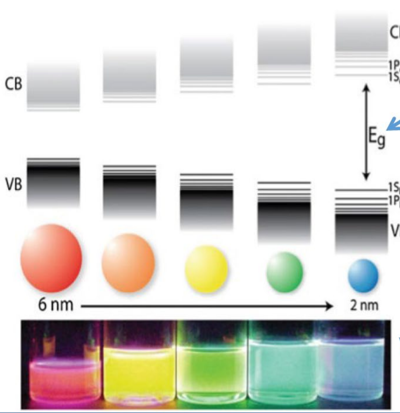
arXiv:2008.00338



- Two layers with $PbWO_4$ crystals (high density, short radiation length, small Moliere radius, fast signal, reasonable C/S ratio (~30%), cost effective, relatively low light yield)
- BGO and BSO are also good candidates
- Crystal cross-section: 10×10 mm^2

arXiv: 2008.00338

Quantum Confinement changes material properties when particle size < electron wavelength (nm-size particles -> nanoparticles)



Eg increases with decreasing particle size -> ***UV photon absorption***

Discrete energy levels form at the band-edges

Stokes Shift is difference between absorption and emission wavelength

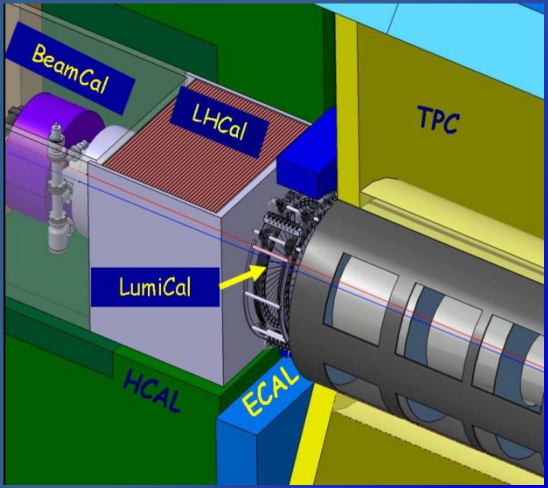
Emission wavelength decreases with decreasing size -> ***tunability***

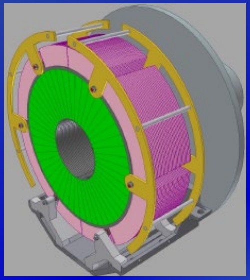
Readout Detector Development R&D: **S. Magill @ILCX2021**

R&D Focus : Optimal readout technologies for scintillation and Cherenkov signals – includes minimization of material between crystals to maximize sampling *(-> homogeneous calorimeter)*

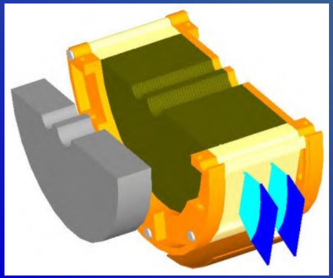
Wavelength conversion by nanoparticles discussed for detection of Cherenkov light

Forward Calorimetry R&D: FCAL Collaboration





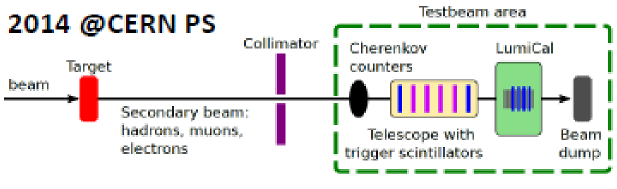
LumiCal:
→ precise luminosity measurement
10^{-3} - 500 GeV @ ILC

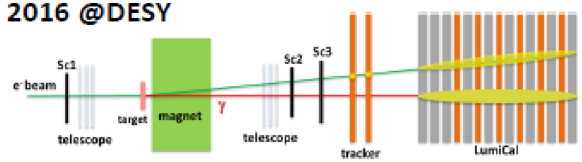


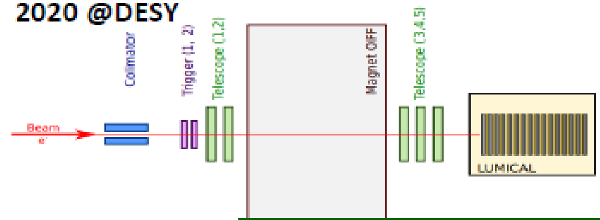
BeamCal:
→ inst. lumi measurement / beam tuning, beam diagnostics

LumiCal: Two Si-W sandwich EM calo at a ~ 2.5 m from the IP (both sides)
BeamCal: very high radiation load (up to 1MGy/ year) → similar W-absorber, but radiation hard sensors (GaAs, CVD diamond, sapphire)
LHCAL: sampling calo (tungsten or iron with SI) → extend HCAL coverage

Beam-test campaings:
LumiCal prototypes multi-plane operation:

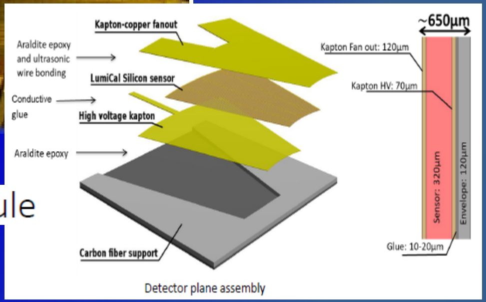






A. Neagu @ ILCX2021

LumiCal thin prototype module



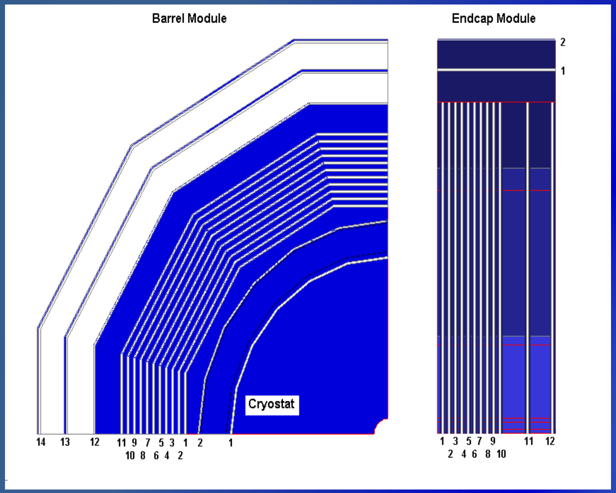
LumiCal Challenges:
- ✓ Build a ultra compact LumiCal (alignment, deformation);
- ✓ Edgeless sensors (to avoid dead areas)
- ✓ Milti-layer LumiCal prototype with new (FLAME) ASIC;

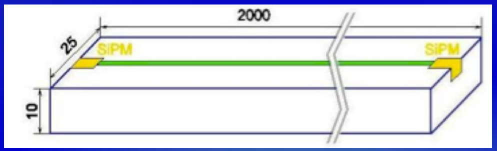
BeamCal Challenges:
- ✓ Development of sapphire sensors with dedicated ASIC;
- ✓ Ongoing radiation damage studies (GaAs, Si diode, CVD diamond, sapphire …)

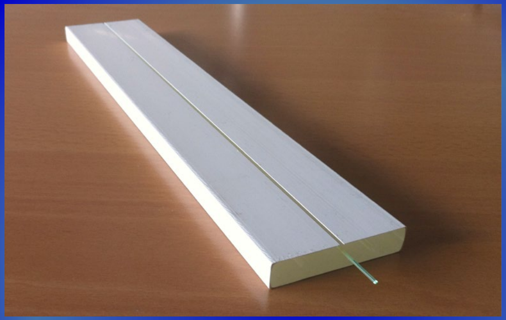
Muon System / York Instrumentation

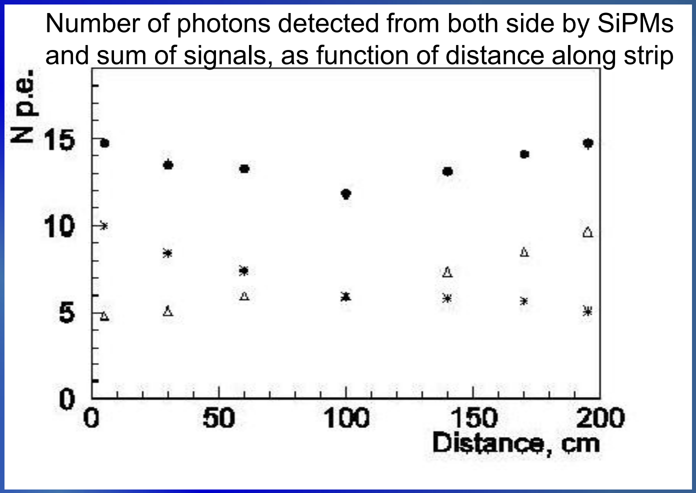
Efficient Muon Identification & Measurement of the Energy Leakage from Hadron Calorimeter

Main technology (compatible with HCAL) – Scintillation strips with WLS and SiPM readout

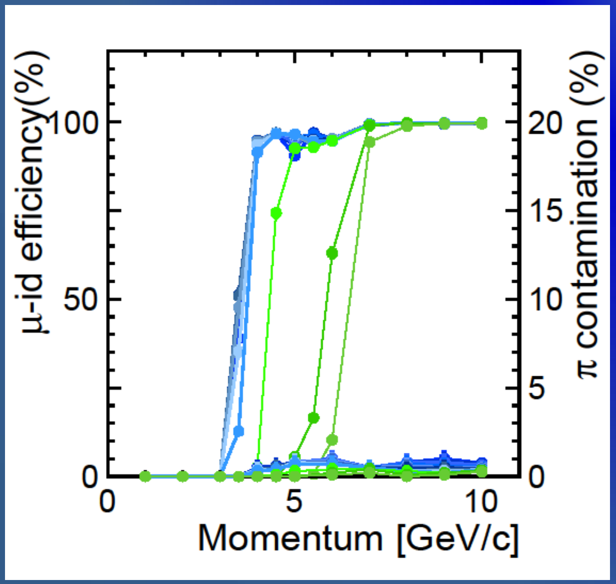








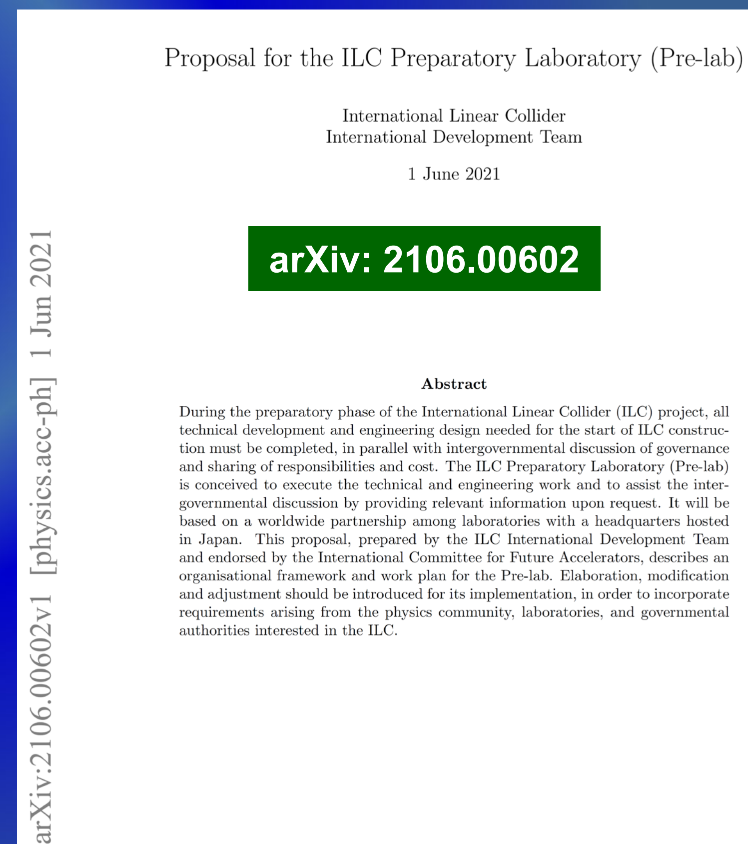
Muon efficiency & Pion contamination:



- ✓ Baseline option under development:
  → Scintillator + WaveLengthShifter + SiPM;
- ✓ Development of the Key Elements Sc/WLS/SiPM – Digital Silicon Photomultiplier in CMOS technology is in progress;
- ✓ Gas Detector - RPC (high coordinate resolution, excellent granularity up to 1 x 1 cm^2 pads) → not active for now;
- ✓ Not many groups are participating in the Muon System Study
- ✓ No significant challenges in terms of particle fluxes and radiation environment → many technologies feasible

ILC International Development Team Goals for 2021-2022

- ✓ Establish a preliminary list of the **ILC Pre-lab tasks and deliverables** (through WG2) and **national/regional laboratories** which might be interested in **contributing to those**;
- ✓ Establish **Pre-lab resources needs for the regional activities** and central office **(a few % of ILC cost)**;
- ✓ Prepare a **preliminary proposal for the ILC Pre-lab organization and governance**:
- ✓ Finalise all the **inputs needed to set-up the Pre-lab**;



Proposal for the ILC Preparatory Laboratory (Pre-lab)

International Linear Collider
International Development Team

1 June 2021

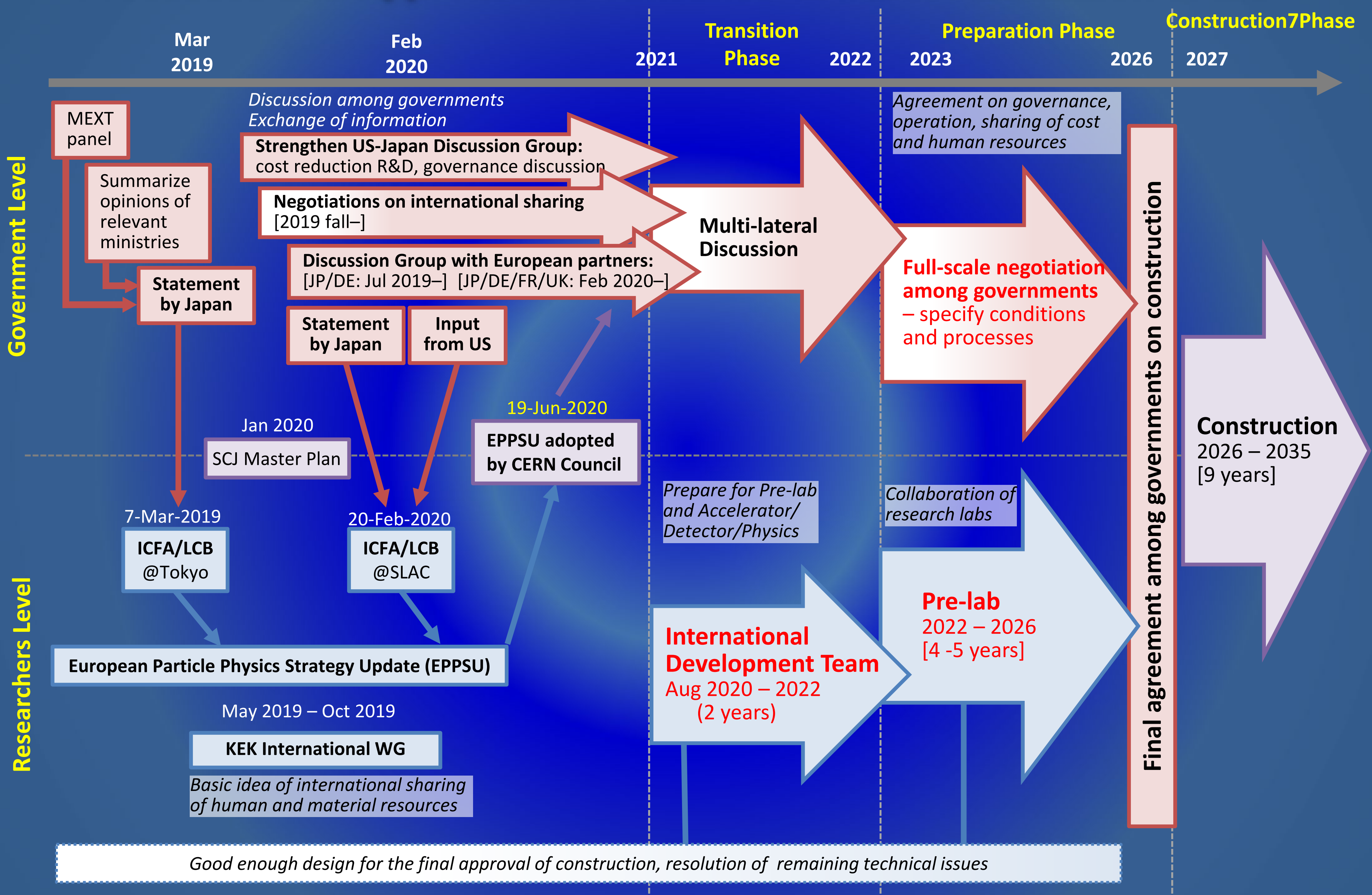
arXiv: 2106.00602

arXiv:2106.00602v1 [physics.acc-ph] 1 Jun 2021

Abstract

During the preparatory phase of the International Linear Collider (ILC) project, all technical development and engineering design needed for the start of ILC construction must be completed, in parallel with intergovernmental discussion of governance and sharing of responsibilities and cost. The ILC Preparatory Laboratory (Pre-lab) is conceived to execute the technical and engineering work and to assist the intergovernmental discussion by providing relevant information upon request. It will be based on a worldwide partnership among laboratories with a headquarters hosted in Japan. This proposal, prepared by the ILC International Development Team and endorsed by the International Committee for Future Accelerators, describes an organisational framework and work plan for the Pre-lab. Elaboration, modification and adjustment should be introduced for its implementation, in order to incorporate requirements arising from the physics community, laboratories, and governmental authorities interested in the ILC.

Processes and Approximate Timelines Towards Realization of ILC



* ICFA: international organization of researchers consisting of directors of world's major accelerator labs and representatives of researchers
* ILC pre-lab: International research organization for the preparation of ILC based on agreements among world's major accelerator labs such as KEK, CERN, FNAL, DESY, etc.