FCAL R&D

Bruce Schumm, UCSC/SCIPP

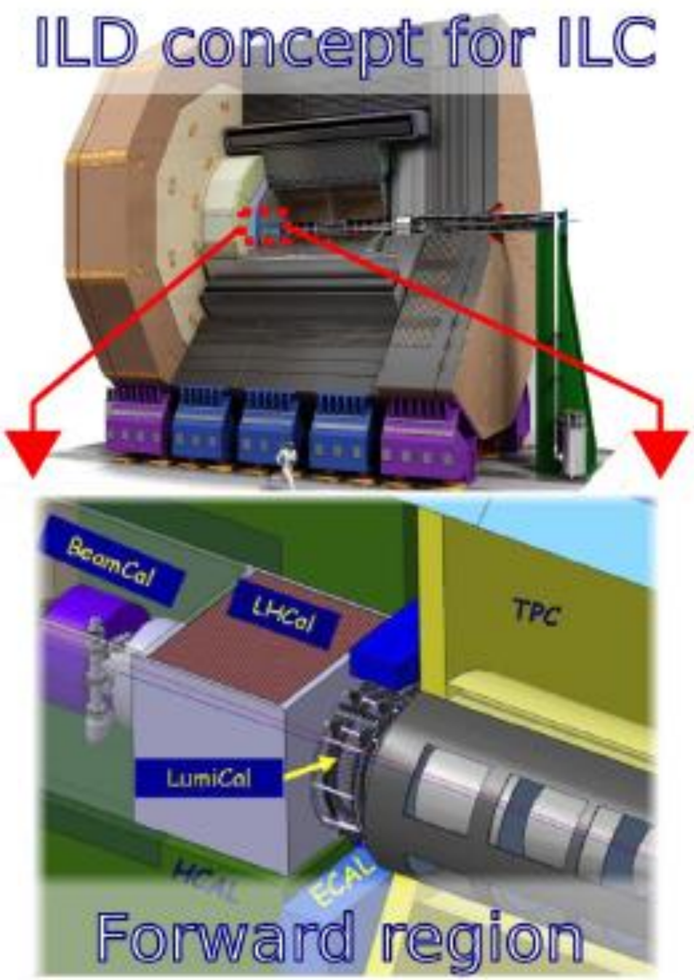
On behalf of the FCAL Collaboration
AGH-UST Cracow, ANL Argonne, CERN Geneva, DESY Zeuthen, IFIN-HH Bukharest, INPPAN Cracow, ISS Bukharest, LAL Orsay, JINR Dubna, NCPHEP Minsk, Pontifica Universidad Catholica Santiago de Chile, SLAC Stanford, Tel Aviv University, Tohoku University Sendai, University of Colorado Boulder, UC California Santa Cruz, Vinca Belgrade

SiD Collaboration Meeting
SLAC
October 14-16, 2013

NOTE: Much of talk purloined from **Marek Idzik**, AGH University of Science and Technology, Crakow, and **Wolfgang Lohmann**, DESY Zeuthen.

Marek Idzik

Introduction
Subdetectors



BeamCal (+Pair Monitor)

- Fast luminosity estimate (bunch-by-bunch at ILC)
- Beam parameter estimation
- Fast feedback to the machine
- Hermeticity & Low angle electron tagging

LumiCal

- Precise measurement of luminosity
- 10^{-3} at ILC
- Hermeticity
- Low angle physics

FCAL Charge and Challenges

- Design of the very forward region of detectors at future linear collider
- Concept for precise and fast measurement of the luminosity
- Development, prototyping and test of the detectors
- Verification of Monte Carlo estimates of the detector performance
- Ensure that critical R&D is addressed in a timely manner

Challenges:

- High precision luminometer
- High occupancy
- High radiation tolerance
- Fast readout electronics

Note: The FCAL collaboration is the single group doing R&D for forward calorimetry

SiD ←→ ILD

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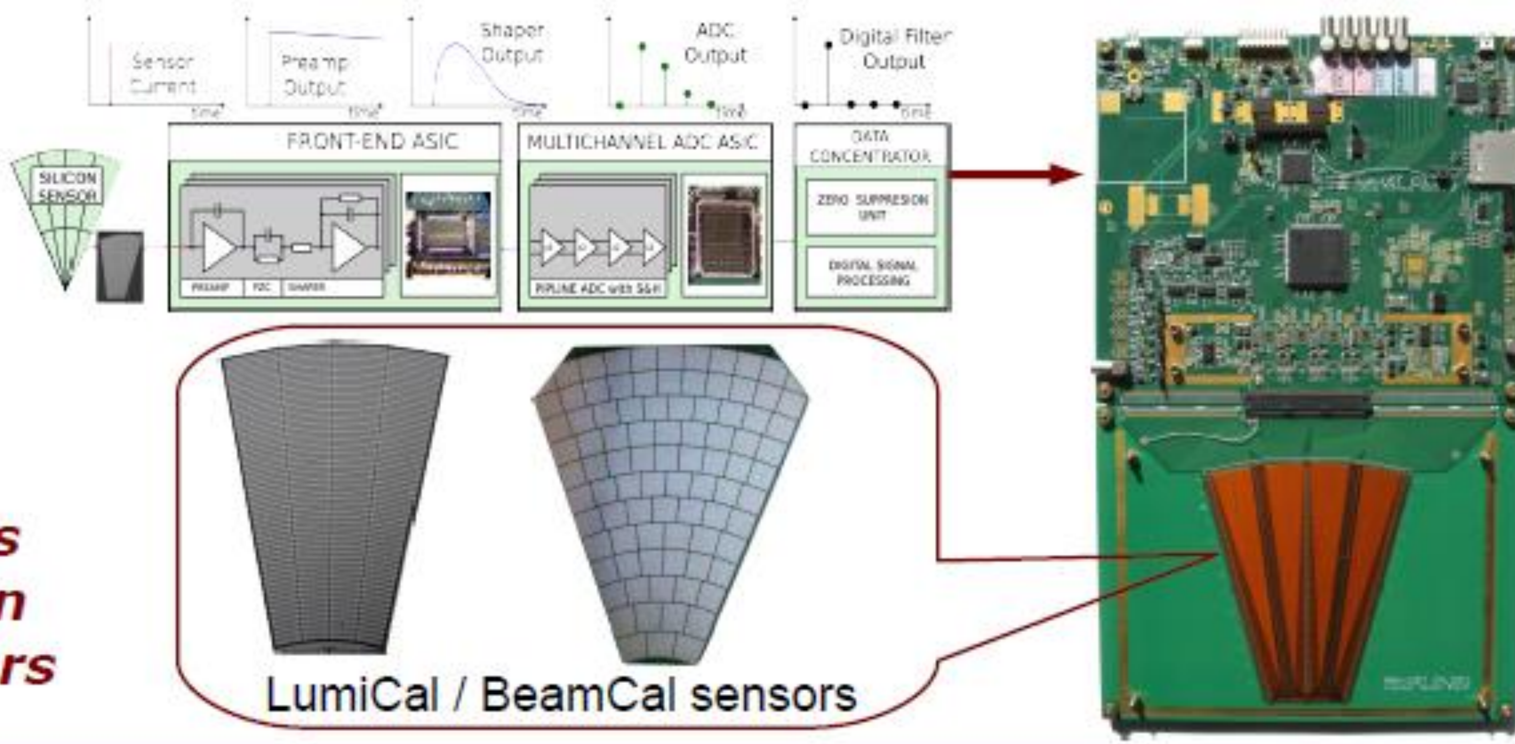
AGH

FCAL Detector R&D Status
Prototype subdetectors

- Readout module (LumiCal) for 32 channels
- LumiCal sensors
- BeamCal sensors



Few succesful test-beams were run in recent years

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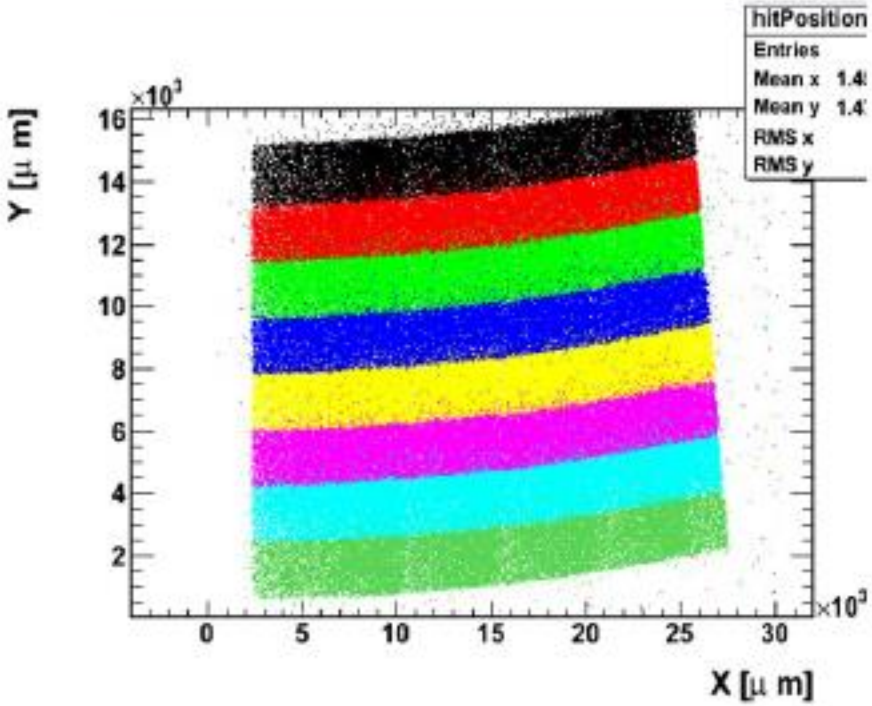
Beam-test result examples
Position reconstruction

Impact point reconstruction
using
the beam telescope
For LumiCal sensor



Impact point
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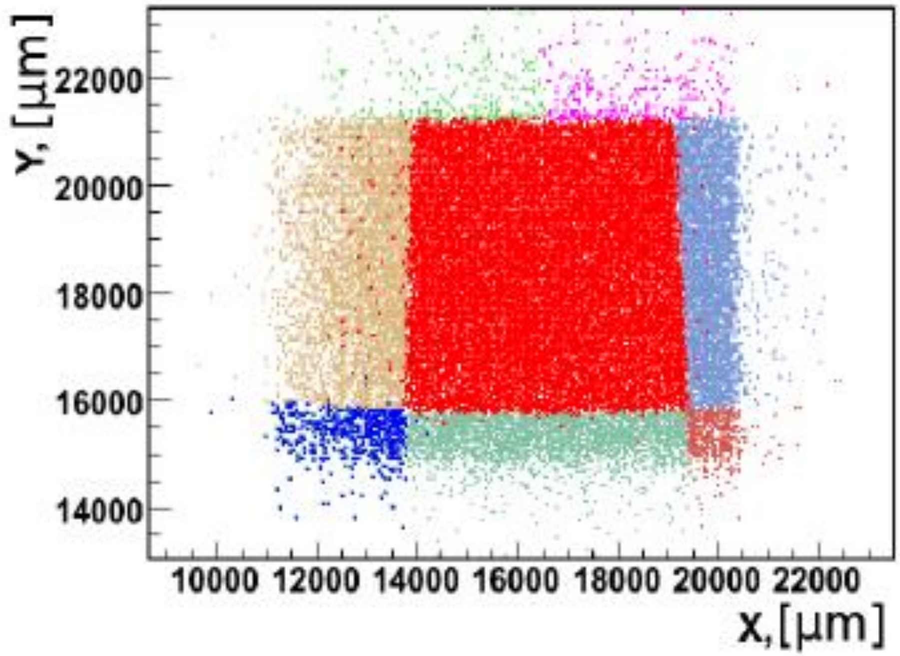

Milestones Achieved So Far

- Designs of the very forward region for ILC and CLIC detectors
- Monte Carlo estimates of the expected performance of a Luminometer for precise luminosity measurement
- Feasibility of fast luminosity measurement, beam parameter determination and electron tagging with BeamCal and Pair Monitor
- Successful development of sensors and dedicated ASICs
- Successful prototyping of major detector components and validation on test-beams
- Unique contributions to the ILC RDR, the CLIC CDR, the ILC TDR and to the detector concepts ILD and SiD

The review by 'European Detector R&D' committee in June 2013 stated that: *"The linear collider community and the funding agencies should strongly support this activity as it is a key issue for precision measurements"*

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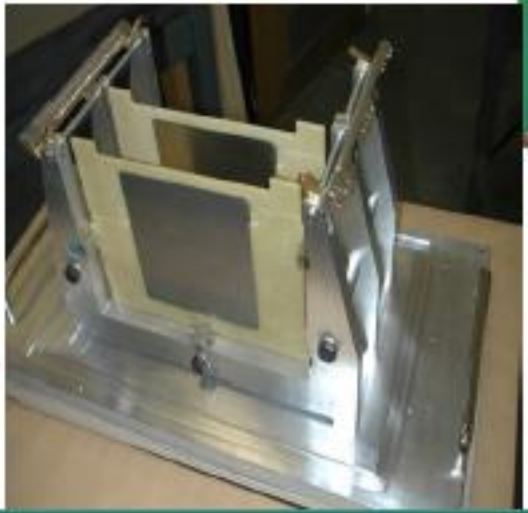
FCAL activities for testbeams – Near future
Mechanical frame with sub-detector modules

- FCAL detector components:
  - Recently we have assembled more LumiCal readout boards so there are 4 completed (which are also used for BeamCal readout)
  - LumiCal: 40 sensor tiles produced, 2 boards ready
  - BeamCal: almost 30 sensor tiles produced, 2 boards ready

- Previous test-beams done with single detector modules and row (not well flattened, composition not known precisely) tungsten material
- For future test-beam we plan to use the flexible mechanical frame with tungsten plates and all detector modules



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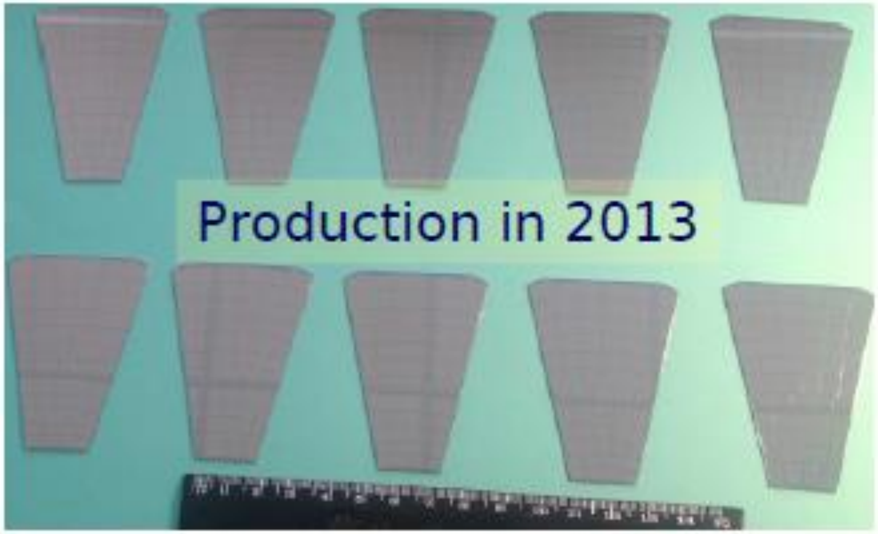
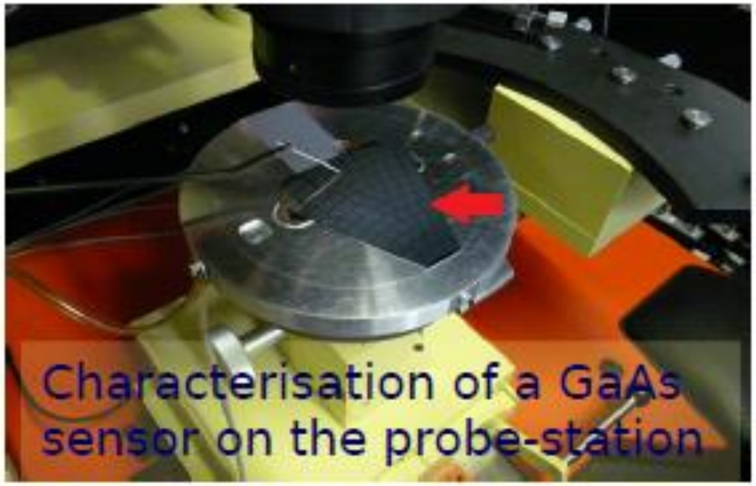
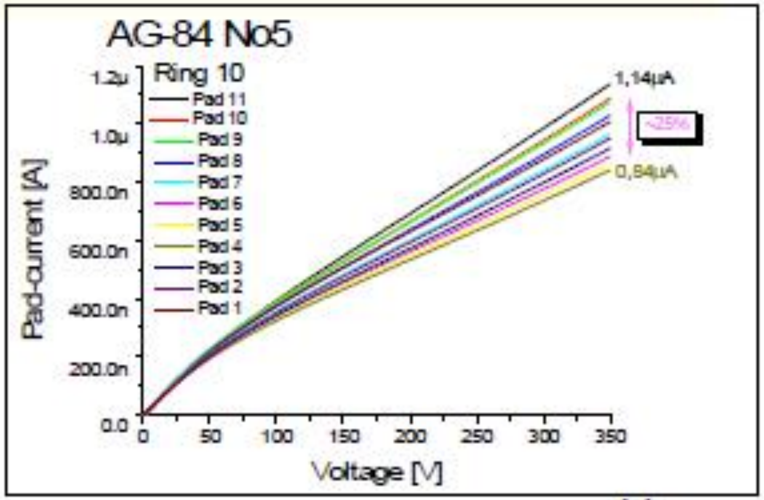
BeamCal Sensor R&D
DESY-JINR collaboration on GaAs sensors





- Test of the guard ring
- Measurement of leakage current for each pad
- Set criteria for later use in the prototype calorimeter



The aim is to produce good sensors for 30 BeamCal layers

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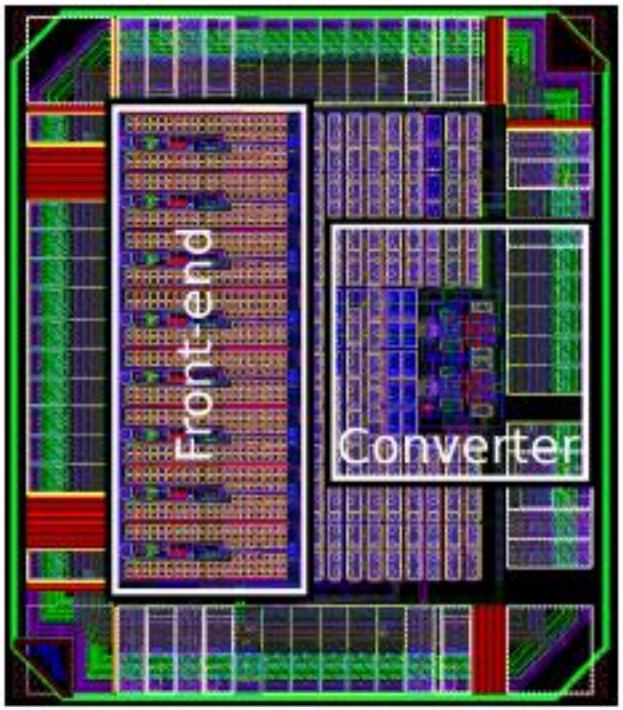
Readout R&D in IBM CMOS 130 nm
Development of LumiCal readout at AGH-UST
AIDA milestone

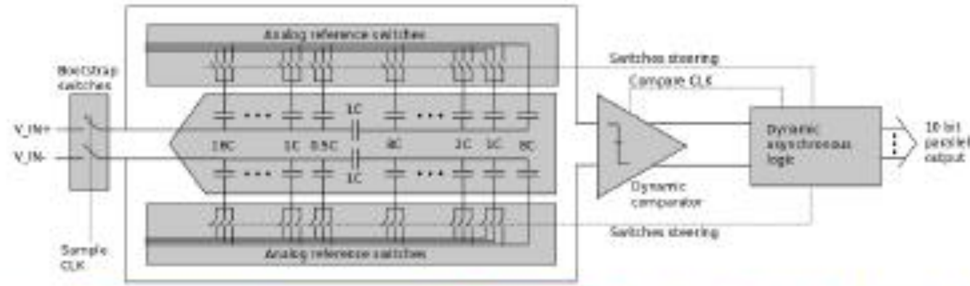
Front-end and Single-to-Diff conv.



Few channels ASIC designed and submitted in February 2013

We are just starting the tests, first signals seen 2 days ago…

10-bit SAR ADC



600um x 146um

Designed and fabricated in 2012

Tests in advanced stage (next slide)

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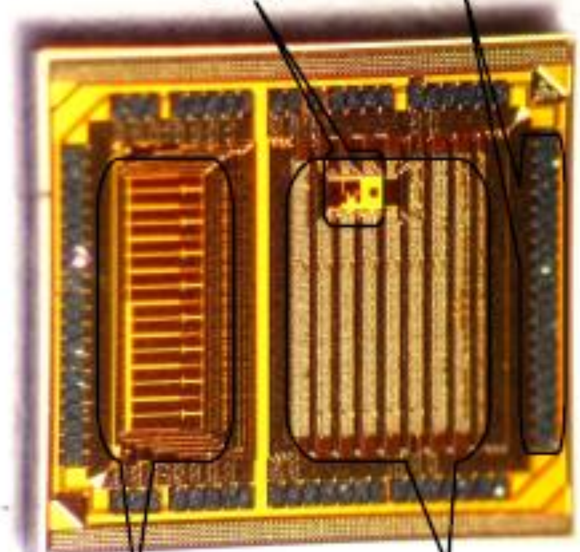
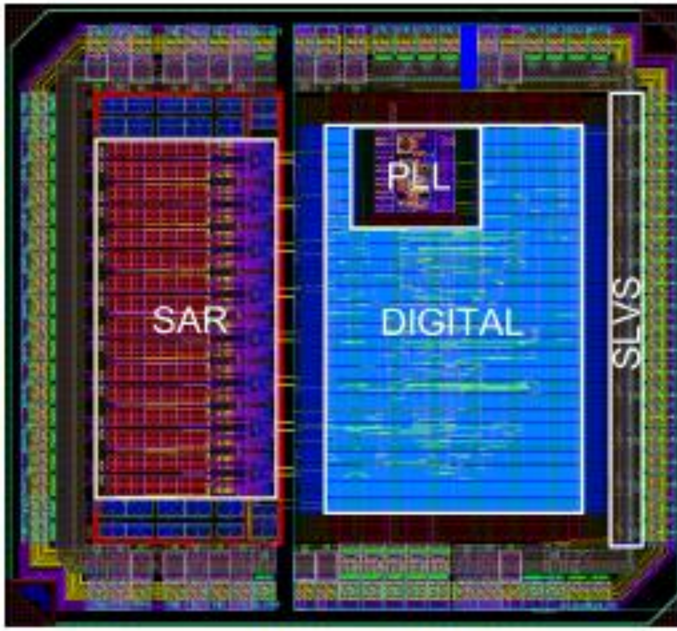
Readout R&D in IBM CMOS 130 nm
Multichannel SAR ADC with data serialization
AIDA milestone

Specifications :

- 8 channels of 10-bit SAR ADC
- Layout with 146um ADC pitch
- Max. sampling frequency 40 MHz
- Multimode digital multiplexer/serializer:
  - Serial mode: one link per all channels
  - Parallel mode: one link per channel
  - Test mode: single channnel output
- PLL for data serialization
- High speed SLVS interface (>1GHz)
- Power pulsing





2200um x 2000um

Tests will start soon…

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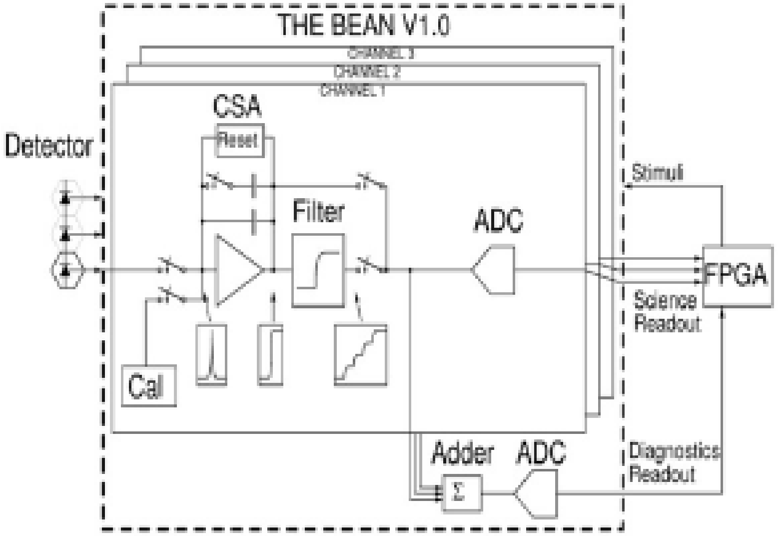
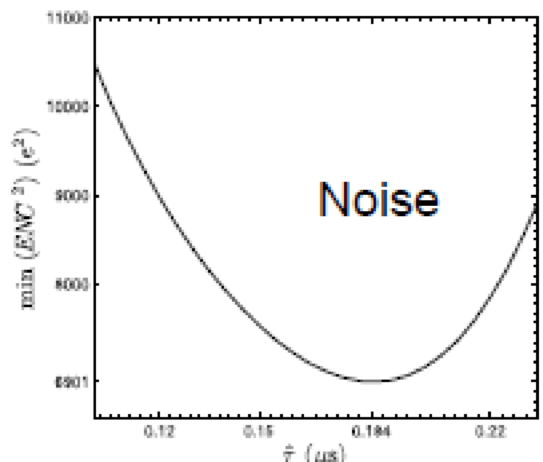
Readout R&D at PUC Chile
BeamCal detector Readout ASIC

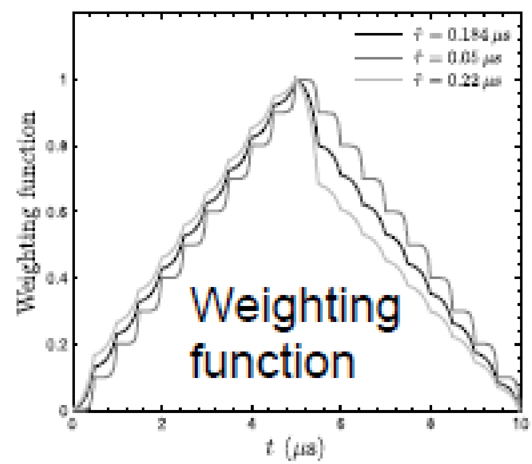


- 180 nm TSMC technology
- BEAN readout ASIC R&D:
  - Front-end: noise analysis for discrete systems in progress
  - Prototype of 10-bit SAR ADC designed and under test

Front-end studies:

Z-domain processing allows configurable filters: with arbitrary weighting functions and optimized parameters



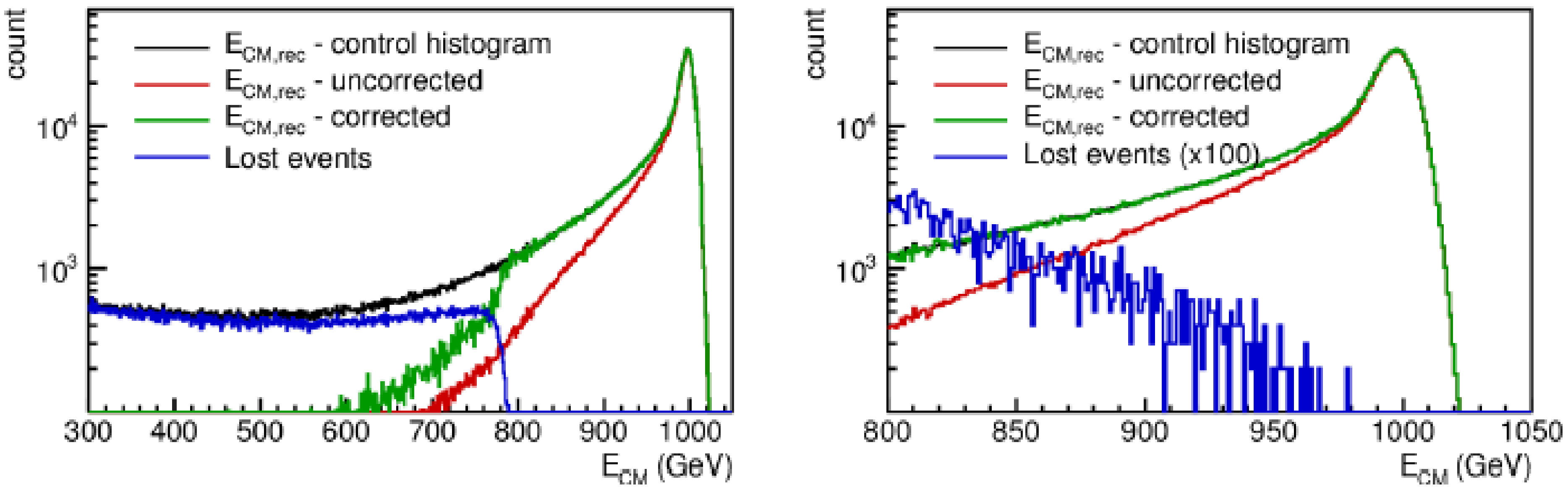


[D. Avila, E. Alvarez, A. Abusleme, *"Noise Analysis in Pulse processing Discrete Time Filters"*, accepted IEEE TNS]

Marek Idzik

MC studies – example from VINCA Belgrade
Precise luminosity measurement

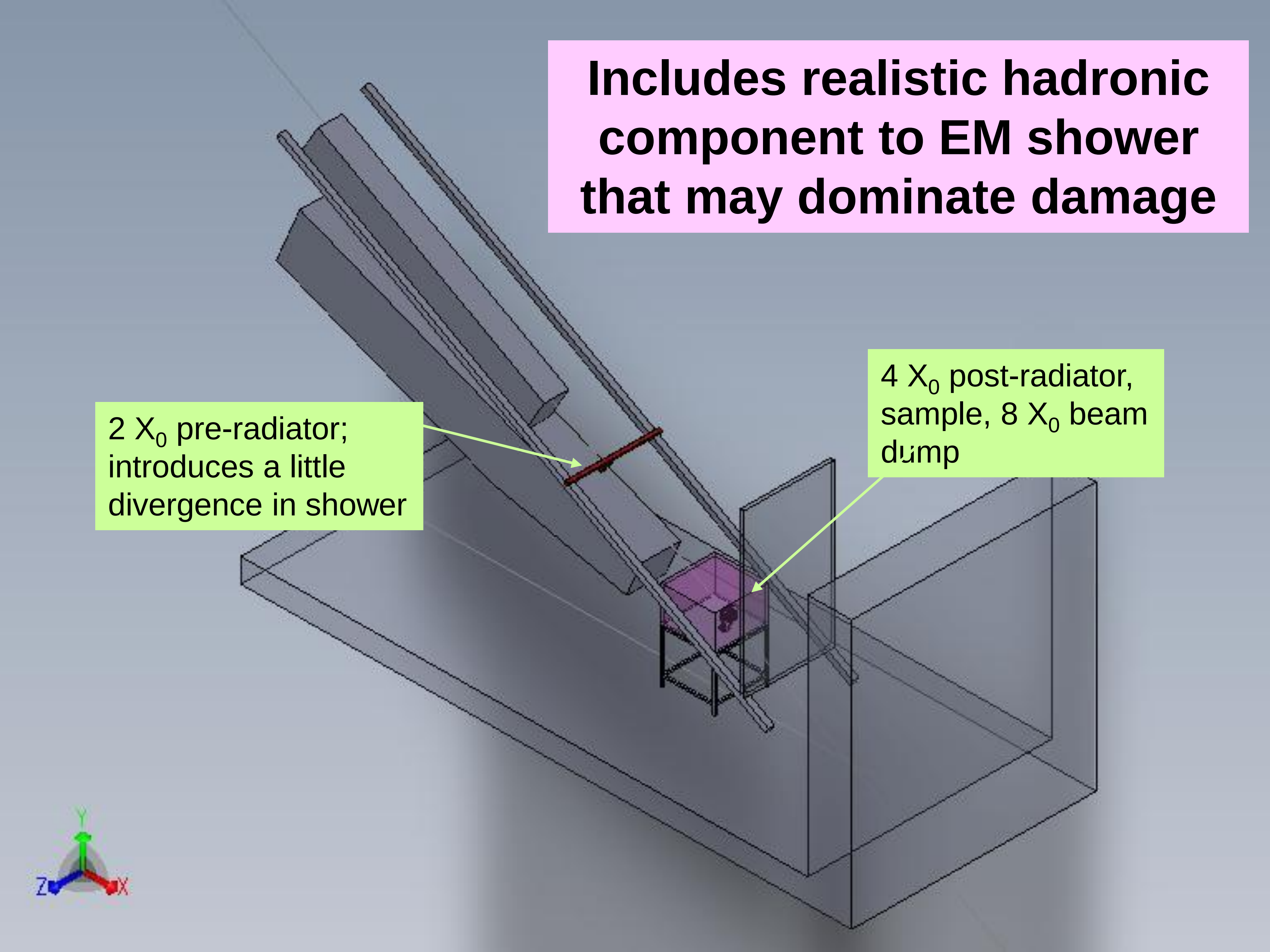
- Correction of the beam-beam effects by reconstruction of the velocity of the collision frame β_{coll} - precision better than 1 ‰
- Estimate and reduction of the physics background
- Total systematic uncertainty of luminosity in the forward region ~2 permille (Božović-Jelisavčić et al., JINST 8 (2013) P08012)



Influence and correction of the beam-beam effects on the luminosity measurement

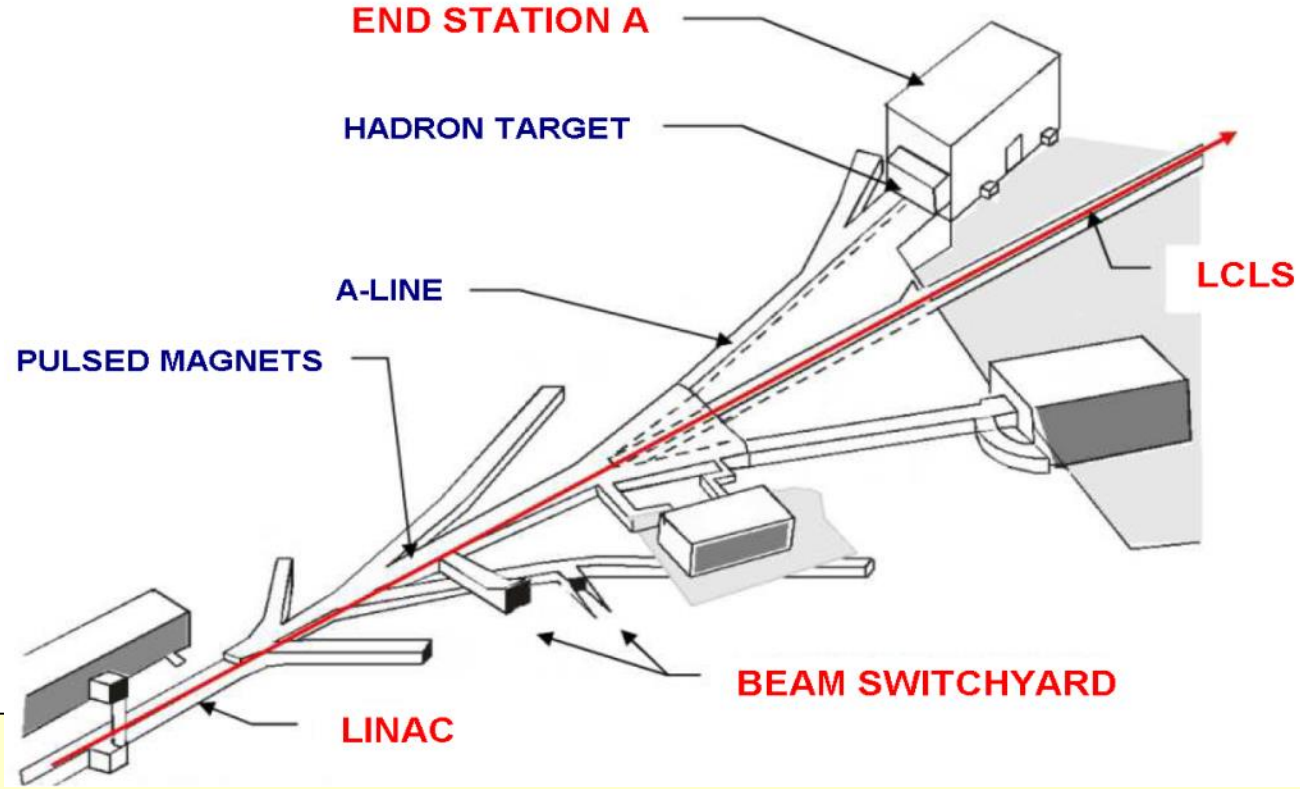
SLAC ESTB ELECTROMAGNETIC RADIATION DAMAGE STUDIES

Includes realistic hadronic component to EM shower that may dominate damage

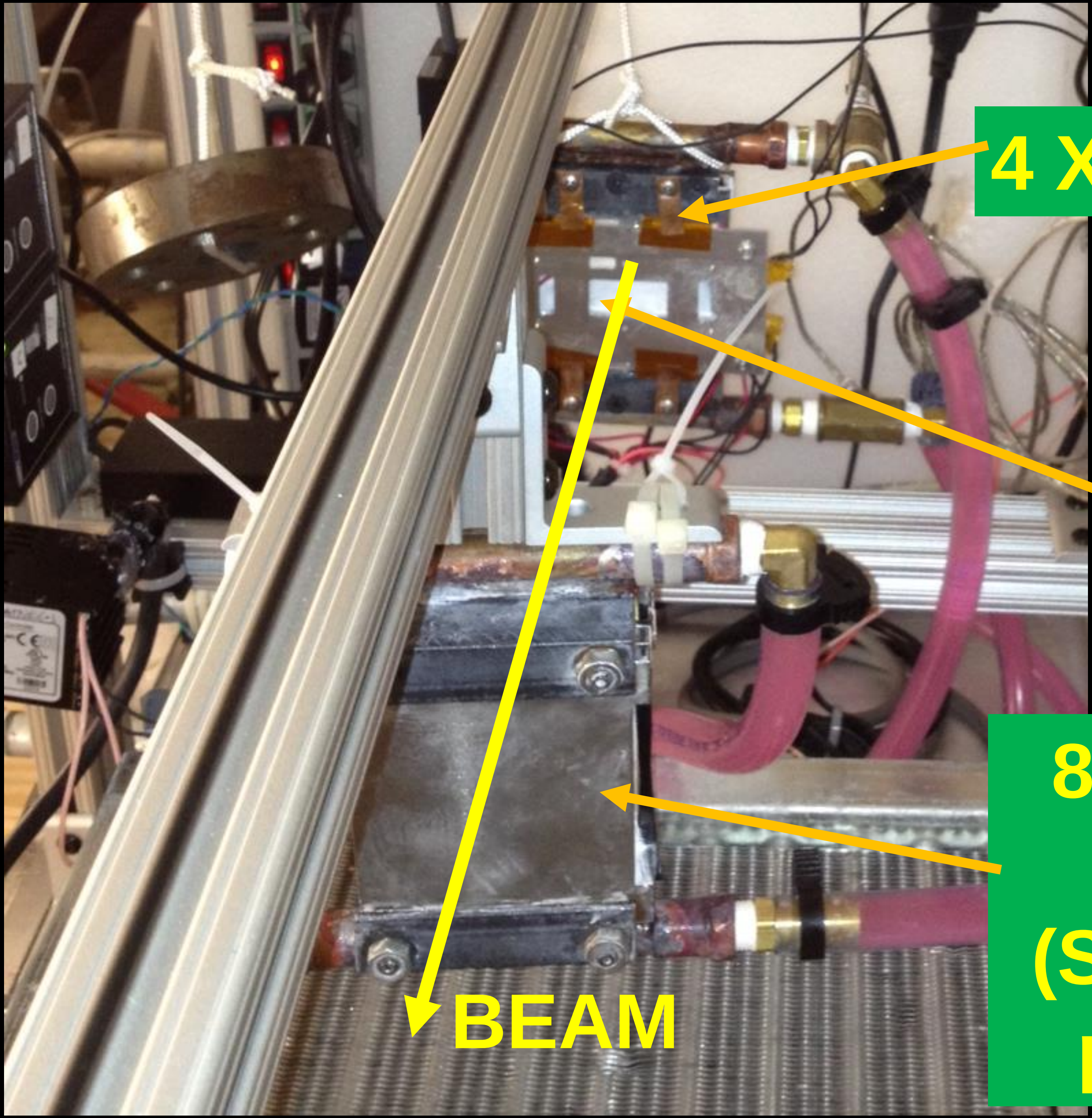


LCLS and ESA

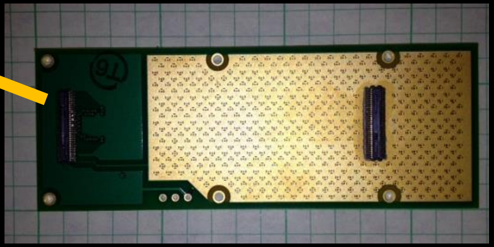
Use pulsed magnets in the beam switchyard to send beam in ESA.




BEAM
CAUTION



$4 X_0$ Radiator
BEAM
$8 X_0$ Beam Dump (Slides into position)



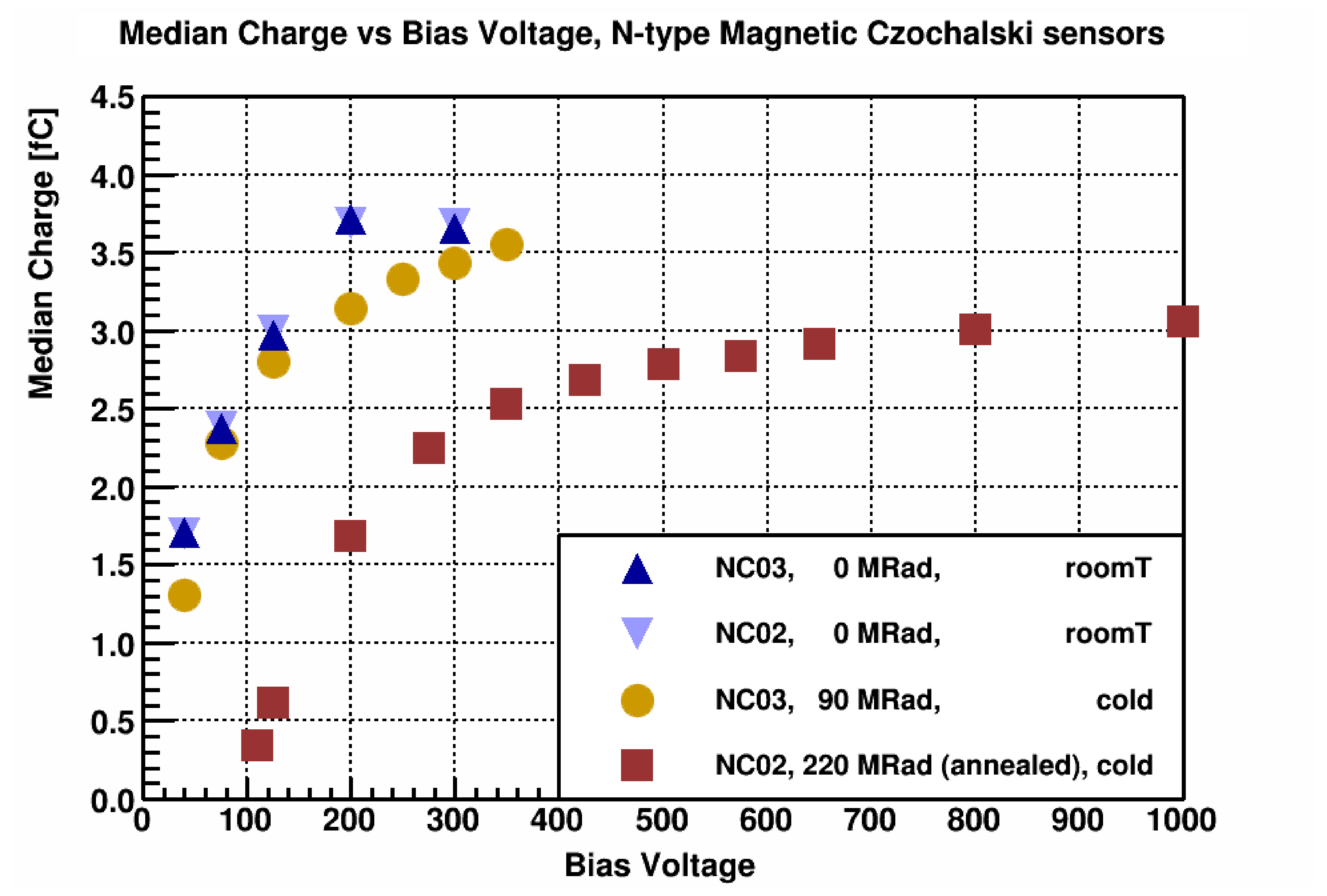
T506 Doses

"P" = p-type **"N" = n-type**

"F" = float zone **"C" = Czochralski**

Sensor	V_{FD}	Irradiation Temp. (C)	Beam Energy (GeV)	Delivered Charge (μC)	Dose (MRad)
PF05	190	0	5.88	2.00	5.13
PF14	190	0	3.48	16.4	19.7
PC10	660	0	5.88	1.99	5.12
PC08	700	0	(5.88, 4.11, 4.18)	(3.82,3.33,3.29)	20.3
NF01	90	0	4.18	2.30	3.68
NF02	90	0	4.02	12.6	19.0
NF07	100	5	8.20	23.6	91.4
NC01	220	0	5.88	2.00	5.13
NC10	220	0	3.48	15.1	18.0
NC03	220	5	4.01	59.9	90.2
NC02	220	5*	(10.60,8.20)	(32.3,13.8)	220

Results: NC sensors



Results: All Sensors

"P" = p-type "N" = n-type
"F" = float zone "C" = Czochralski

Sensor	Dose (MRad)	Median CC Before Irradiation (fC)	Median CC After Irradiation (fC)	Fractional Loss (%)
PF05	5.1	3.70	3.43	7
PF14	20	3.68	3.01	18
PC08	20	3.51	3.09	12
NF01	3.7	3.76	3.81	0
NF02	19	3.75	3.60	4
NC01	5.1	3.71	3.80	0
NC10	18	3.76	3.74	1
NC03	90	3.68	3.55	4
NC02	220	3.69	3.06	17*

Submitted to NIM; next are annealing studies

Recommendations by the ECFA R&D Committee

Wolfgang Lohmann

Wolfgang Lohmann, BTU and DESY

October 7, 2013

The review committee

R. Brenner, M. Diemoz, D. Eckstein (scientific secretary), Y. Karyotakis (chair), E. Koffeman, G. Mikenberg, H.G. Moser, C. Padilla and A. White. T. Sumiyoshi was unable to attend.

HELMHOLTZ | ASSOCIATION

DESY

Status of the Collaboration

Wolfgang Lohmann

The collaboration is composed of a good number of physicists and laboratories / universities from all around the world. They have successfully run the present phase, and the committee believes that in view of the recent rearrangement of the LC management and the promising developments in Japan they need from now on to adopt a more integrated approach of the different aspects, aiming to produce when required a complete TDR.

Given the expected scientific and technological value, we believe that the FCAL collaboration should continue its activities, in order to provide a reliable and realistic scheme to measure luminosity for the future experiments

- **The linear collider community and the funding agencies should strongly support this activity as it is a key issue for precision measurements.**
- **The collaboration should get organized in a more formal way, to be prepared for future challenges as to give a strong input for a complete luminosity measurement system when experiment collaboration(s) are formed.**
- **Adequate prototypes for both the luminometer and BeamCal should be built to address all the problems and prepare the final design.**
- **Additional physics studies should be performed to assess the physics performance of the BeamCal calorimeter.**

LumiCal Critical Issues

- Beam spot variations (set specs?)
- Temperature control (specs)
- Beam parameter uncertainties (crossing angle, spot size, divergence)
- Impact of two-photon backgrounds
- Explore value of small overlap with small-angle tracking
- Alignment (FSI system?)
- Prototyping

Wolfgang Lohmann

BeamCal Design

We recommend that the physics motivations and requirements for the BeamCal are studied in more detail to reinforce the case for this detector. The connection between BeamCal and beam monitoring for the accelerator should be strengthened.

BeamCal sensors:

....that more detailed evaluations of radiation damage are needed to demonstrate that the sensors will provide the uniformity and quality required. In particular simulations on energy and type of particles contributing to the damage and determination of the damage constants of these particles should be performed. Estimates should be made of the contribution from neutrons coming from reactions in machine components. We encourage further irradiation studies of GaAs sensors with pre-shower; these tests are suggested to take place at SLAC .

Other alternatives to be followed are silicon based technologies optimized for radiation hardness such as thinned sensors and 3D technology (or both combined). Those might eventually require cooling to reduce the leakage current. Studies of an alternative technology and the implication for BeamCal could be done by collaboration with groups already involved in the development of advanced silicon detectors.
These studies could only be done with enhanced personnel resources.

[NOTE: This review done before T-506 Si Irradiation results were available.]

Recommendations

Wolfgang Lohmann

Critical issues:

ASICs:

The ASIC development need to continue in order to stay compatible and take advantage of the continuously changing technology. It is important that the designers of the current generation ASICs can continue being involved in the project so as not to lose competence. We recognized that the designers are well integrated in the CERN activities to develop 130 nm ASICs for applications in the upgrades of LHC experiments, exploiting possible synergies. Changing to 130 nm technology reduces the power consumption considerably and facilitates temperature stabilization. Software from EUROPRACTICE is a standard tool of the chip designers. We think that the next step is to have a single chip including ADC (going to smaller structure size this should become possible).

Radiation damage does not seem to be a real challenge. Some information on the expected radiation level would be useful nevertheless. From there one could judge whether the CMOS technology can be used as it is or if special features like embedded transistors need to be used. Also SEU effects need to be evaluated.

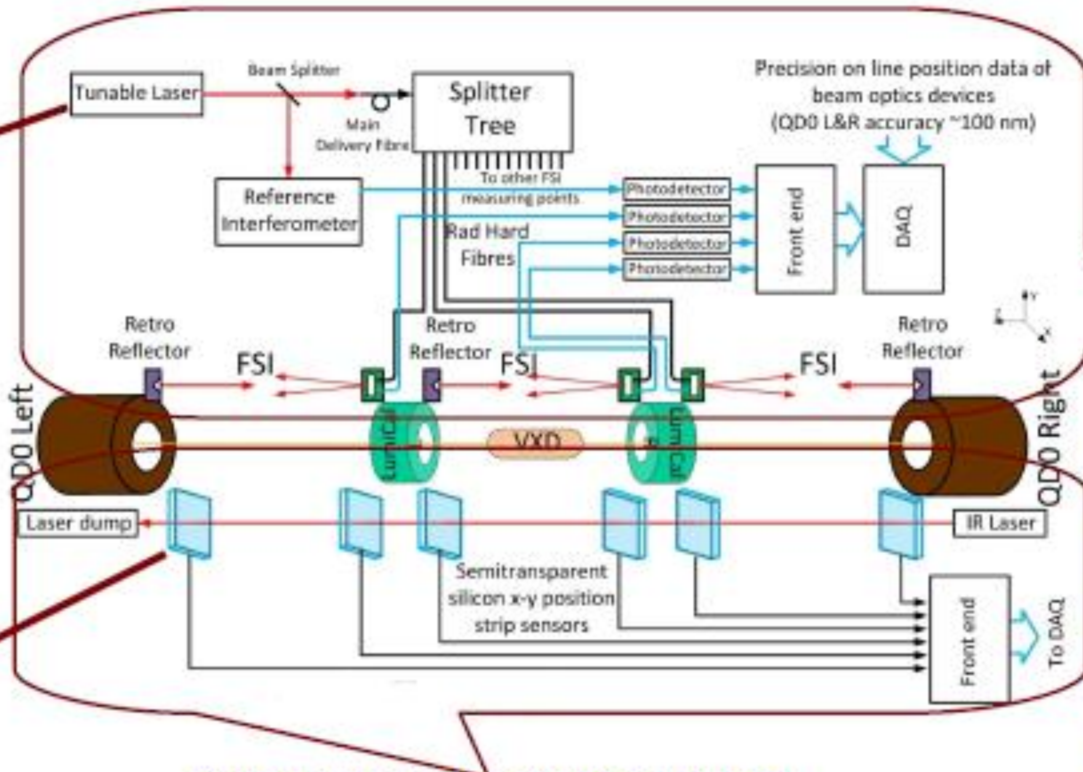
A Few Parting Thoughts

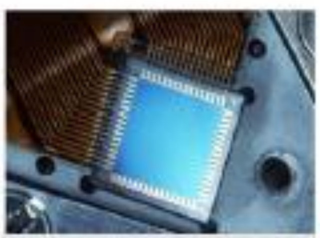
- Progress is being made, but there seems to be a sense that it is now time to focus the effort with a more structured collaboration
- Center of gravity is central Europe, with a few outliers [Chile, Santa Cruz, SLAC (?)]
- Clear role for CA group to contribute to sensor qualification; called out explicitly by ECFA collaboration
- FCAL collaboration would clearly welcome this and other efforts (simulations!), but from where comes the support? (SCIPP ILC funds down to about $400 of direct costs; won't even pay for repair critical precision power supply that winked out yesterday)
- But effort is needed and sought ➔ will take creative thinking to bring together effort
- But has generated one ESTB journal submission and another on the way after annealing studies.

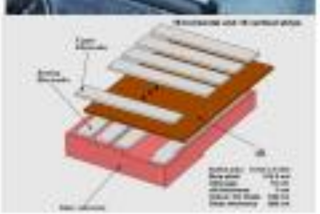
BACKUP

Laser alignment R&D at INP PAN
LumiCal Laser Alignement System (LAS)

The proposed laser alignmet system for LumiCal combines two components:
- infra-red laser beam and semi-transparent position sensitive detectors (PSDs) - already available
- tunable laser(s) working within Frequency Scanning Interferometry (FSI) system - in preparation







Semi-transparent sensors : LumiCal displacements of the internal Si layers and detectors relative positions

FSI – using tunable lasers will measure the absolute distance between LumiCal calorimeters by measurement of interferometer optical path differences (counting the fringes)