ALICE upgrade plans

ALICE Program

- Baseline Program:
  - initial Pb-Pb run in 2010 (1/20th design *L*, i.e. ~ 5 x 10^{25})
  - 2-3 Pb-Pb runs (medium -> design Lum. *L* ~ 10^{27}, 2.75 TeV -> 5.5 TeV) **integrate ~ 1nb^{-1}** at least at the higher energy
  - 1-2 p A runs (measure cold **nuclear** matter **effects**, e.g. shadowing)
  - 1 low mass ion run (**energy density & volume** dependence) typ. ArAr
  - **continuous running with pp** (comp. data, genuine pp physics)
- -> Baseline Program fills “HI runs” to ~ 2019
- Following:
  - program and priorities to be decided based on results
    - **Increase int. Luminosity** by an order of magnitude (to **~ 10nb^{-1}**)
      - Address rare probes
        (statistics limited: example with 1nb^{-1} :J/Y: excellent, Y’: marginal, Y: ok (14000) , Y’: low (4000), Y’’: very low (2000))
    - lower energies (energy dependence, thresholds, RHIC, pp at 5.5 TeV)
    - additional AA & pA combinations

ALICE Timeline
(before latest developments, to be revised)

- **2010-2012:** complete the approved detector configuration by adding modules of PHOS, **TRD** and **EMCal** (plus the 6-module *extension* **Dca**l). During the same period, upgrade R&D effort will continue to progress for VHMPID, for innovative pixel detectors, TPC readout, DAQ and for high-density calorimetry for FOCAL .
  - *Critical for any design definition are the first Heavy Ion data to be taken in November 2010*
  - *During the 2012 shutdown, installation of VHMPID Module-0 in ALICE to asses the technology (part of R&D)*
- **2013-2014:** Decisions on upgrade plans in terms of physics strategy, based on analysis of the first data, detector feasibility, results of the R&D, funding availability, and approval by LHCC.

“old” timeline continued

- **2015** shutdown - install a Phase I upgrade. For ALICE, it **could** include TPC readout, DAQ, VHMPID and Phase-I FOCAL (in the PMD location).
- **2017 :** Install major upgrades requiring the change of the beampipe, **could** include (some elements like Phase-II FoCal could be installed later):
  - ITS (addition of a small R layer + replacement of n of the existing layers)
  - Phase-II FoCal (very forward)
  - Forward tracking
  - Trigger and DAQ Upgrades
  - **> NEEDS at least 12 months**
- **Priority for ALICE: fewer but longer shutdowns**

Major Constraint:
Installation of a new beampipe and new ITS detector

From past experience we can get a good estimate of the needed time:

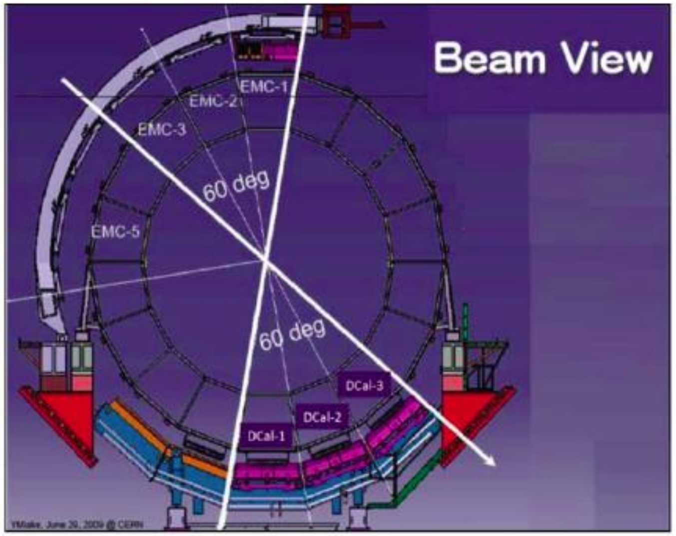
Opening the experiment and moving the TPC to parking position	11 weeks
Disconnecting and removing ITS and beampipe	6 weeks
Moving ITS to the surface and perform modifications	x weeks
Reinstallation of new beampipe, ITS detector, commissioning	16 weeks
TPC to IP and closing the experiment	15 weeks
	=========
Total time without contingency->	48 +x weeks

Whether we just replace the Silicon Pixel Detector (x=0 weeks) or whether we also modify the Silicon Drift Detector or Silicon Strip Detector is still not decided. This would add at least (x=10 weeks).

→ For the ALICE beampipe and tracker upgrade we need an absolute minimum of 1 year.

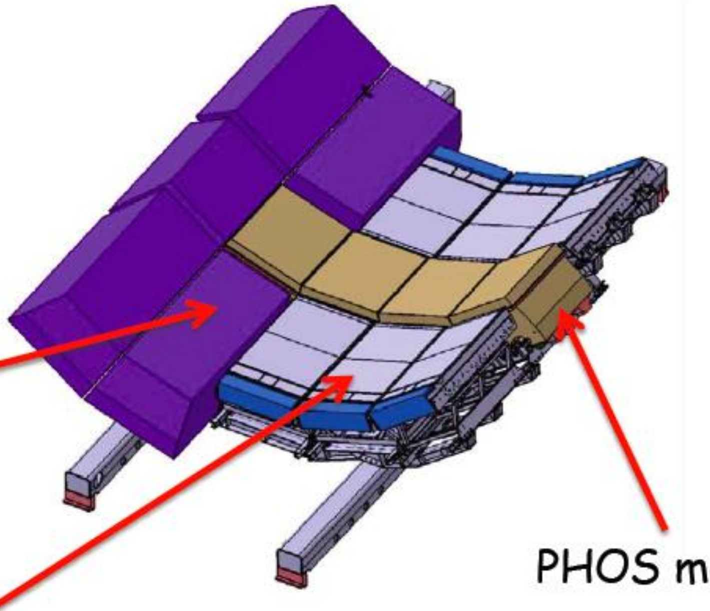
DCAL: Di-Jet Calorimeter

A 60% **expansion** of EMCal acceptance arranged to permit back-to-back hadron-jet and jet-jet correlations



Incorporate PHOS and new Pb/Scint super modules to produce a single, large electromagnetic calorimeter patch back-to-back with EMCal

Acceptance $\Delta\eta \times \Delta\phi = 1.4 \times 0.7$

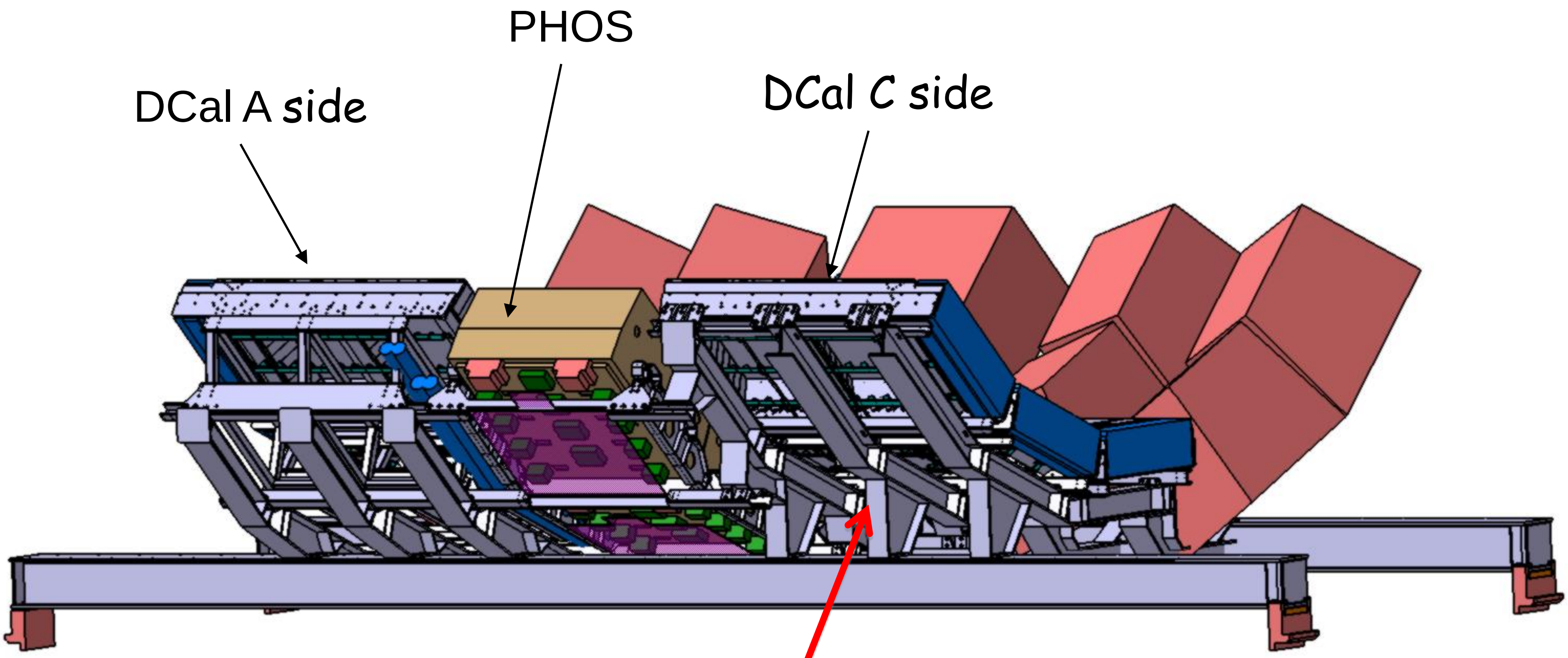


integration of VHMPID modules

PHOS modules

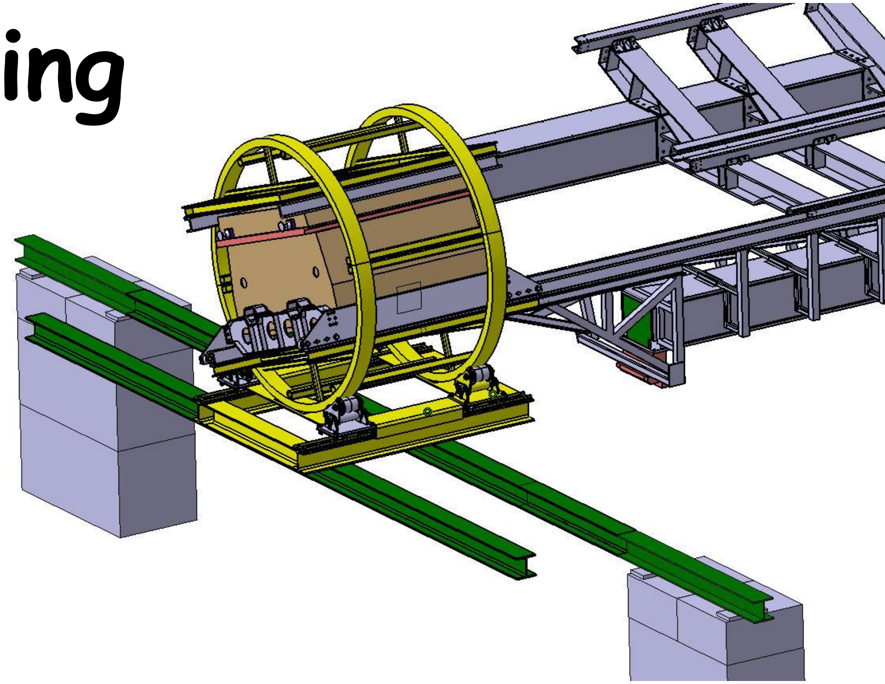
New DCal super modules

DCal+PHOS+VHMPID, Sideview



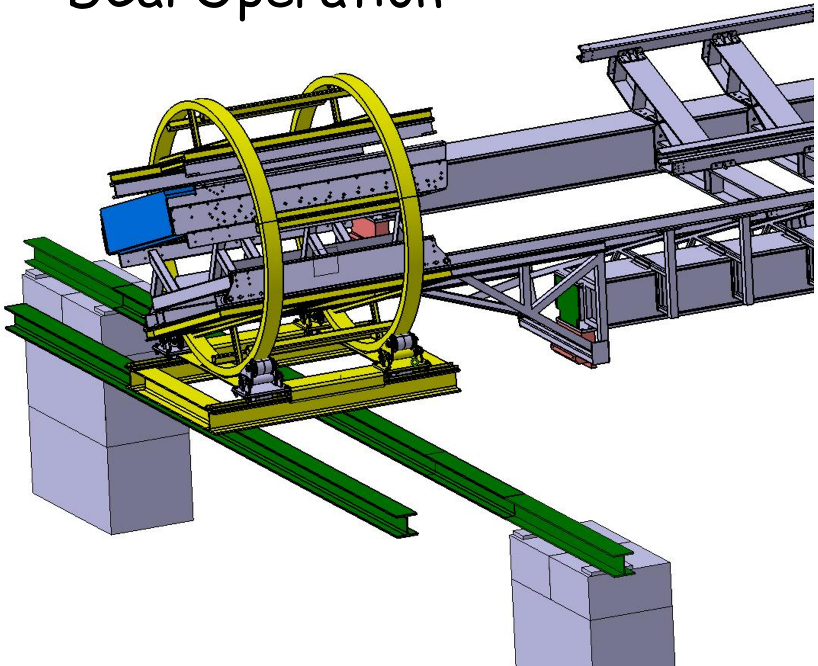
New common support structure for PHOS and DCal

Common DCal / PHOS Insertion Tooling



PHOS Operation

DCal Operation



Dcal Project organization (EMCAL + China and Japan)

China:

- Provide 1 DCal super module
- Proportional contribution of support structure costs
- Provide manpower for WLS fiber production for 3 SM in Frascati
- Proportional contribution of infrastructure, installation and integration costs
- Proportional contribution of electronics and trigger cost
- Proportional contribution to HLT and DAQ integration cost
- Provide proportional contribution to all shipping costs
- Proportional contribution of cosmic calibration manpower

France:

- Provide 0.5 DCal super modules (Nantes)
- Assemble and test all 2.5 EU and Asian strip modules (Nantes)
- Assemble and cosmic calibrate all DCal SMs: US, EU and Asian. (Grenoble)
- Provide engineering, design and fabrication oversight of support structure and installation tooling (Nantes)
- Proportional contribution of support structure costs
- Provide an advance of 200k euros toward the support structure cost in 2010
- DCal Installation oversight (Nantes)
- Proportional contribution of infrastructure, installation and integration costs
- Proportional contribution to HLT and DAQ integration cost
- Proportional contribution of electronics and trigger cost
- Provide proportional contribution to all shipping costs
- Proportional contribution of cosmic calibration manpower

Italy:

- Provide facilities, expertise and manpower for WLS fiber bundle assembly for EU and Asian modules (Frascati)
- provide module assembly tooling to Wuhan (two stations) (Frascati)
- provide module assembly tooling to Tsukuba (one station) (Catania & Frascati)
- Provide module assembly facilities, expertise and manpower for modules and strip modules for 0.5 Japanese SM (Catania)
- Provide facilities, expertise and manpower for all EU and Asian APD assembly and calibration (Catania)
- Contribution to US group of 2 DCal crates (Catania)
- Contribution of cosmic calibration manpower

Japan:

- Provide 1.5 DCal super modules (1 SM assembled in Japan, and for 0.5 in Catania)
- Provide manpower for APD assembly and calibration for 3 SM
- Proportional contribution of support structure costs
- Proportional contribution of infrastructure, installation and integration costs
- Proportional contribution of electronics and trigger cost
- Proportional contribution to HLT and DAQ integration cost
- Provide proportional contribution to all shipping costs
- Proportional contribution of cosmic calibration manpower

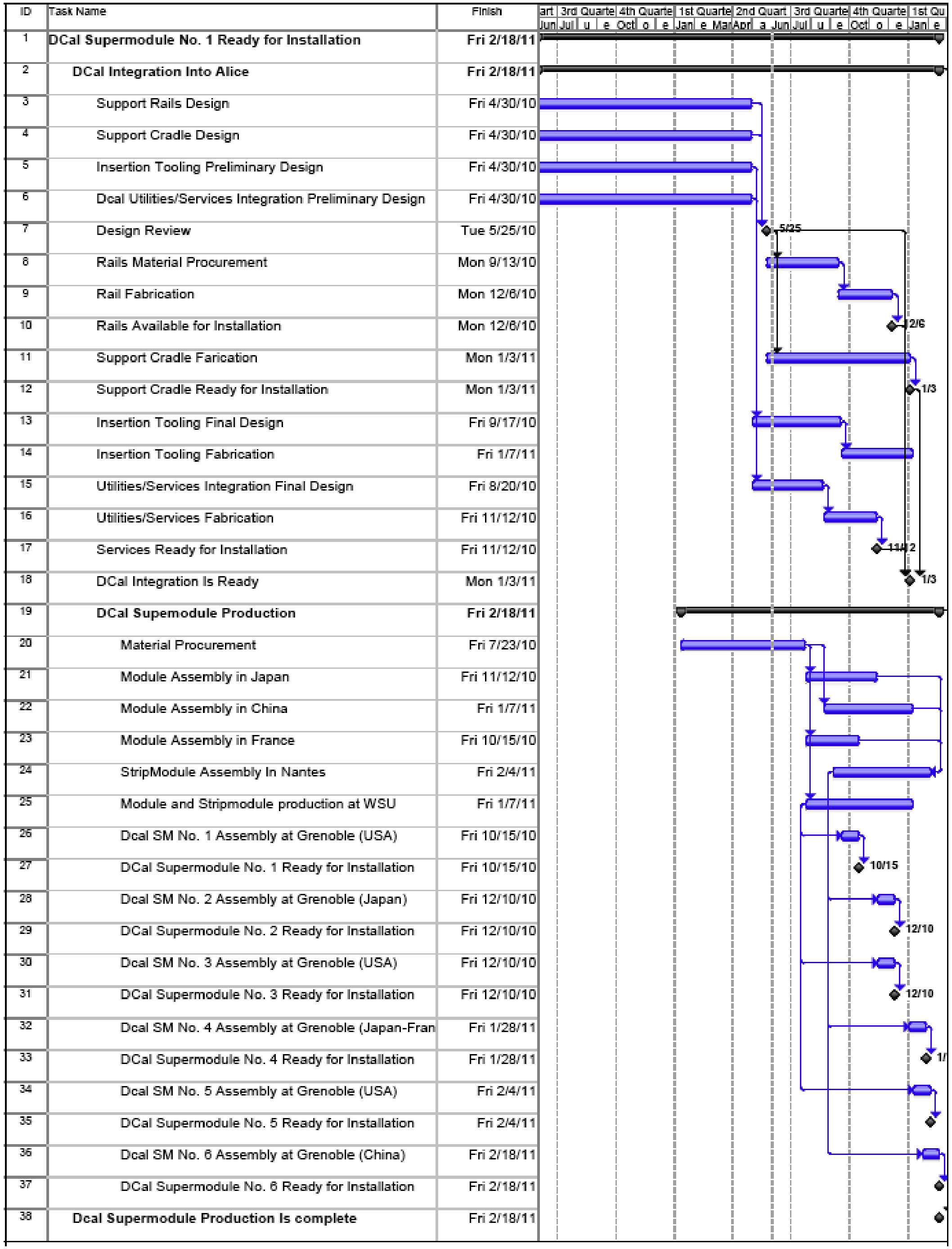
USA:

- ALICE DCal Project Management
- ALICE DCal Project Technical Coordination
- Provide module assembly tooling to Tsukuba (one station)
- Provide LED calibration fibers for the full DCal
- Provide APD plastic parts, fiber plastic parts
- Provide oversight of electronics procurement, installation and testing
- Provide 3 DCal super modules
- Proportional contribution of support structure costs
- Proportional contribution of infrastructure, installation and integration costs
- Proportional contribution of electronics and trigger cost
- Proportional contribution to HLT and DAQ integration cost
- Provide proportional contribution to all shipping costs
- Proportional contribution of cosmic calibration manpower (From all US Labs)

DCAL cost and schedule

Completion February 2011

DCAL System	Estimated Cost (kCH) 6 Supermodules
Mechanical Components production	**1,744**
Electronics Production	**1,047**
DCal Service Integration	**174**
Rails and Support Structure	**436**
Insertion Tooling	**140**
Total Shipping Cost	**419**
DCal total cost	**3,959**



ID	Task Name	Finish
1	**DCal Supermodule No. 1 Ready for Installation**	**Fri 2/18/11**
2	**DCal Integration Into Alice**	**Fri 2/18/11**
3	Support Rails Design	Fri 4/30/10
4	Support Cradle Design	Fri 4/30/10
5	Insertion Tooling Preliminary Design	Fri 4/30/10
6	Dcal Utilities/Services Integration Preliminary Design	Fri 4/30/10
7	Design Review	Tue 5/25/10
8	Rails Material Procurement	Mon 9/13/10
9	Rail Fabrication	Mon 12/6/10
10	Rails Available for Installation	Mon 12/6/10
11	Support Cradle Farication	Mon 1/3/11
12	Support Cradle Ready for Installation	Mon 1/3/11
13	Insertion Tooling Final Design	Fri 9/17/10
14	Insertion Tooling Fabrication	Fri 1/7/11
15	Utilities/Services Integration Final Design	Fri 8/20/10
16	Utilities/Services Fabrication	Fri 11/12/10
17	Services Ready for Installation	Fri 11/12/10
18	DCal Integration Is Ready	Mon 1/3/11
19	**DCal Supemodule Production**	**Fri 2/18/11**
20	Material Procurement	Fri 7/23/10
21	Module Assembly in Japan	Fri 11/12/10
22	Module Assembly in China	Fri 1/7/11
23	Module Assembly in France	Fri 10/15/10
24	StripModule Assembly In Nantes	Fri 2/4/11
25	Module and Stripmodule production at WSU	Fri 1/7/11
26	Dcal SM No. 1 Assembly at Grenoble (USA)	Fri 10/15/10
27	DCal Supermodule No. 1 Ready for Installation	Fri 10/15/10
28	Dcal SM No. 2 Assembly at Grenoble (Japan)	Fri 12/10/10
29	DCal Supermodule No. 2 Ready for Installation	Fri 12/10/10
30	Dcal SM No. 3 Assembly at Grenoble (USA)	Fri 12/10/10
31	DCal Supermodule No. 3 Ready for Installation	Fri 12/10/10
32	Dcal SM No. 4 Assembly at Grenoble (Japan-Fran	Fri 1/28/11
33	DCal Supermodule No. 4 Ready for Installation	Fri 1/28/11
34	Dcal SM No. 5 Assembly at Grenoble (USA)	Fri 2/4/11
35	DCal Supermodule No. 5 Ready for Installation	Fri 2/4/11
36	Dcal SM No. 6 Assembly at Grenoble (China)	Fri 2/18/11
37	DCal Supermodule No. 6 Ready for Installation	Fri 2/18/11
38	**Dcal Supermodule Production Is complete**	Fri 2/18/11

Quick status of other projects

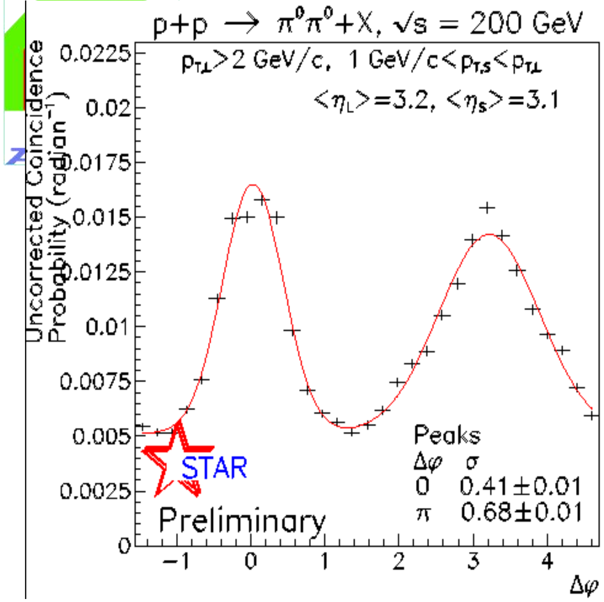
- Studies to define the projects progress
- R&D programs have been launched and are vigorously pursued:
    - Fast drift and fast readout for TPC
    - Enhanced capacity DAQ
    - Hadron Identification up to over 20 GeV
    - High density Calorimetry
    - Low-mass, high-resolution pixel detectors
- **Comprehensive report last time, concentrate on few items now**

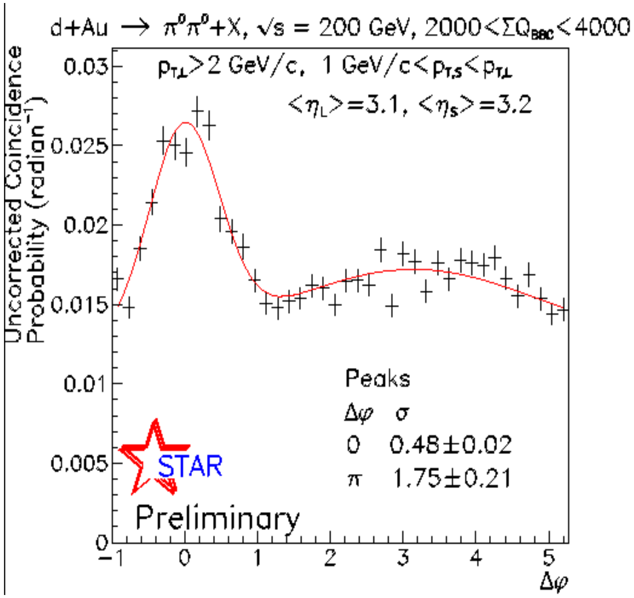
FoCal Physics Motivation

- Study low-x parton distributions
  - implies large rapidities

$$x \approx \frac{p_T}{\sqrt{s}} \exp(-y) \approx \frac{p_T}{\sqrt{s}} \exp(-\eta)$$

- Main physics issues:
  - gluon saturation (pA)
  - elliptic flow (AA)
    - rapidity gap reduces non-flow
  - long-range rapidity correlations: ridge (AA)
  - …
- Provide forward ($\eta > 3$) coverage for identified particle measurements
  - EM calorimeter for photons, neutral pions (eta?), jets
  - Requires high granularity (lateral and longitudinal)
- Favoured technology: SiW
- **Phased approach**
  - **Phase 1: inside magnet, $\eta < 4.5$**
  - **Phase 2: outside magnet, $\eta > 4.5$**



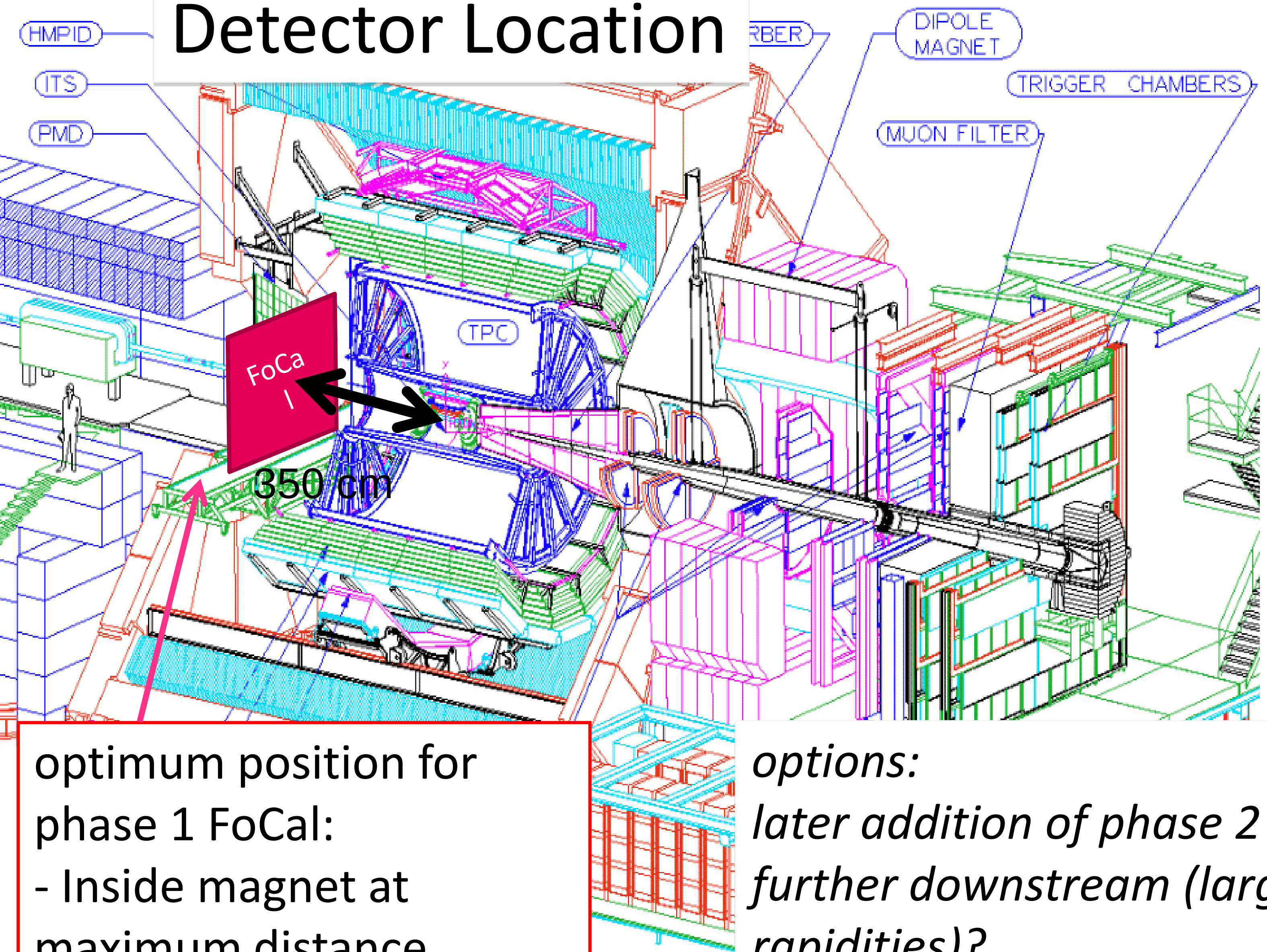


Akio Ogawa et al.

Signals of gluon saturation

- At forward forward rapidities:
  - Single hadron suppression
  - De-correlation of recoil yield
- Interesting observations at RHIC, consistent with gluon saturation
  - Still too low p_T! Reference measurement not describable by pQCD?
  - Limited by small saturation scale
- Measurements at LHC advantageous
  - Larger kinematic reach (smaller x)!
  - Larger saturation scale: larger p_T possible!

Detector Location



optimum position for phase 1 FoCal:

- Inside magnet at maximum distance (before T0, flange, etc.)

options:

later addition of phase 2 detector further downstream (larger rapidities)?

detector integrated in muon absorber?

Institutes/Current Activities

- Tokyo (simulation, electronics R&D, prototype tests, 10x10 mm^2 pads)
- Kolkata + collaborating Indian institutes (simulation, Si-strips)
- Utrecht/Nikhef (simulation)
- Yonsei (prototype tests)
- Prague, Jyväskylä
- *expression of interest: Bergen, Copenhagen, Nantes, Oak Ridge, …*

Design Decisions

- technology: Si-W sandwich
  - active layers pads and/or strips
- location: 3.5 m from vertex (replacing PMD)
  - alternative option to be studied: integrate in muon absorber
- pad size: 10 x 10 mm^2 or smaller
- tower geometry
  - bring services to back of detector

Open Design Issues

- exact granularity?
  - Driven by overlap probability in heavy ion collisions
    - Needs November data on Multiplicity
  - information on longitudinal shower development
- dynamic range?
  - depends on granularity
  - consequences for front-end electronics
- electronics/integration
  - front-end electronics: only preamp/shaper or also ADC, integrated in Si layers?
  - modify existing design?

Timeline (tentative)

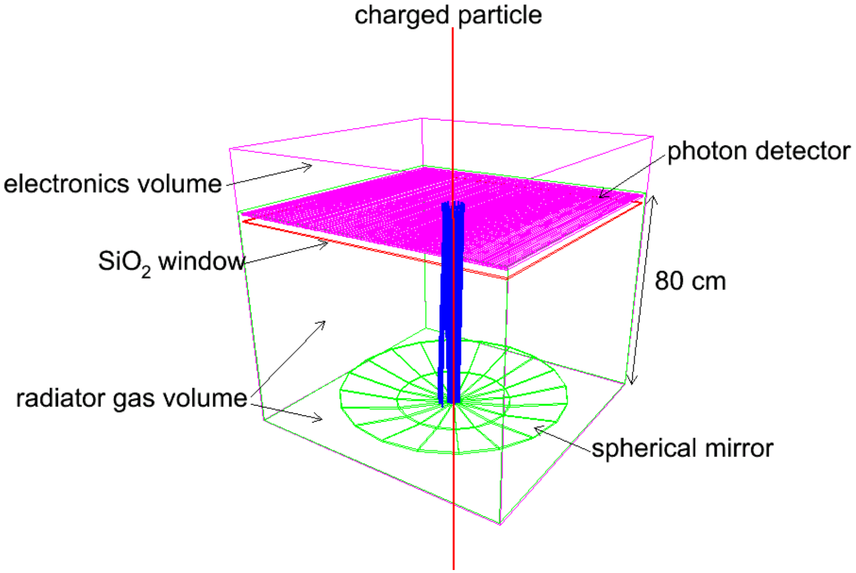
2010	crucial design decisions: granularity, dynamic range, eta coverage establish options for front end electronics prepare Letter of Intent
2011	detailed simulations and mechanics design: number of layers, exact thickness, necessary gaps, etc. electronics R&D, construction of physics prototype
2012	physics prototype in beam (test beam or physics beam?) continue electronics R&D
2013	production, tests
2014	production, tests
2015	detector installation

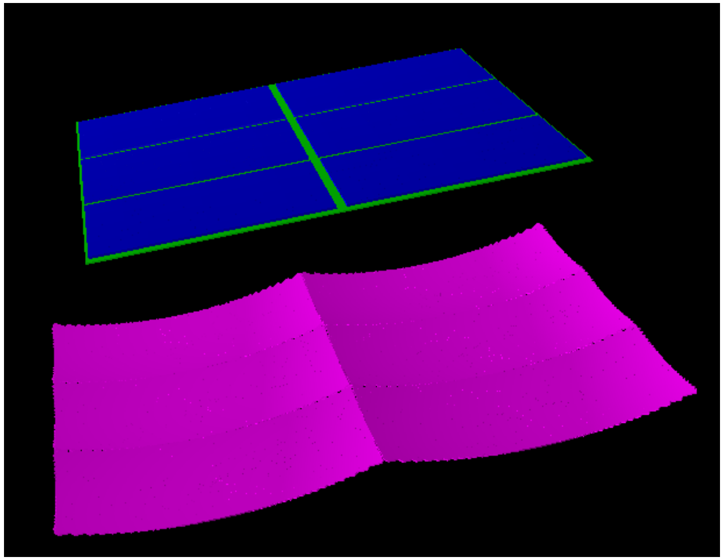
Cost Estimates (tentative)

	max	min
radius [cm]	75	75
layers	30	21
pad size [cm^2]	0.5x0.5	1x1
# of channels	2 120 000	371 000
mechanics, cooling etc.	2 000 k€	2 000 k€
tungsten	380 k€	270 k€
Si sensors	5 300 k€	3 700 k€
read-out	5 300 k€	930 k€
total	12 980 k€	6 900 k€

Extending ALICE PID capability: The VHMPID project

- RHIC results: importance of high momentum particles as hard probes and the need for particle identification in a very large momentum range, in particular protons.
- The VHMPID (Very High Momentum PID) detector will extend the track-by-track identification capabilities of ALICE up to ~ 26 GeV/c
- The VHMPID will also represent a tool to help TPC in calibration of PID based on dE/dx





- It is a RICH in focusing geometry using 80 cm C_4F_{10} gaseous radiator, segmented spherical mirror and CsI-based photodetector (with MWPC or Thick-GEM)
- Same HMPID FEE, based on Gassiplex chip
- Most of the design derived from HMPID know-how, issues needing R&D:
  - CsI-TGEM reliability over large area
  - Pad cathode segmentation and structure
  - Large area quartz windows segmentation and fixation
  - Spherical mirror structure and segmentation

The VHMPID collaboration

- **Instituto de Ciencias Nucleares Universidad Nacional Autonoma de Mexico, Mexico City, Mexico**

E. Cuautle,I. Dominguez, D. Mayani, A. Ortiz, G. Paic, V. Peskov

- **Instituto de Fsica Universidad Nacional Autonoma de Mexico, Mexico City, Mexico**

R. Alfaro

- **Benemerita Universidad Autonoma de Puebla, Puebla, Mexico**

M. Martinez, S. Vergara, A. Vargas

- **Universita' degli Studi di Bari and INFN Sezione di Bari, Bari, Italy**

G. De Cataldo, D. Di Bari, E. Nappi, C. Pastore, I. Sgura, G. Volpe

- **CERN, Geneva, Switzerland**

A. Di Mauro, P. Martinengo, L.Molnar, D. Perini, F. Piuz, J. Van Beelen

- **MTA KFKI RMKI, Research Institute for Particle and Nuclear Physics, Budapest, Hungary**

A. Agocs, G.G. Barnafoldi, G. Bencze, L. Boldizsar, E. Denes, Z. Fodor, E. Futo, G. Hamar, P. Levai, C. Lipusz, S. Pochybova

- **Eotvos University, Budapest, Hungary**

D. Varga

- **Chicago State University, Chicago, IL, USA**

E. Garcia

- **Yale University, New Haven, USA**

J. Harris, N. Smirnov

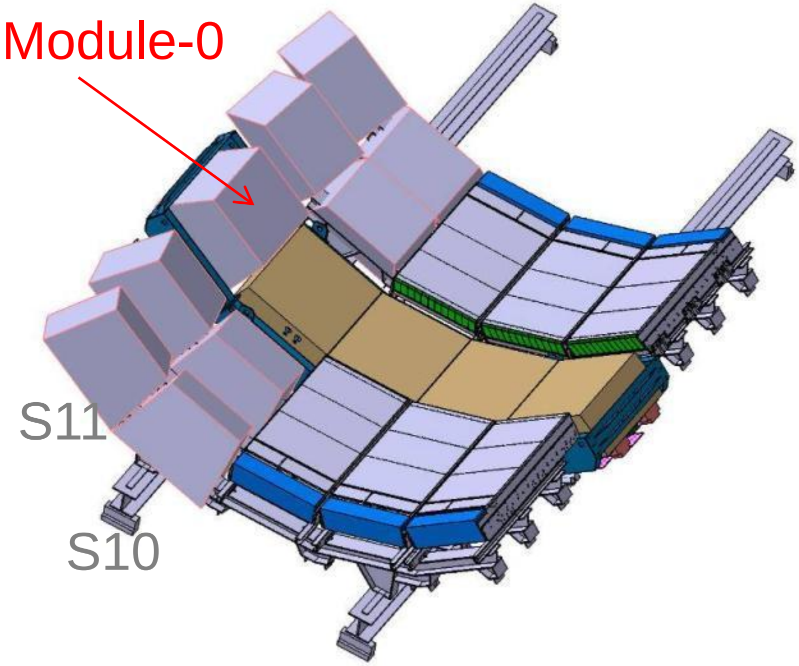
- **Pusan National University, Pusan, Korea**

In-Kwon Yoo, Changwook Son, Jungyu Yi

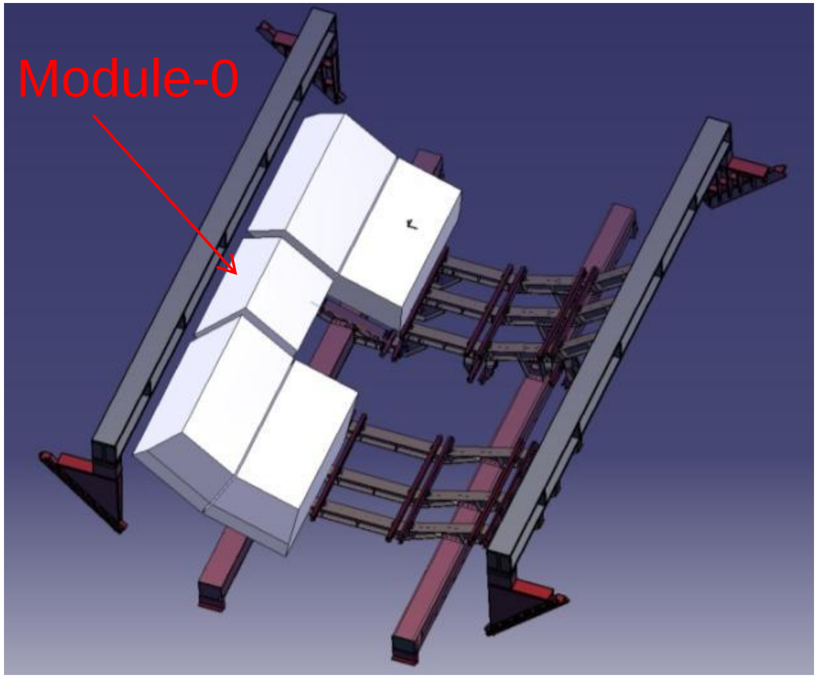
Integration in ALICE

- Design constraint: exploit all available space to maximize acceptance
- Tilted single modules: problems with different clearance in S10 and S11, acceptance ~ 8% wrt to TPC in $|\eta| < 0.5$ (jet fully contained)
- "Super-modules" layout: h=130 cm everywhere, acceptance ~ 12%
- Module-0 size doubled acceptance (~ 3%) due to new PHOS support structure (i.e. no cradle in S11)

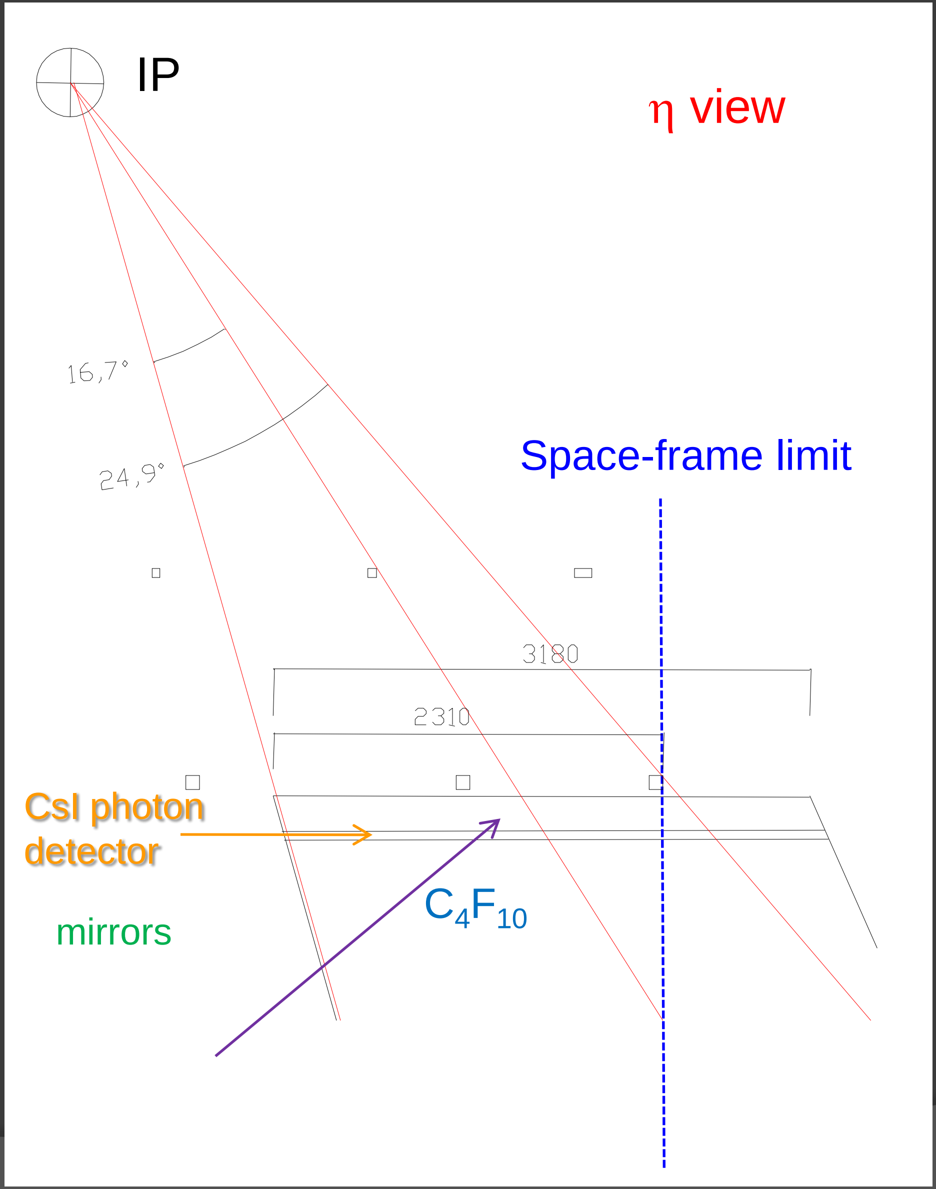
2009 layout: projective geometry



new layout, super-modules



Supermodule layout



IP

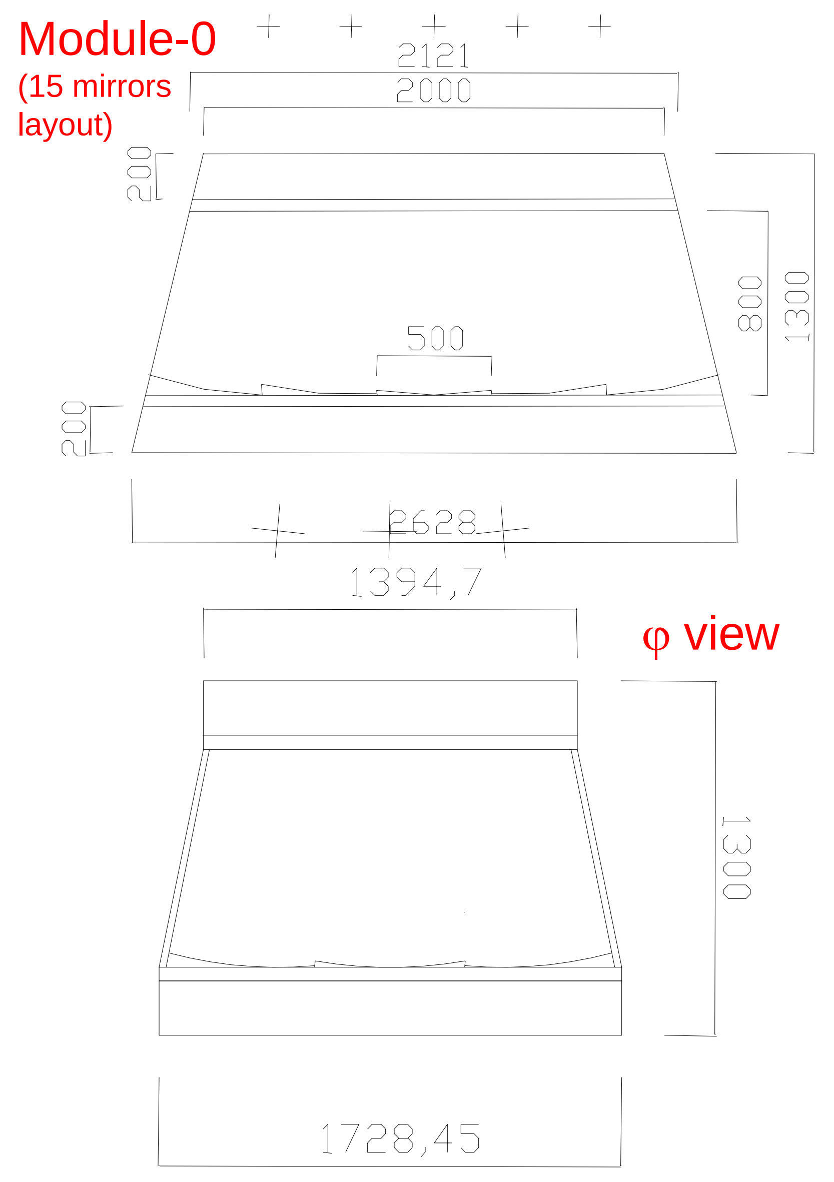
η view

Space-frame limit

CsI photon detector

C_4F_{10}

mirrors

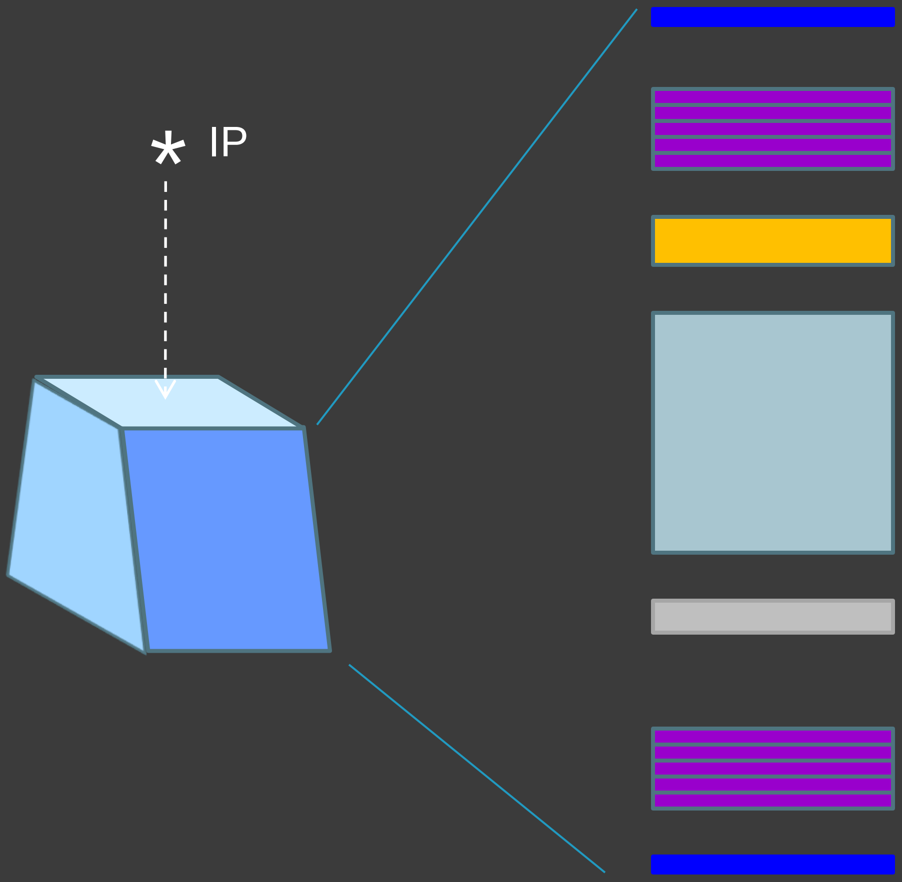


Module-0

(15 mirrors layout)

φ view

Module-0 layout



Cooling+cover: 3cm

Trigger A + MIP layer: 16cm

Photon-detector+FEE: 8cm

C_4F_{10} radiator: 80 cm

Mirror+cover: 4cm

Trigger B + MIP layer: 16cm

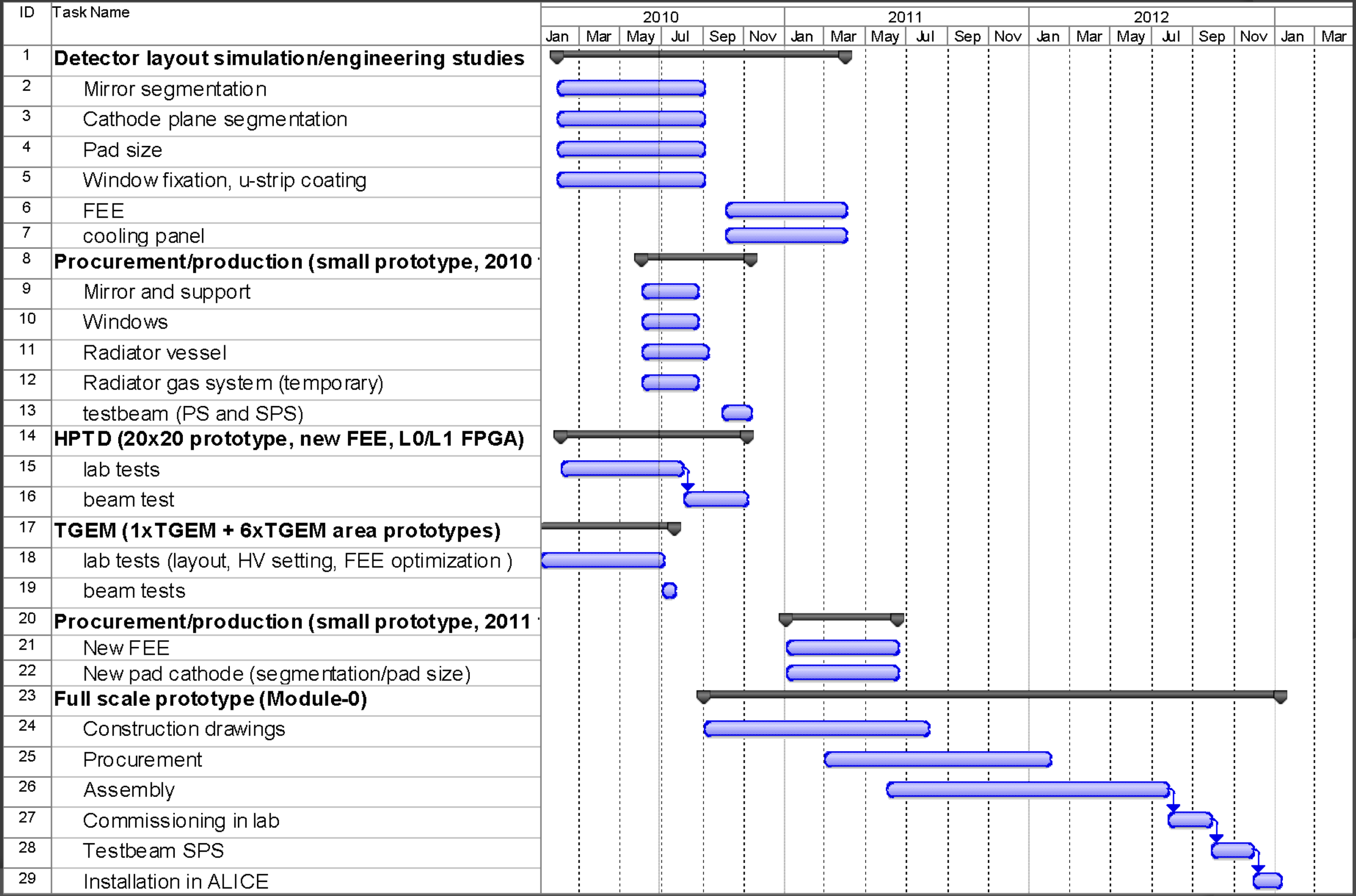
Cooling+cover: 3cm

Total: 130 cm

Beam tests program

Period A	1-19 Jul	PS/T10	TGEM
Period B	16-30 Aug	PS/T10	HPTD
Period C	27 Sept-11 Oct	PS/T10	Small prototype
Period D	1-8 Nov	SPS/H4	HPTD+Small prototype

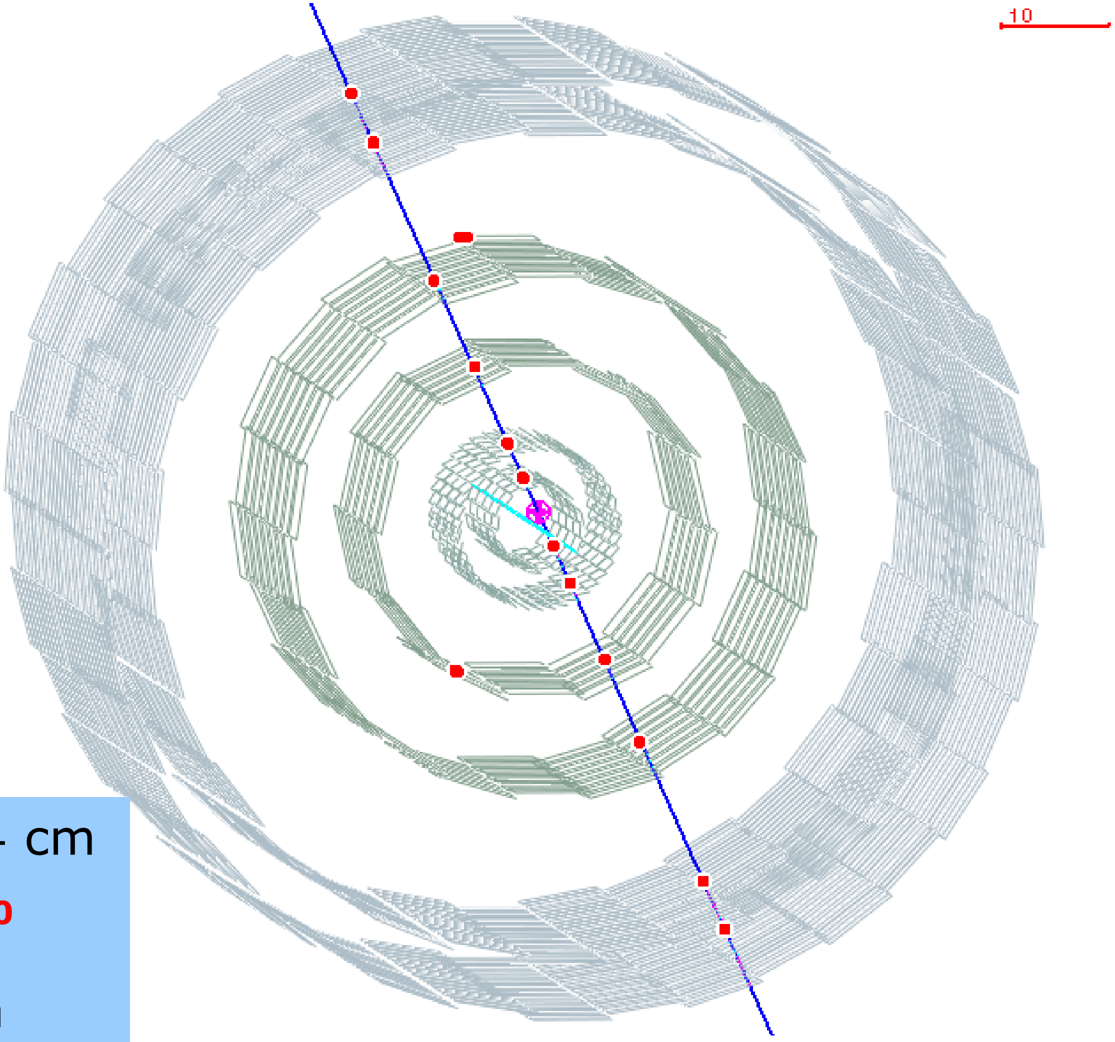
Module-0 production planning



ID	Task Name
1	**Detector layout simulation/engineering studies**
2	Mirror segmentation
3	Cathode plane segmentation
4	Pad size
5	Window fixation, u-strip coating
6	FEE
7	cooling panel
8	**Procurement/production (small prototype, 2010**
9	Mirror and support
10	Windows
11	Radiator vessel
12	Radiator gas system (temporary)
13	testbeam (PS and SPS)
14	**HPTD (20x20 prototype, new FEE, L0/L1 FPGA)**
15	lab tests
16	beam test
17	**TGEM (1xTGEM + 6xTGEM area prototypes)**
18	lab tests (layout, HV setting, FEE optimization)
19	beam tests
20	**Procurement/production (small prototype, 2011**
21	New FEE
22	New pad cathode (segmentation/pad size)
23	**Full scale prototype (Module-0)**
24	Construction drawings
25	Procurement
26	Assembly
27	Commissioning in lab
28	Testbeam SPS
29	Installation in ALICE

Inner Tracking System upgrade

- Present 6 detector layers based on three silicon technologies:
  - SPD (pixels)
  - SDD (Si Drift)
  - SSD (Si strips)
- Unique level-zero trigger (fast OR)



Radii: **4**, 7, 15, 24, 39, and 44 cm
Total material budget of **7%X_0**
(normal incidence)
Pixel size 50 μm times 425 μm
Beam pipe radius 2.98 cm

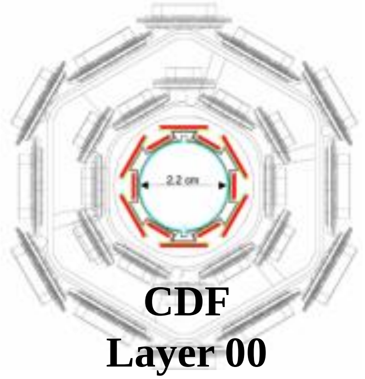
Inner Tracking System upgrade

- Goal: a factor of 2 improvement in impact parameter resolution
- Secondary goal: improve stand-alone tracking capability
- Improving the impact parameter resolution by a factor 2 or better will:
  - Increase sensitivity to charm by factor 100;
  - Give access to charmed baryons (baryon/meson ratio in charm sector – main issue is understanding of recombination);
  - Allow study of exclusive B decays;
  - Allows first measurement of total B production cross section down to zero P_T ;
  - Improve flavor tagging.

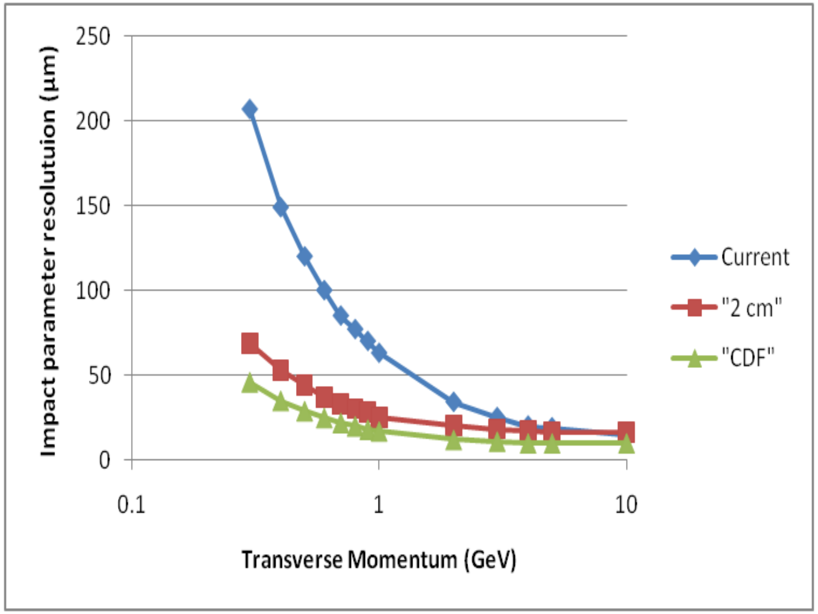
Inner Tracking System Upgrade

- **Detector Layout and Technology:**
  - 6/7 cylindrical layers
  - First layer as close as possible to the interaction point: smaller and thinner beam-pipe (present 29/0.8mm)

    goal: at least O(20mm) radius or smaller
  - Extend the use of pixel detectors to larger radii (replace SDD, slowest det in ITS)
    - strips where pixels not affordable
    - re-use of the existing pixel and/or strip layers being considered
  - Extremely low material budget, trigger capability, granularity, fast readout
  - New mechanics and cooling



CDF Layer 00



- **Target dates defined by the LHC shutdown schedule: 2017**

ITS Upgrade Time-scale

- **R&D phase: 2010-2013/14**
  - Explore two Pixel technologies:
    - Hybrid pixel detectors: “state of the art”
      - low cost bump-bonding
      - new sensor type (3D, edgeless planar)
      - further thinning (SPD: 200 μm sensor + 150 μm FEE)
    - Monolithic pixel detectors: Mimosa and LePix
      - larger detector areas at considerably lower cost
  - Layout Studies and Technical Design report
- **Production and pre-commissioning: 2014-2016**
- **Installation and commissioning: 2017**

R&D Progress

- Hybrid Pixels:

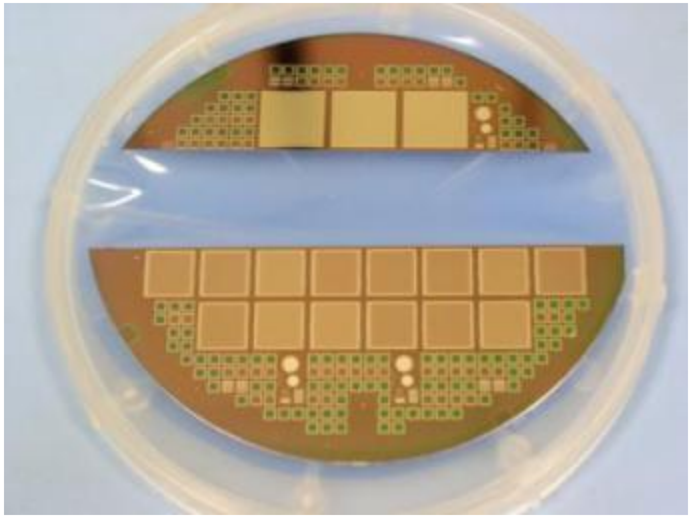
- Investigating possible application of hybrid silicon pixel detectors by studying possibilities to reduce the material budget
- 3 main targets defined
  - Thinning studies of chip wafers (150 μm in ALICE SPD, is 50-100 μm feasible?)
  - Thin silicon sensors (reduce the thickness from 200 um to 150 um, non-linear yield problem!)
  - Reduce the need for overlaps between modules (active edge, 3D sensor technologies)

- Lepix:

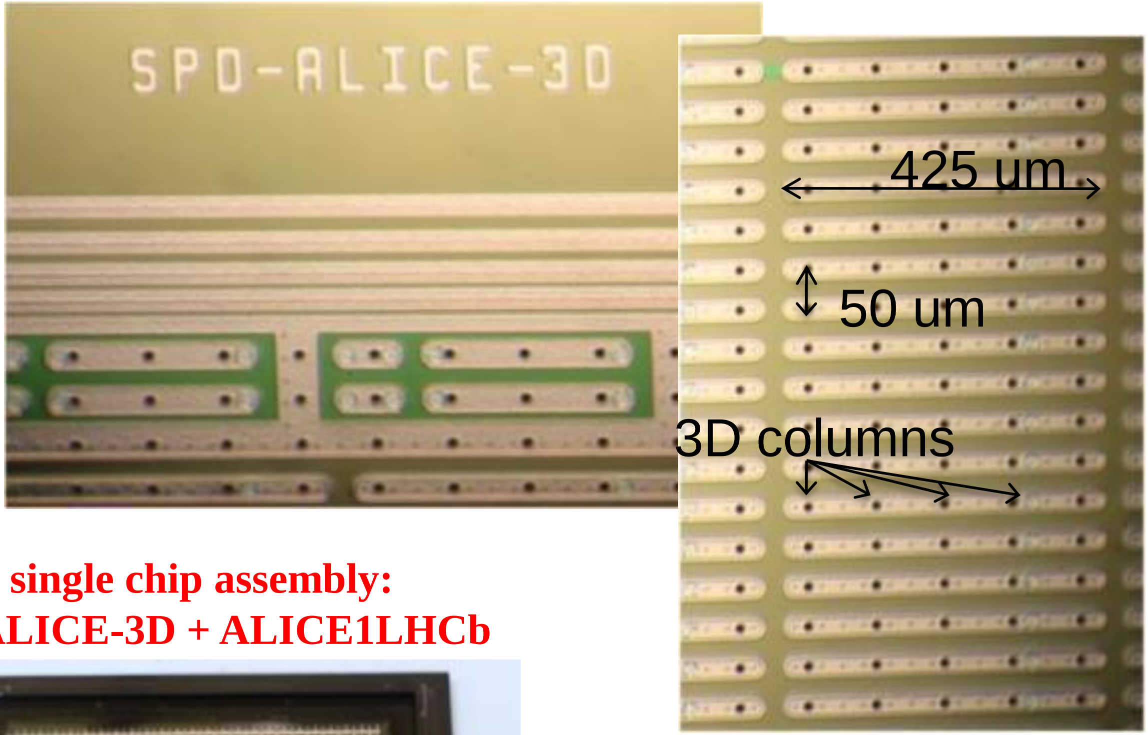
- Submission in 90nm finalized March 2010, prototypes expected back now
  - Several issues: ESD, special layers and mask generation, guard rings
- 7 chips submitted :
  - 4 test matrices C90_MATRIX1_V0…C90_MATRIX4_V0
  - 1 diode for radiation tolerance C90_DIODE_V0
  - 1 breakdown test structure C90_VBRDOWN_V0
  - 1 transistor test: already submitted once in test submission C90_TESTC90_V1
- Very significant testing effort for which we need to prepare (measurement setup, test cards…)

Happening … 3D assemblies

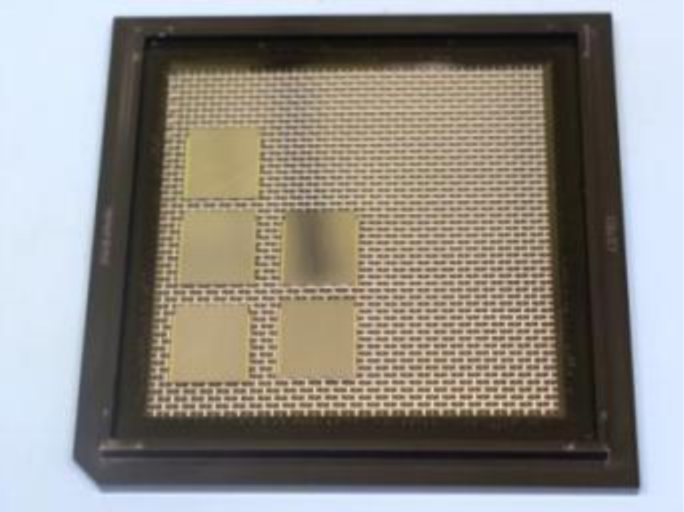
FBK 3D sensor wafer



Details of the SPD-ALICE-3D sensor



5 single chip assembly:
SPD-ALICE-3D + ALICE1LHCb



3D prototype

Single chip assembly glued and wire-bonded to the test card