Next Steps and Issues of 3D R&D In ATLAS

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OUTLINE

- Pixel sensors milestones for Replacement and Upgrade
- Sensor Requirements for the Replacement/Upgrade
- Present results and Issues
- Proposed schedule and Work Plan

Pixel Sensors Replacement and Upgrade Milestones

- LHC will start in 2007

- The goal for b-layer replacement is fall 2012

  … with nominal luminosity profile, expect b-layer performance to start degrading after 2-3 years at LHC design luminosity (or about 300 fb^{-1} or $10^{15} n/cm^2$) The performance of the b-layer has a large impact on Atlas physics – particularly for b-tagging! (from K. Heinsweiler talk, Atls upgrade workshop 1-10-06)

- The upgrade of the entire tracker should take place in 2016 –

If we want to use 3D technology for the replacement (and for the upgrade) we need to organise ourselves NOW!

Decisions will need to be taken by 2008 to match the schedule for the ROC engineering run and allow design matching

Before choosing a future 'new' pixel sensor technology like 3D we need to make sure that:

- Radiation hardness : for the replacement $3x10^{15}$ n/cm^3 with 3 times more charge (up to 10^{16} n/cm^2 for the upgrade)

- Speed better than present planar technology
  Reduced bunch crossing, pileups, rate

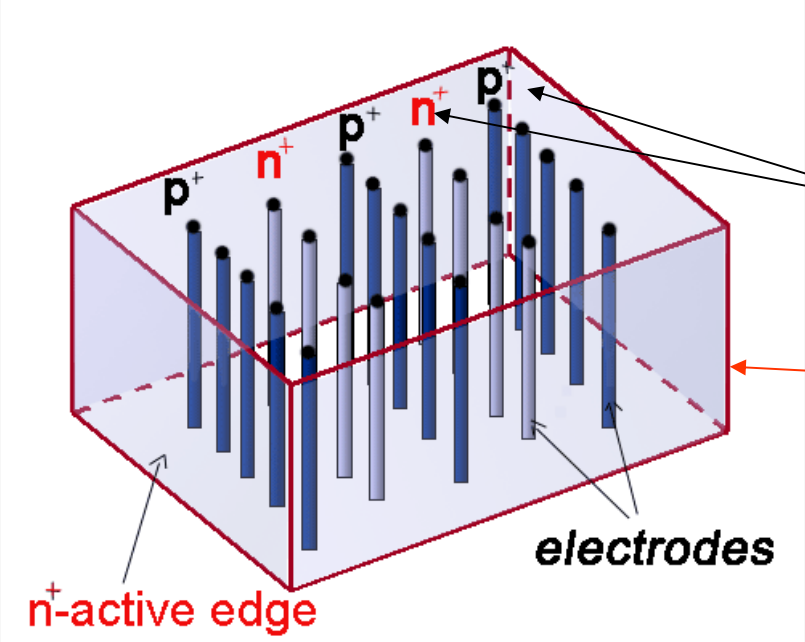
- Improved layout geometry, Implications on the final system design
  Reduced dead edge – material budget
  MCM compatible – Lorentz angle free

- Reduced depletion voltage – Cooling - HV power distribution
  (present technologies operate at~ 600-800V after $3x10^{15}$n/cm^2
  - partial depletion)

->Large scale production – industrial vendors active by 2007-2008
present production made at Stanford. Can support small area projects like part of Totem and FP420

->Timescale Yield and Cost

3D silicon sensors were originally proposed by Sherwood Parker and are presently fabricated at Stanford by J. Hasi (Brunel/Manchester) and C. Kenney (MBC)



Combine traditional VLSI processing and MEMS (Micro Electro Mechanical Systems) technology.

Both electrode types are processed inside the detector bulk instead of being implanted on the Wafer's surface.

The edge is an electrode (following an idea by C. Kenney). Dead volume at the Edge < 5 microns! Essential for forward physics experiments and material budget

3DC collaboration was formed in January 06
Core Members: Brunel/Manchester, Hawaii Oslo University, Sintef and Stanford (MBC)

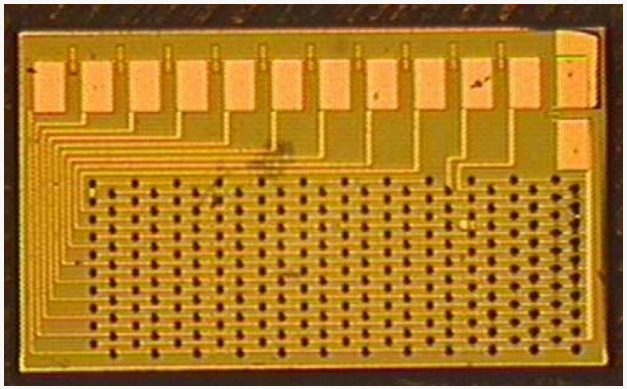
Ongoing successful collaboration with Praha Technical University, Bonn and LBL

1. NIMA 395 (1997) 328
2. IEEE Trans Nucl Sci 464 (1999) 1224
3. IEEE Trans Nucl Sci 482 (2001) 189
4. IEEE Trans Nucl Sci 485 (2001) 1629
5. IEEE Trans Nucl Sci 48 6 (2001) 2405
6. CERN Courier, Vol 43, Jan 2003, pp 23-26
7. NIM A 509 (2003) 86-91
8. MIMA 524 (2004) 236-244

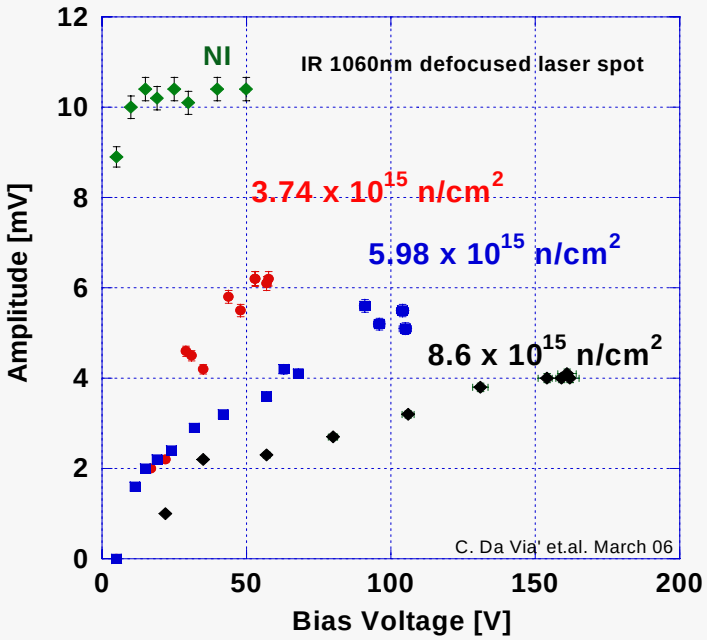
So far we know that →

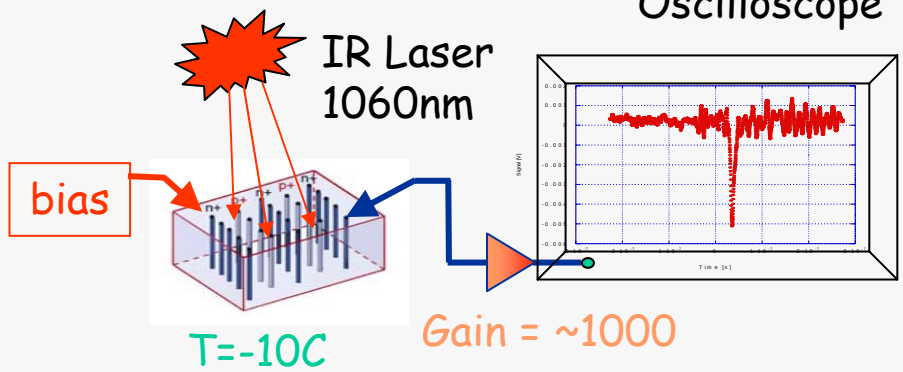
3D is radiation hard: Tests with baby-Atlas sensors

C. DaVia. J. Hasi, S Watts, (Brunel/Manchester),V. Linhart, T. Slavicheck,
T Horadzof, S. Pospisil (Technical University, Praha), C. Kenney (MBC), S. Parker (Hawaii/LBL)



- Volume = 1.2 x 1.33 x 0.23 mm^3
- 3 electrode Atlas pixel geometry 71 μm IES
- n-electrode readout
- n-type before irradiation -12 kΩ cm
- Irradiated with reactor neutrons (Praha)

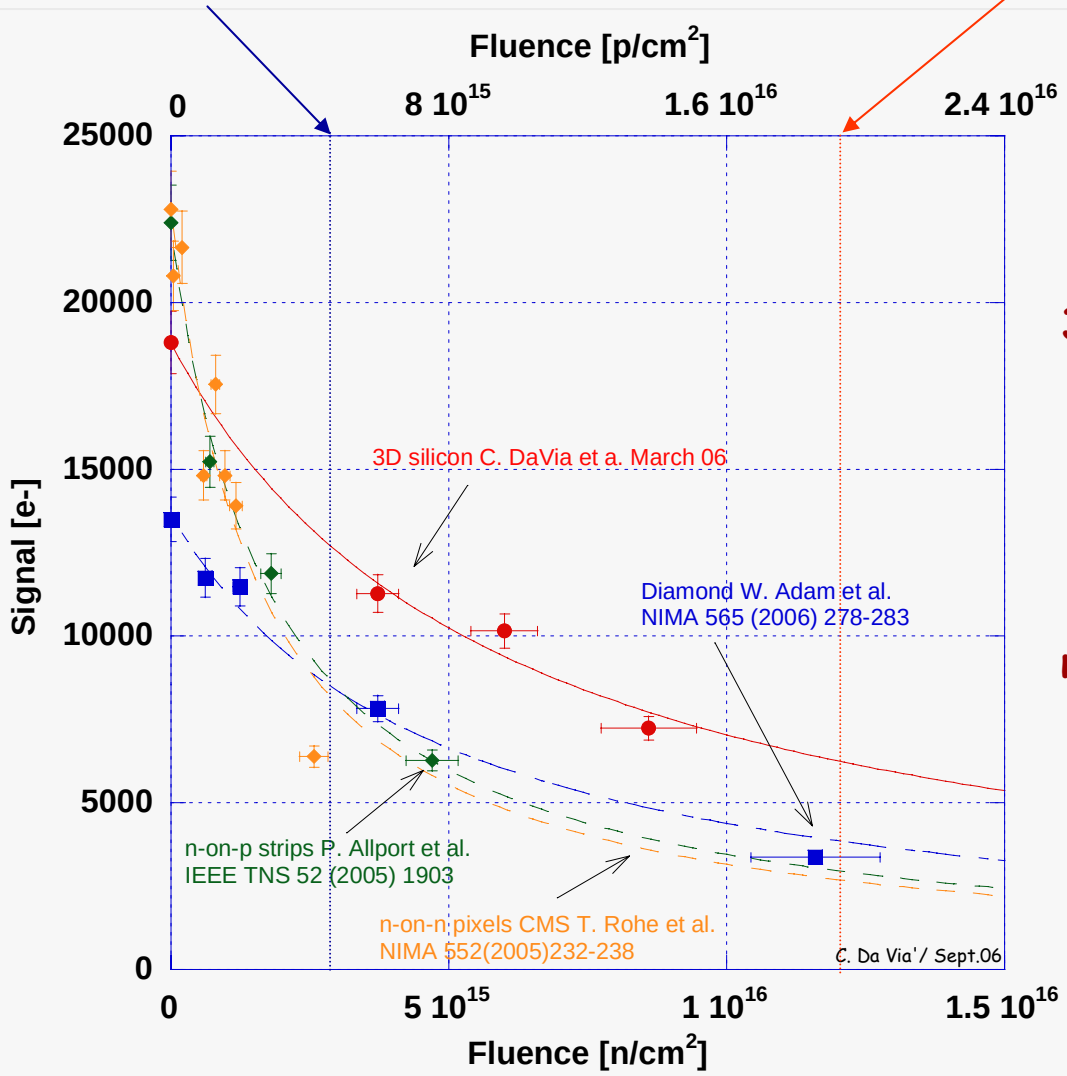




Radiation Hardness

$3x10^{15}$ p/cm^2 =
10 years LHC at 10^{34} cm^{-2}s^{-1}
At r=4cm and target for b-layer replacement

1.8×10^{16}p/cm^2 =
10 years SLHC at 10^{35}cm^{-2}s^{-1}
At r=4cm



Fluence [n/cm^2]	Bias voltage [V]	
3D		
$3.74x10^{15}$	60	**B-layer**
$5.98x10^{15}$	100	
8.60×10^{15}	160	**upgrade**
n-on-n pixels CMS		
~3×10^{15}	600	

We can expect:

Twice as much charge
Factor 10 less bias

3D can be fabricated to match FP420/Atlas pixel

(bump-bonding IZM organised by the Bonn Group) – PPARC funding

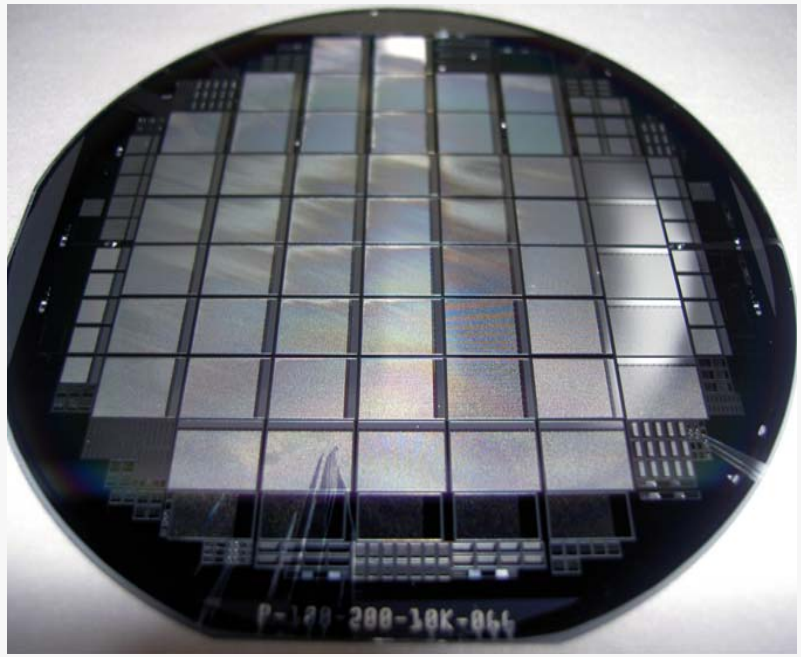
DIMENSIONS	RO SIGNAL	Technology	BUFFER/speed
50x400 μm^2 7.2x8mm^2	binary and time over threshold	0.25 μm IBM CMOS6SF	2 - 6.4μs 40 MHz

Atlas chip picture from Bekerle Vertex03

FP420 PLANS:

FP420 is a common Atlas/CMS R&D to study the feasibility of proton taggers installation at 420m from the IP.- goal-> Diffractive physics

- Test beam with single chips and rad-hardness tests – September 06
- Common R&D till beginning 2007
- Separate proposals to ATLAS and CMS by summer 2007
- Station system test beam summer 07 using single Atlas pixel-chips
- 3D production in spring 08 (~50 wafers both experiments will use single atlas pixel chips)
- Stations production by 2008
- Installation foreseen for the Long shut-down of 2008-09



10 wafers completed : Yield on one wafer ~80%

We also know that 3D

+Has been tested with Atlas pixel ROC and we understand the geometry – signal formation, charge sharing , test beam results

see S Watts talk

+Can be processed with Active edges

see C. Kenney talk

+Is fast

see S. Parker talk

+The capacitance is not a 'catastrophic' problem

see S. Seidel talk

+There are alternative geometries being proposed

see IRST, Barc./Gla. talks

However…

We still need to demonstrate

- That 3D can be produced " reliably" in large volume by more than 1 source
  b-layer 0.2m^2 ~200 - 4" wafers
  see Sintef/IRST talks

- The alternative 3D layouts are radiation hard

- The efficiency of the electrodes can be improved or there are alternative ideas

- Yield of the single sensor and Yield- module design - are acceptable

- The field implant will work after heavy irradiation

→ continue with basic R&D

Proposed schedule (with inputs from Kevin's Atlas Upgrade Workshop talk)

TARGET: 3D devices ready for b-layer replacement as an intermediate stage towards the upgrade

- Agreement on 3D-Atlas pixel R&D Dec. 07 – Proposal – manpower- resources-organisation

- Test samples from second sources in test beam by summer2007

->Inputs to ROC design before engineering run (2008)

- Vendors need to demonstrate that they are ready for pre-production by 2008 – Cost estimate

- Radiation hardness to be evaluated at the same time (2007-2008)

Proposed –aggressive!- Work Plan

Phase 1 – Jan-Dec 2007-

Objectives : ATLAS-pix compatible 3D sensors from vendors, test beam, irradiation tests, data analysis, status report and risk evaluation.
Management : call meetings every 2 weeks and 4 milestone-meetings

Phase 2. Jan-Oct. 2008

Objectives: implementation of R&D studies - test structures compatible with new ROC layout.
Management: bi-weekly call meetings, 3 status meeting at Cern, regular visit to vendors and institutes

Pre-production phase Dec08-Sept09

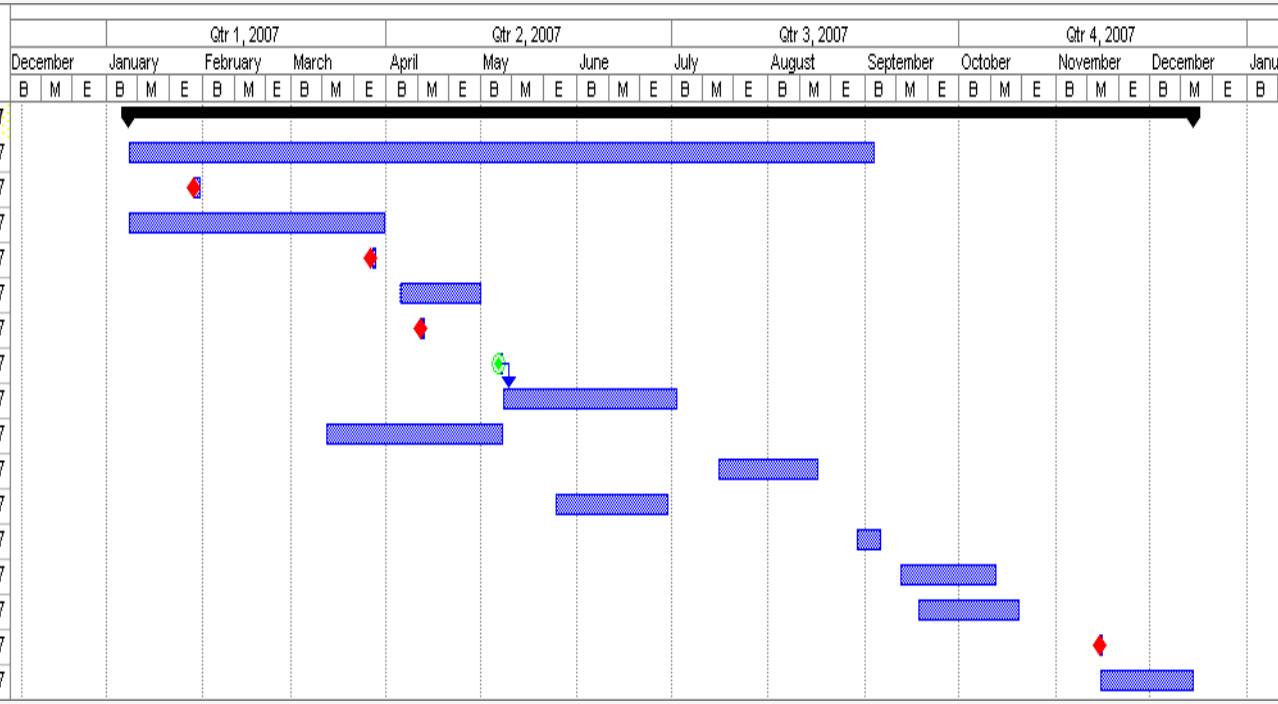
Objectives: Design of new masks for pre-production tests-
Evaluation of modules with new FEC

Production PHASE starts **Jan 2010**

Phase 1 – Jan-Dec 2007-

Objectives :atlas-pix compatible 3D sensors from vendors, test beam, irradiation tests, data analysis, status report and risk evaluation.
Management : call meetings every 2 weeks and 4 milestone-meetings

ID	Task Name	Duration	Start	Finish
	Milestone: IIo	**246 days**	**Mon 08/01/07**	**Fri 14/12/07**
1	PHASE 1	172 days	Mon 08/01/07	Mon 03/09/07
2	Technical meeting – R&D	2 days	Mon 29/01/07	Tue 30/01/07
3	Processing	61 days	Mon 08/01/07	Fri 30/03/07
4	Mid-term meeting – status	1 day	Tue 27/03/07	Tue 27/03/07
5	test structures test	18 days	Thu 05/04/07	Mon 30/04/07
6	Bump bonding organisatic	1 day	Thu 12/04/07	Thu 12/04/07
7	3D-Atlas pixel sensors re	1 day	Mon 07/05/07	Mon 07/05/07
8	Bump bonding	40 days	Tue 08/05/07	Mon 02/07/07
9	boards production	41 days	Mon 12/03/07	Mon 07/05/07
10	assembles on boards	24 days	Mon 16/07/07	Thu 16/08/07
11	irradiation praha/lublijana	26 days	Fri 25/05/07	Fri 29/06/07
12	test beam	6 days	Wed 29/08/07	Wed 05/09/07
13	test irradiated samples	23 days	Wed 12/09/07	Fri 12/10/07
14	data analysis	24 days	Tue 18/09/07	Fri 19/10/07
15	results and risk analysis	1 day	Thu 15/11/07	Thu 15/11/07
16	status report and phase :	22 days?	Thu 15/11/07	Fri 14/12/07



Funds requests is not included in this plan and will be performed independently by the participating institutes

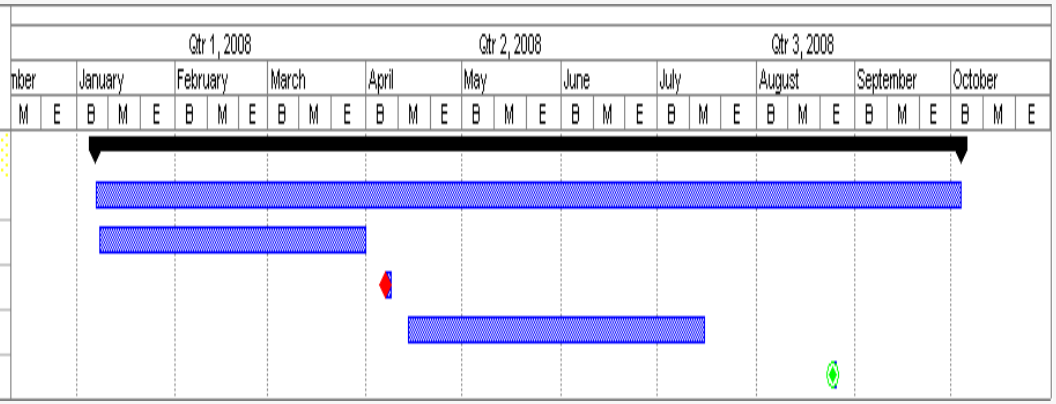
Risk analysis after phase 1

risk	impact	action
Design failure	high	Implementation of new design during second run
processing failure	high	Processing step performed in one of collaborating facilities
Bump bonding failure	high	3 facilities available
Yield	high	Yield controls, extra run, postpone goal
Cost	medium	Improve budget, reduce costs
Non sensor component failure after assembly	high	Complete other wafers
Radiation hardness failure	high	Implementation of radiation hard design during second run, postpone goal

Phase 2. Jan-Oct. 2008

Objectives: implementation of R&D studies - test structures compatible with new ROC layout.
Management: bi-weekly call meetings, 3 status meeting at Cern, regular visit to vendors and institutes

ID	Task Name	Duration	Start	Finish	Predecessors
	Milestone: Ho	**196 days**	**Mon 07/01/08**	**Fri 03/10/08**	
1	PHASE 2	196 days	Mon 07/01/08	Fri 03/10/08	
2	new run with R&D implen	61 days	Tue 08/01/08	Mon 31/03/08	
3	mid-term test definition	2 days	Mon 07/04/08	Tue 08/04/08	
4	tests	67 days	Mon 14/04/08	Tue 15/07/08	
5	status report to ATLAS r	1 day?	Mon 25/08/08	Mon 25/08/08	



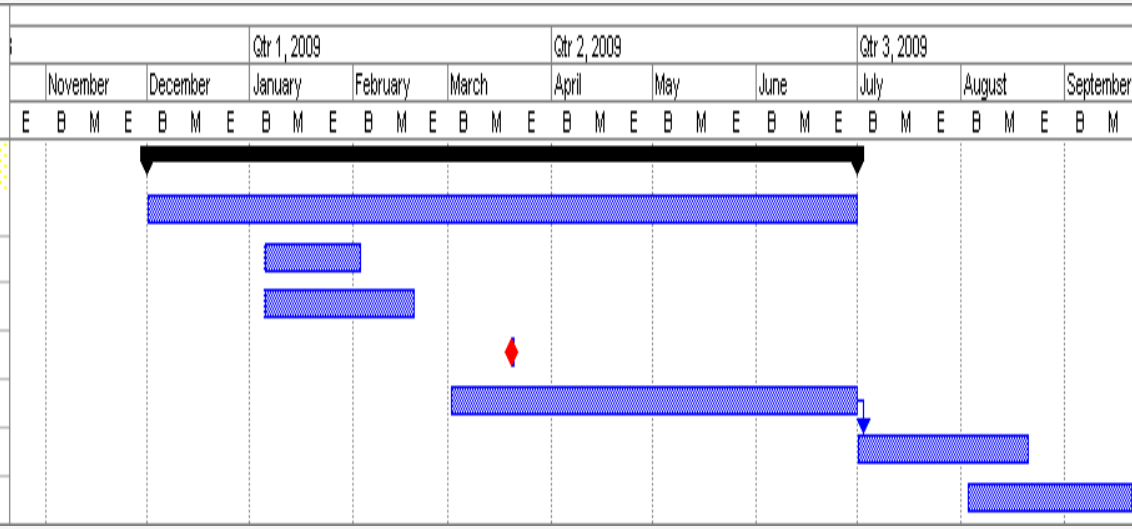
Successful completion of phase 2 would result in proposal for the b-layer replacement to Atlas and start of pre-production phase

Pre-production phase Dec. 08 Sept 09

Objectives: Design of new masks for pre-production tests- Evaluation of modules with new FEC – Cost evaluation and funding requests

Management: Structure the share of responsabilities, TDR, funding organisation

ID	Task Name	Duration	Start	Finish	Predecessors
	Milestone: No	**152 days**	**Mon 01/12/08**	**Tue 30/06/09**	
1	pre-production PHASE	152 days?	Mon 01/12/08	Tue 30/06/09	
2	plan agreement - contact	21 days?	Mon 05/01/09	Mon 02/02/09	
3	design of new masks for	33 days?	Mon 05/01/09	Wed 18/02/09	
4	mid-term meeting status r	1 day?	Fri 20/03/09	Fri 20/03/09	
5	processing	87 days?	Mon 02/03/09	Tue 30/06/09	
6	bump-bonding	37 days?	Wed 01/07/09	Thu 20/08/09	5
7	mounting and evaluation	99 days?	Mon 03/08/09	Thu 17/12/09	



Production PHASE starts **Jan 2010**