SiLC: Silicon tracking For the Linear Collider

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on behalf of the SiLC Collaboration

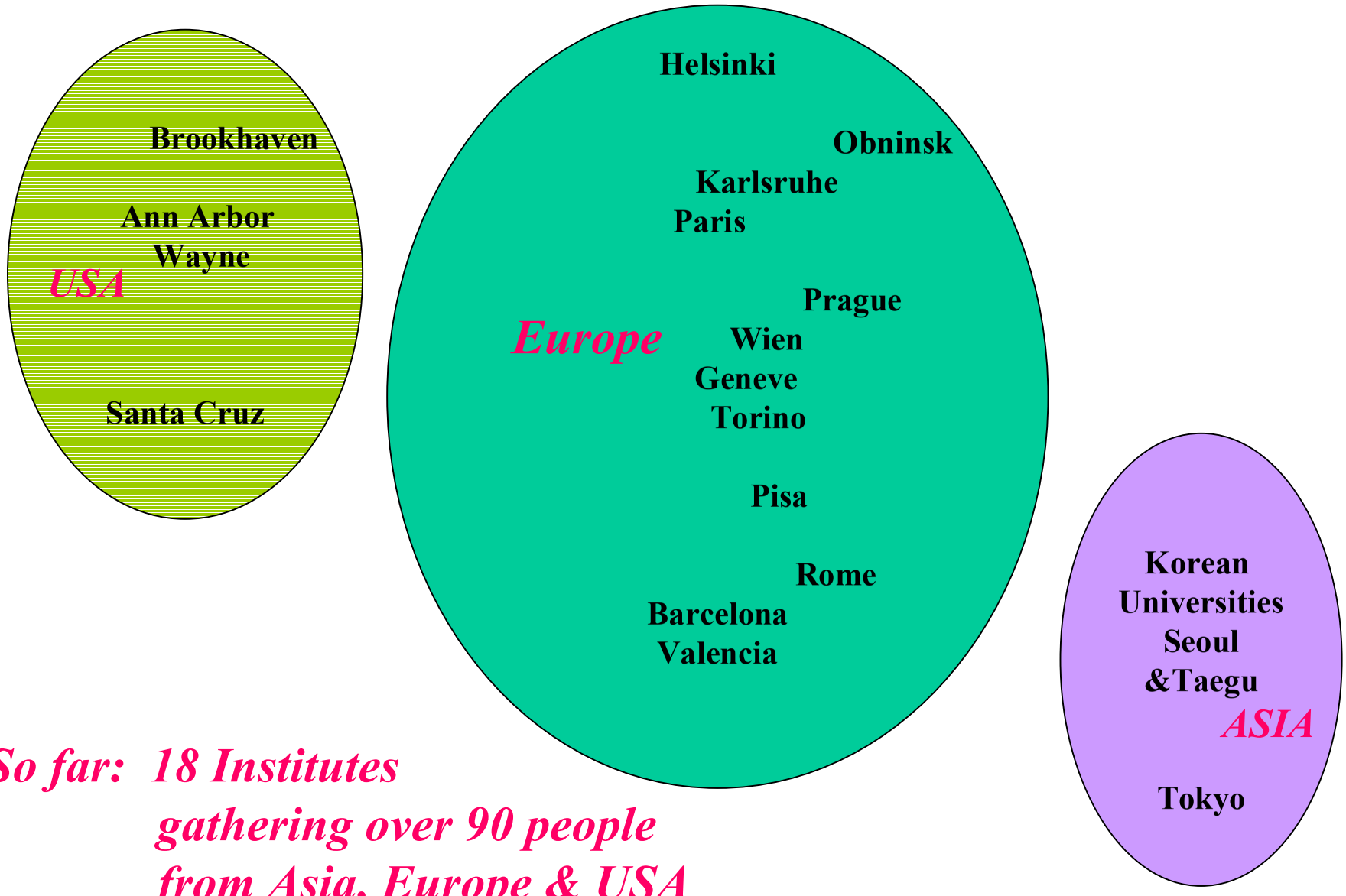
SilC: an International R&D Collaboration to develop Si-tracking technologies for the LC

(except microvertex)

PRC Meeting

DESY, Hamburg, May 7 and 8, 2003

The SiLC Collaboration



So far: 18 Institutes
gathering over 90 people
from Asia, Europe & USA

Most of these teams are and/or have been collaborating.

Department of Physics, The University of Michigan, Ann Arbor, USA
T. Blass, S. Nyberg, K. Riles, H.Yang

Centro Nacional de Microelectronica, IMB-CNM/CSIC, Barcelona, Spain
F. Campabadal, C. Fleta, M. Lozano, M. Ullan

Brookhaven National Laboratory, BNL Physics & Instrumentation, Brookhaven, USA
W. Chen, V. Jain, F. Lanni, Z. Li, D.Lissauer, V.Radeka

Departement de Physique Nucleaire et Corpusculaire, University of Geneva, Geneva, Switzerland
P. Azzarello, E. Cortina-Gil, M.Pohl, X.Wu

Department of Physical Sciences & Helsinki Institute of Physics, Helsinki, Finland
R.Orava, K.Osterberg, R. Lauhakangas, T.Schulman

Institut fur Experimentelle Kernphysik, Karlsruhe University, Karlsruhe, Germany
W. de Boer, A. Furgeri, F. Hartmann, T. Mueller

Obninsk State University, Dept. of Applied Mathematics, Obninsk, Russia
S. Aplin (OSU & Portsmouth U.), I. Bagdasarova, V. Galkin, D. Rizhikov, V. Saveleiev, M. Zaboudko

LPNHE-Universites de Paris 6&7/IN2P3-CNRS, Paris, France
J.E. Augustin, M. Baubillier, M. Berggren, W. Bertoli, B. Canton, C. Chapron, W. DaSilva, D. Imbault, F. Kapusta, H, Lebbolo, F. Rossel, A. Savoy-Navarro, D. Vincent

University of Pisa/INFN, Italy
F. Bedeschi et al.

Charles University in Prague, Prague, Czech Republic
Z. Dolezal, P. Kodys, P.Kubik, P. Reznicek

University of Roma 1, La Sapienza, Roma, Italy
C. Dionisi, C. Luci

Santa Cruz Institute for Particle Physics and the UC in Santa Cruz, Santa Cruz, USA
C. Flacco, A. Grillo, C. Nesom, H. Sadrozinski, B.A. Schumm, A. Seiden, N. Spencer

***I.H. Park,* Department of Physics, Ewha Womans University, Seoul, Korea**
***J.H. Kang, H.J. Kim, Y.J. Kwon,* Department of Physics, Yonsei University, Seoul, Korea**
***J.S. Kang,* Department of Physics, Korea University, Seoul, Korea**
***S.K. Kim, J. Lee,* Department of Physics, Seoul National University, Seoul, Korea**
***Y.I. Choi, B.G. Chean,* Department of Physics, SungKyunKwan University, Seoul, Korea**
***H. Park,* Kyungpook National University, Taegu, Korea**

Department of Physics, University of Tokyo, Tokyo, Japan
H. Aihara, M. Iwasaki

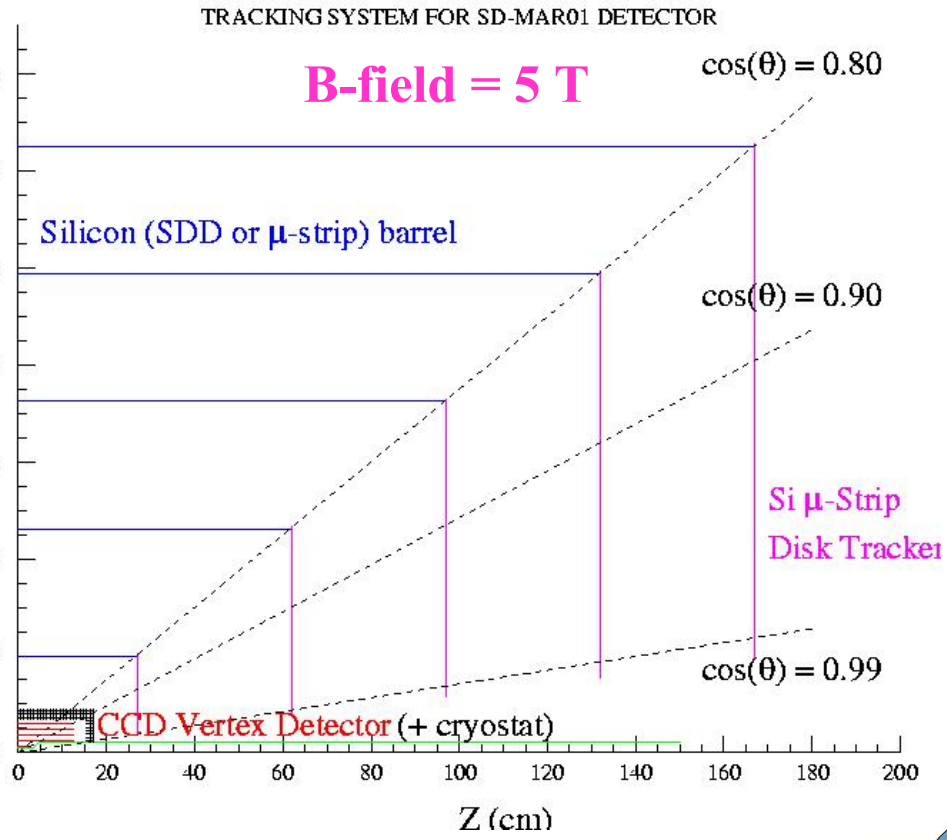
University of Torino, Torino, Italy
F. Dauda, L. Demaria, D. Gamba

University of Valencia/IFIC-CSIC, Valencia, Spain
J. Fuster et al

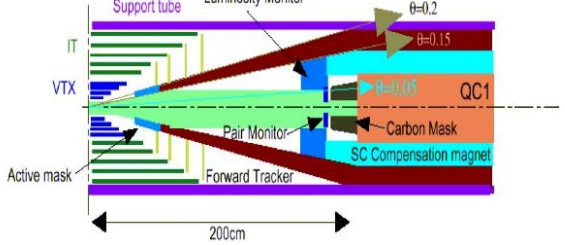
Institut for High Energy Physics, Austrian Academie of Sciences, Vienna, Austria
T. Bergauer, M. Friedl, M. Krammer, M. Pernicka

State University of Wayne, Wayne, USA
R. Bellwied, D. Cinabro, M. Coscione, V. Rykov (*WSU and KEK)

The SiLC R&D Collaboration is driven by the* PHYSICS MOTIVATIONS *to build the outmost performing tracking system for the experiment at the future Linear Collider



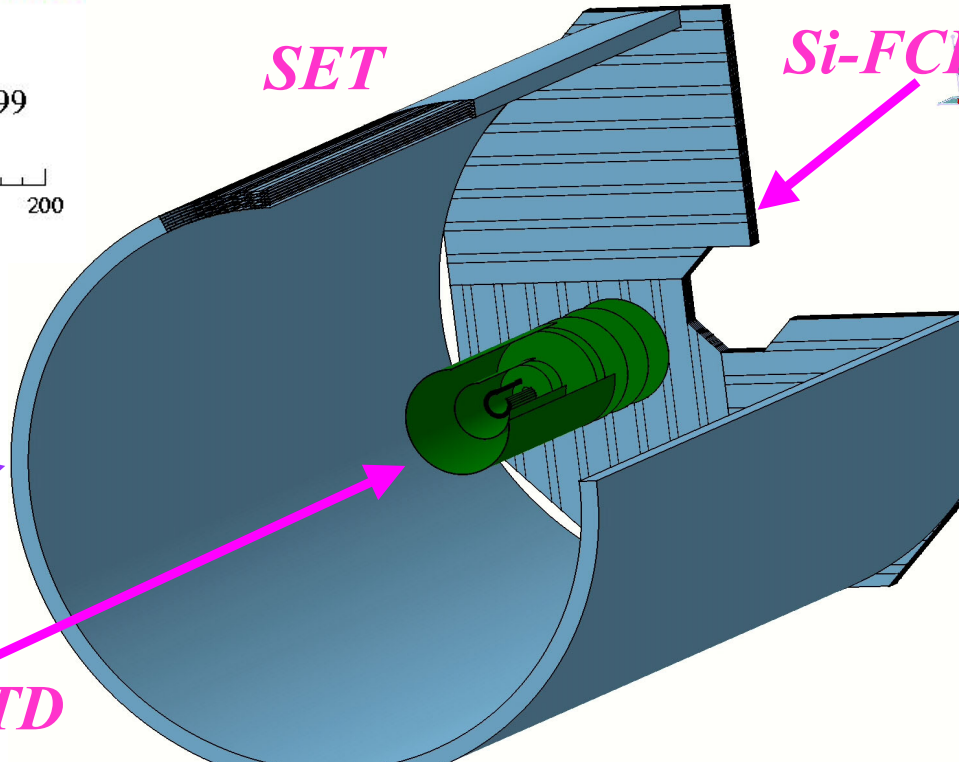
JLC



The Si-Envelope: Si-trackers surrounding the TPC

SET

Si-FCI



The SD detector (all Si detector)

Two detectors concepts

SIT + FTD

Independently of the detector concepts:

Period from 2003 till end 2006 will be dedicated to a collaborative worldwide effort on: GENERIC R&D

Starting from the present state-of-the-art

The LEP/SLC legacy:

First µvertex @ MarkII –SLAC

LEP II µvertex ➔ first long ladders & VA FEelectronics

(extended to B-factories experiments)

The currently running experiments: AMS1&2, CDF II & STAR

AMS1: 1st very long ladders (up to 15 sensors), fabrication.

CDF II & AMS2 : 1st ''large area Si-trackers'', 5 to 6 m2

sophisticated RT Si-data processing (SVT).

STAR: 1st ''large Si-drift tracker'', 0.7 m2, Si-drift FE & RO electronics & mechanical structure.

The LHC detectors in construction: ATLAS, CMS & ALICE

CMS & ATLAS: Very large area Si-tracking systems (200 m2)

ALICE = further improvements wrt STAR

Impressive progresses in Si-tracking technology this past decade !!

Most teams in SiLC: part of these experiments & built the Si-tracker

The R&D Program and Main objectives: from mid 2003 to end 2006

R&D on Si- Sensor technologies

R&D on Electronics

R&D on Mechanics

Test set-ups

Calibration, Monitoring and Slow Control Issues

Simulation studies

1.- R&D on Si-sensor technologies

Three main streams:

➔ **The long µstrips:**

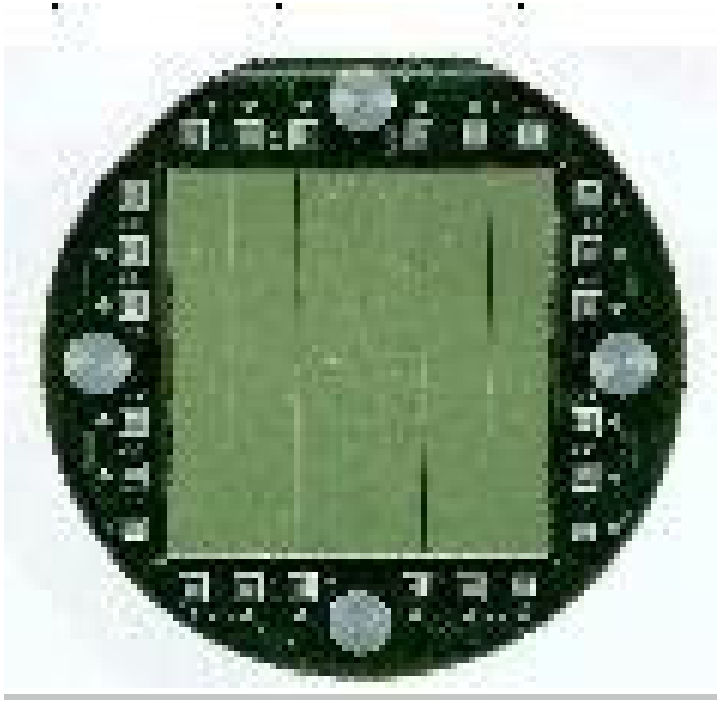
***Main appealing features*: drastic diminution of FE channels**
thus less material and power dissipation (transparency
high position resolution, simplified mechanical design
Starting from AMS & GLAST experience

1st prototyped long ladder
with strips of variable
length:28, 56, 112, 224 cm
Tests: Geneva+Paris+Peruggi

R&D objectives on wafers:
6'' ➔ 12'', thinner, smaller pitch, double-sided & yield > 50%
Collaboration with Hamamatsu, ST Microelectronics, MICRON

➔ Si-Drift sensor technology

Appealing features: Equivalent to solid state TPC, thus 3-D tracker with timing measurement (ns), position resolution = 10 to 15 μm



R&D objectives on wafers:
thinning of sensors & improving timing and position resolutions
Industry contacts: SINTEF, CSEM, EURISYS, CANBERRA
Potential interest: MICRON, HAMAMATSU

➔ New solid-state sensor technologies

SiLC will investigate new SS-techs relevant for our applications, in collaboration with high-tech firms & solid-state research Labs.

Z !! Depending the locations and/or functions of the Si-trackers, various Si-sensor technologies might have to be considered.

2.- R&D on electronics

➔**Developing VFE electronics** for each Si-sensor

optimisation of S/N and power dissipation => power cycling ?

➔**Digital architecture: on-detector electronics:**

Sparsification, pedestal substraction

Charge = pulseheight measurement

clusterisation for better position resolution/point

(preprocessing of the data at the earliest possible stage)

Timing for noise rejection *(& Z measurement ??)*

➔**"Triggering" & realtime data processing**

(using the capabilities of standalone Si-tracking system)

➔ **Data transmission** to the outside world

➔**Going to submicroelectronics** *(<0.25 μm)*

➔ **Packaging and cabling** *(TAB etc…)*

Integration in the overall readout & DAQ system

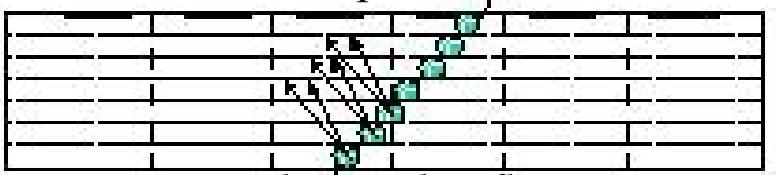
VFE electronics: main present electronics issue

.- *VFE for long µstrips:*

SCIPP @ Santa Cruz

mulation studies & design of a
ledicated preampli-long shaper
ith power-cycling, in 0.5 µ tech,
une'03

Pulse development simulation



ffects incorporated: Landau fluctuations
Carrier (hole) diffusion / space-charge repulsion
Lorentz angle, electronic noise, pulse dig+rec
o be answered: S/N for long ladders,
Optimal sensor geometry & detector bias
Evaluation of analog readout scheme
Effect of large B-field, of oblique angles of incidence(also: De Boer et al.).

LPNHE-Paris

Detailed studies on test bench of VA-based FE electronics (VA_64-hadr, VA-1) from LEP/AMS & other FE's

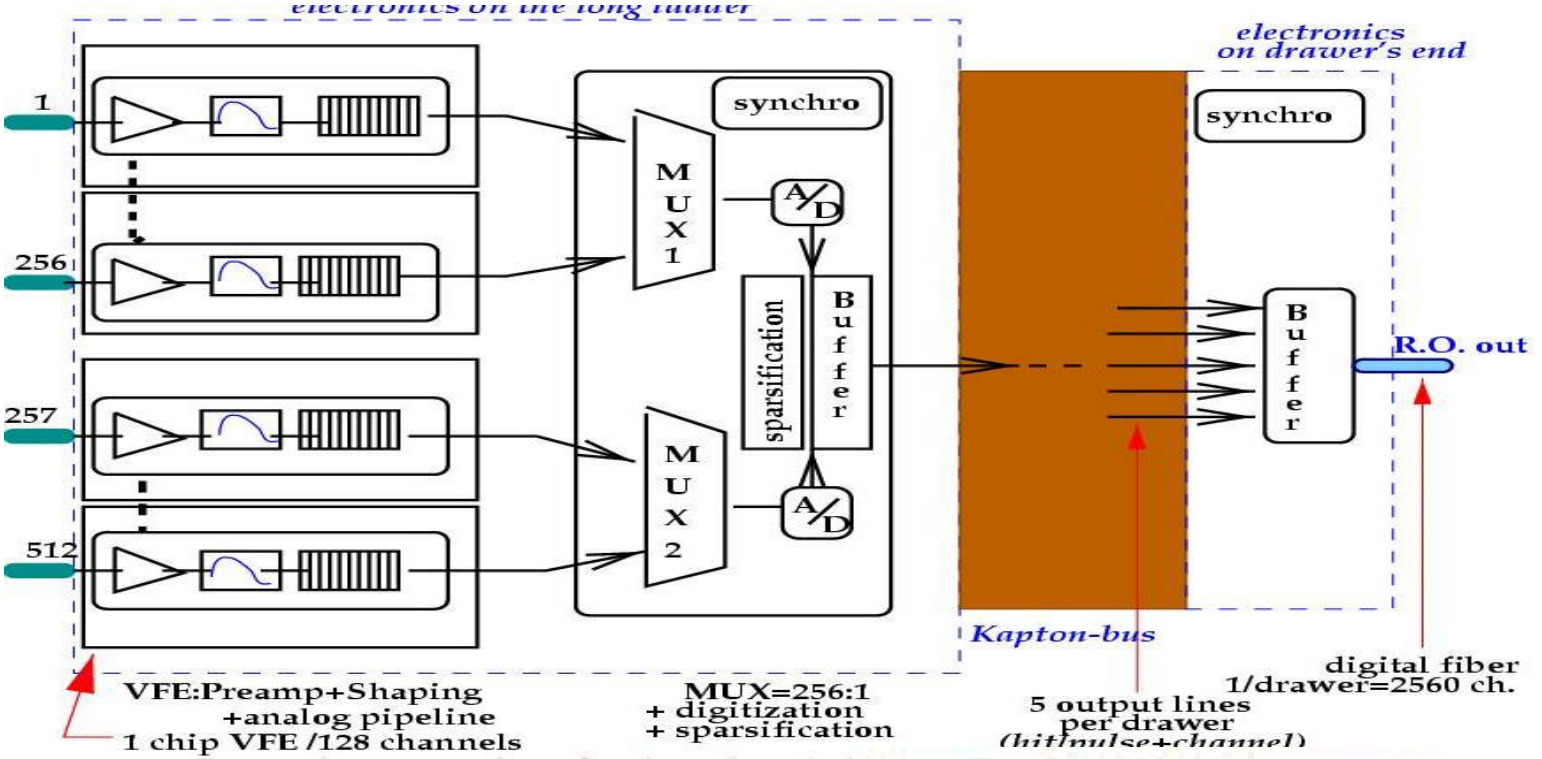
Design of a new VFE in 0.35ν (fall'03)

.- *VFE Si-drift:* (BNL & WSU)

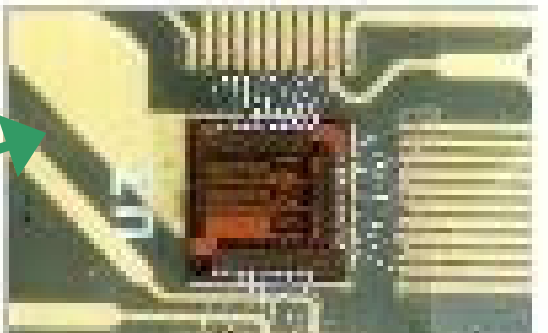
resent bipolar PASA & CMOS SCA (STAR) ➔ Future 0.25 ν (DSM) CMOS echnology for all 3 stages in one single chip (PASA, SCA, 10-bit ADC), see next

Si-readout scheme: very preliminary

First stage in the readout chain: digisation; *Preliminary ideas how to implement on-detector this function, and related issues. But still many questions ????*



Si-drift: {PASA + SCA + 10-bit ADC} into a single chip as for ALICE



3.-R&D on Mechanics

Mechanics are a major issue to build the appropriate Si-trackers for the future LC detector.

Main challenges = need for:

➔An ‘’extreme’’ transparency or as less material as (im)possible

➔Very high precision in position, mechanical stability

➔ large surface detector

➔ cheap and easy to build devices

THIS IMPLIES a real and multi-facets R&D on mechanics to achieve a step forward in mechanics as compared to presently running or under construction Si-trackers.

Main R&D Mechanics topics:

- *Detailed CAD mechanical design of a complete Si-tracking system*
- *Studies related to the need for transparency*
- *Cooling studies on mechanical prototypes & CAD simulations*
- *Tests & studies on materials & approaches (mechanical structure, cooling etc …)*
- *Mechanical precision*
- *Mechanical constraints & stability*
- *Alignment*
- *Techniques to build large number of basic mechanical elements: Technology transfer to Industry*
- *Tests & Studies on mechanical prototypes (feasibility of mechanical design components, Industry transfers)*

3.1- Detailed CAD design of the Si-envelope & outcomes:

It allows to address all the possible Si-tracking cases:

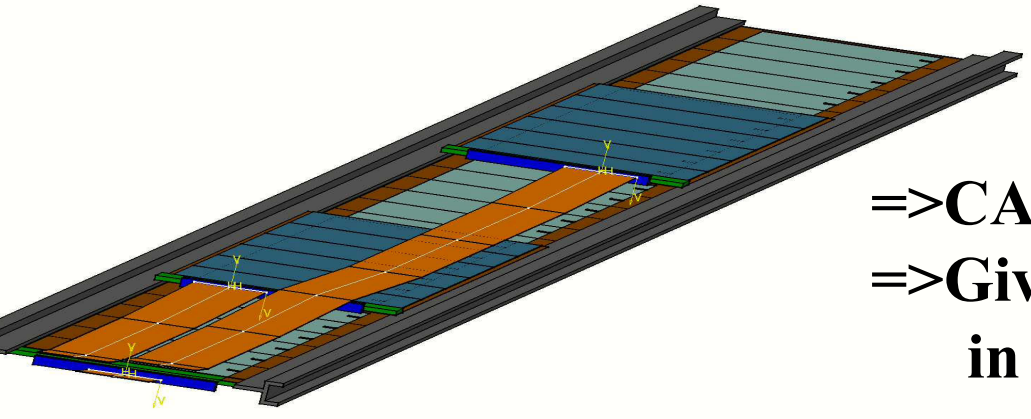
SET=large area Si-tracker

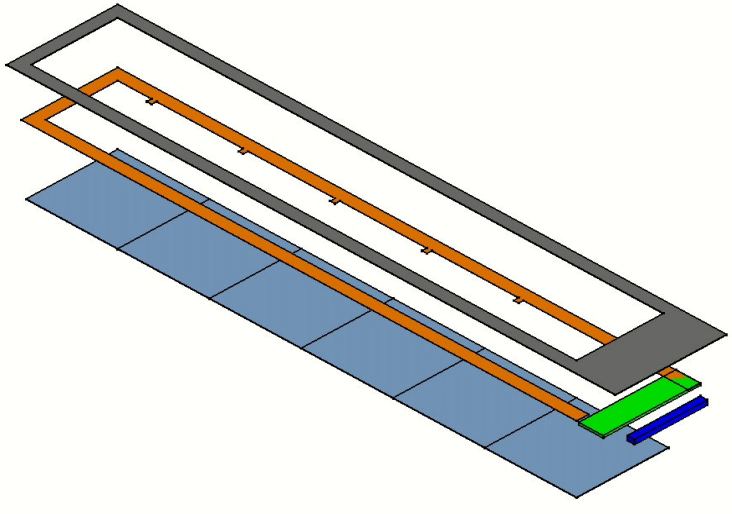
Si-FCH = forward Si-tracke

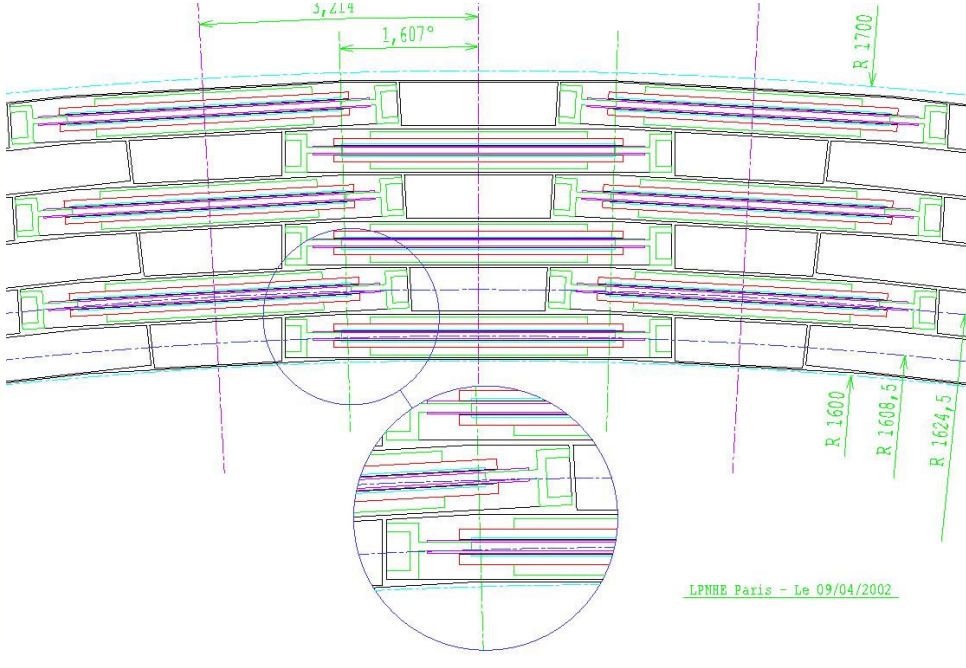
SIT intermediate Si-tracker

=>CAD detailed design reveals pbs

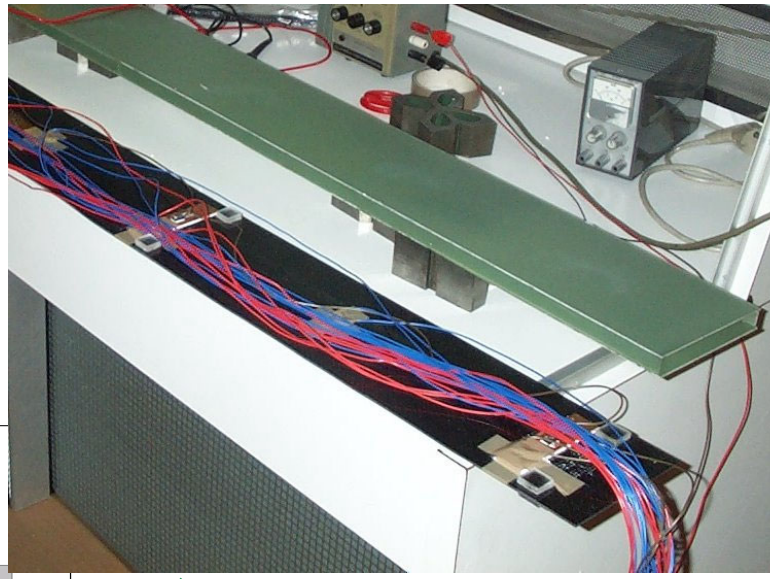
=>Gives inputs for geometry DB in GEANT4 based simus

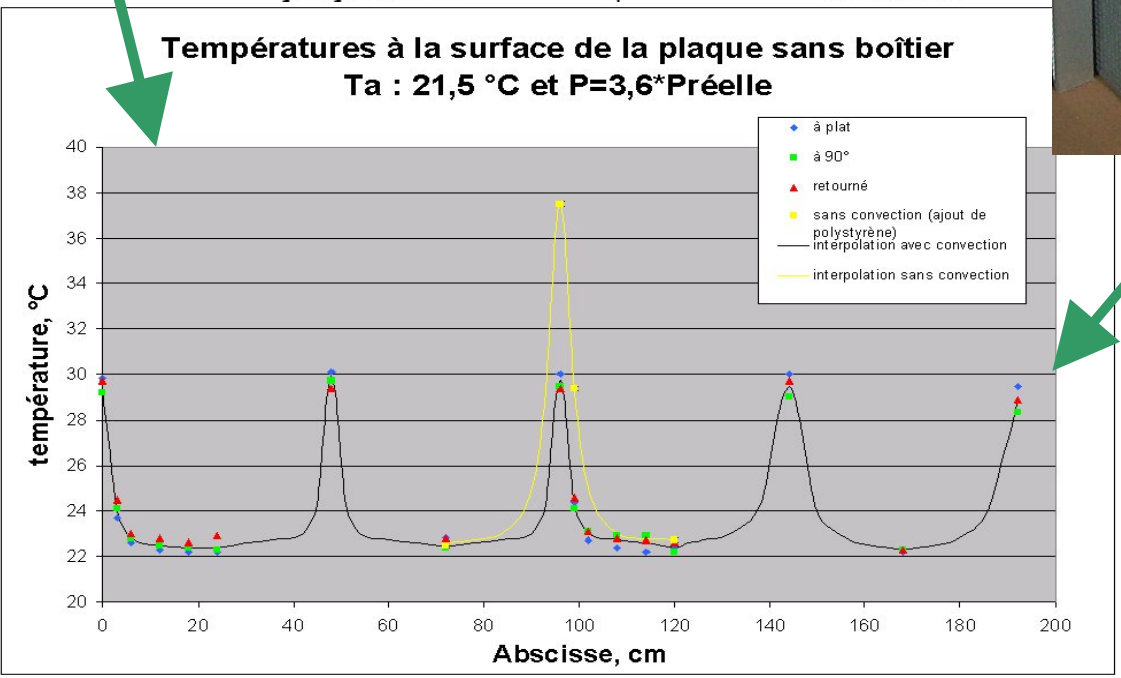


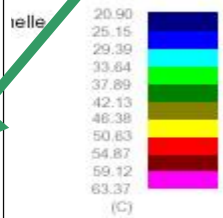




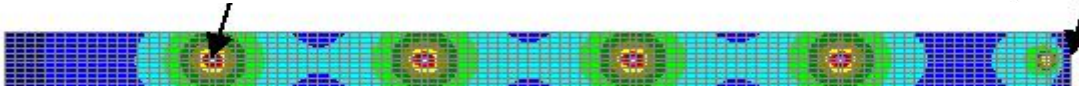
3.2- Cooling studies on prototypes & comparison/CAD simulations







Tuning/modeling CAD simulations with test bench measurements



4.- Test set-ups

Three types of test set-ups:

Example of test bench set up in clean room in Valencia-IFIC

***Lab test benches to characterise sensors & FE electronics*, in clean rooms. Most Institutes are already equipped .**

***Test benches for mechanical prototypes* (cooling, mech. constraints …)**

***Test-beams*: A beam test is foreseen by fall 2006, with a full proto. Possibly preceeded by intermediate beam tests studies.**

(under discussion)

5.- Calibration, Monitoring and Slow control issues

Three main issues will be addressed:

➔The handling of distorsions in the tracking system

➔The alignment issues

➔ The required very high precision in position, conflicting with the very thin mechanical support (low material budget)

Expertise developed for CDF and LHC on these issues will be very useful.

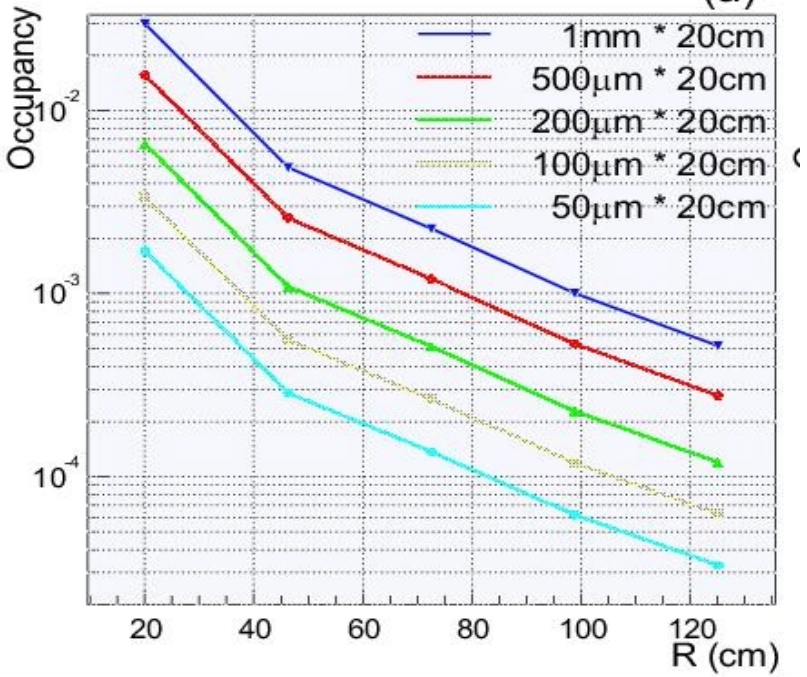
The University of Michigan group is studying a very high precision alignement system based on an interferometer

6.- Simulations studies (Fast and Geant-based)

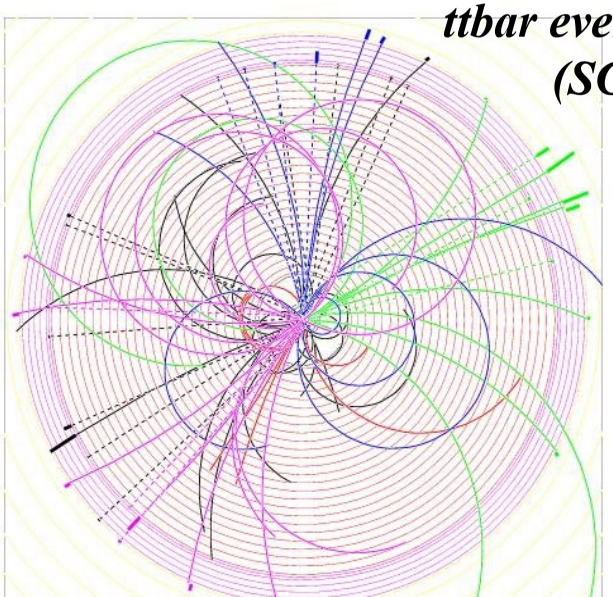
Work to be done or underway:

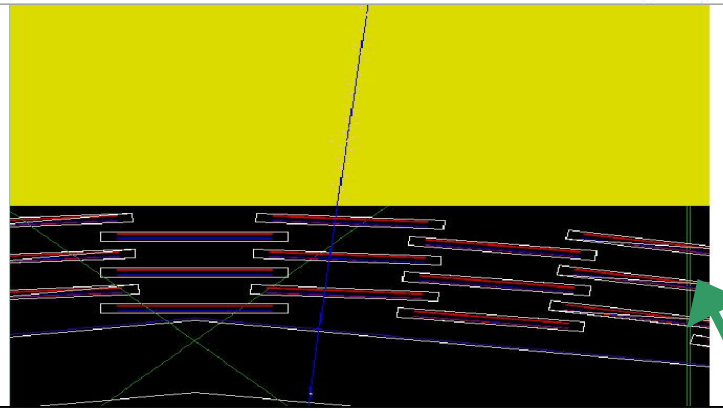
- Detailed pattern reconstruction
- GEANT-4 detailed simulation developement
- Comparison of various detector set-ups & technologies including TPC
- Background studies[including results of beam line simulation & related detector issues forward)]
- Calorimeter-assisted tracking (for SD)
- Physics studies to establish performance requirements

Geant4-based full simulation(JLC)



ttbar event display (SGV)





MOKKA-geometry DB detector definition using detailed CAD mechanical design

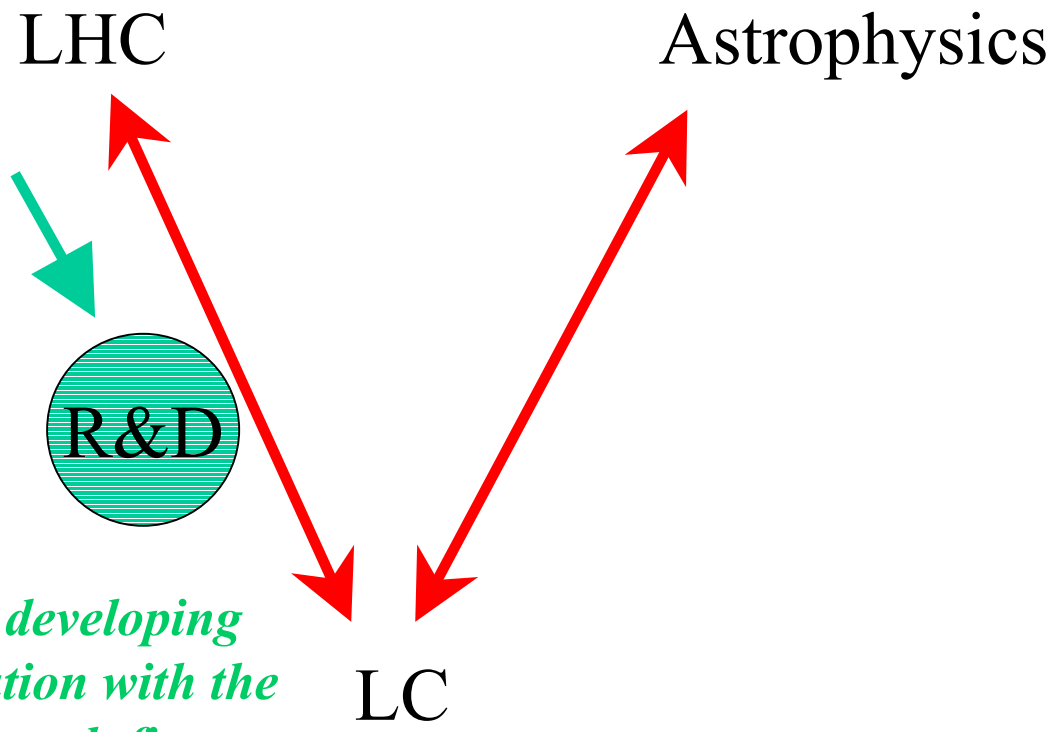
SiLC: schedule & milestones & management

The roadmap for the 3 coming years comprises 2 main phases:

- **PHASE 0*:* mid 2003 to mid 2004 is the WARM UP of the collab.**
  - ***1) Organization & extension of our collaborative work***
    (meetings at ACFA, American & ECFA Workshops + dedicated ones)
  - ***2) First series of tests on prototyped Si-sensors & VFE electronics & progress on CAD mechanical design of various Si-trackers***

- **PHASE A*:* mid 2004 to mid 2006 , with main goals*:***
  - ***1) Developt. with Industry & characterization of new Si-sensors***
  - ***2) Design, production and tests of associated F.E.& R.O.electronics***
    1)+2) will result in the construction of a prototype for a beam test by fall' 0
  - ***3) R&D on Mechanics with as a focus a full detailed design including developments of tools & prototype studies of:***
    Detector architecture, related Industrial transfers, cooling, alignment

Simulation studies will follow in parallel this overall R&D program



Keeping and developing the collaboration with the relevant high tech firms to further progress.

This R&D project is an example of

LC ⊕ LHC synergy,

as well as with astrophysics

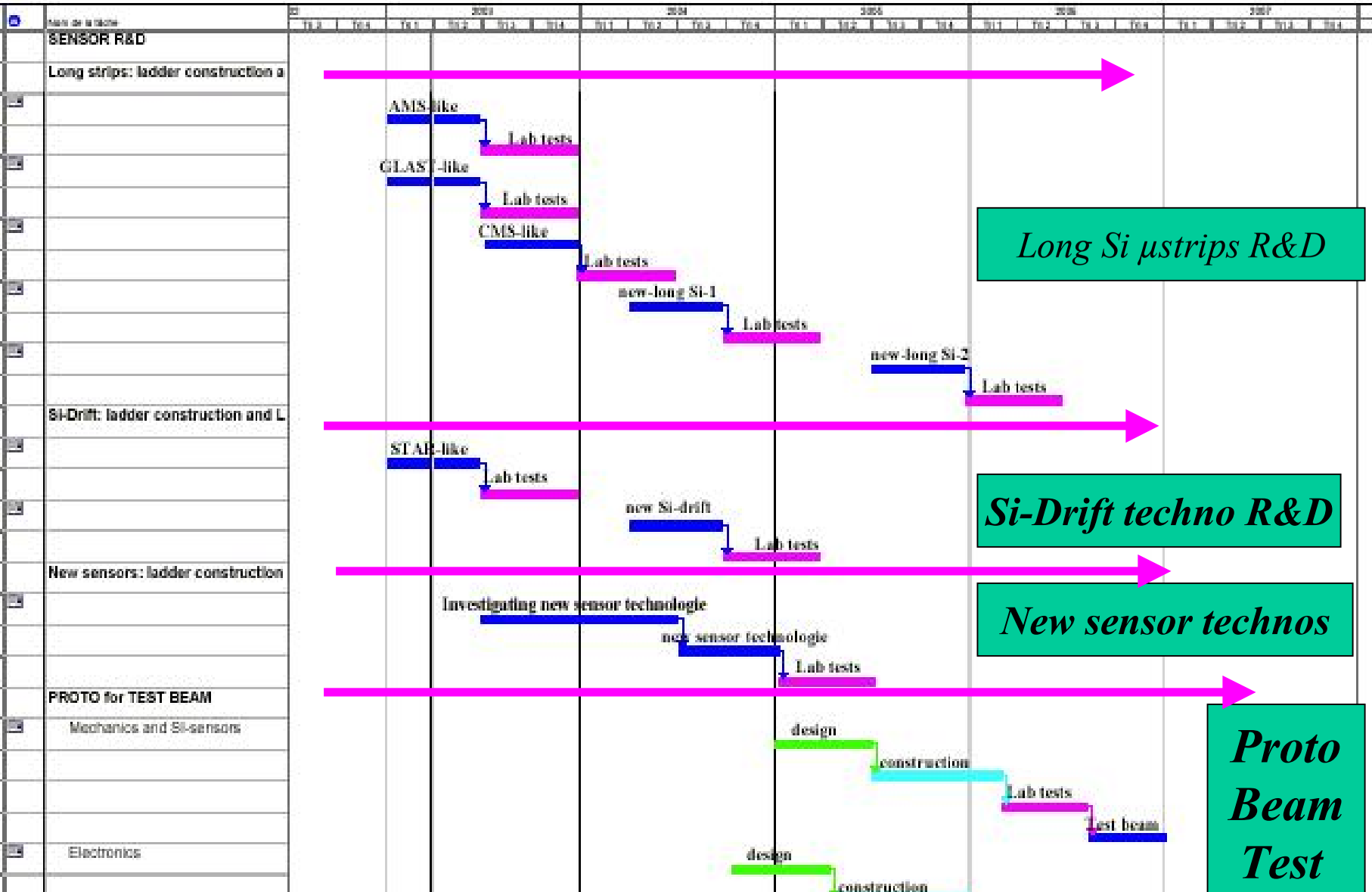
Backup slides for some more details on:

The schedule & milestones

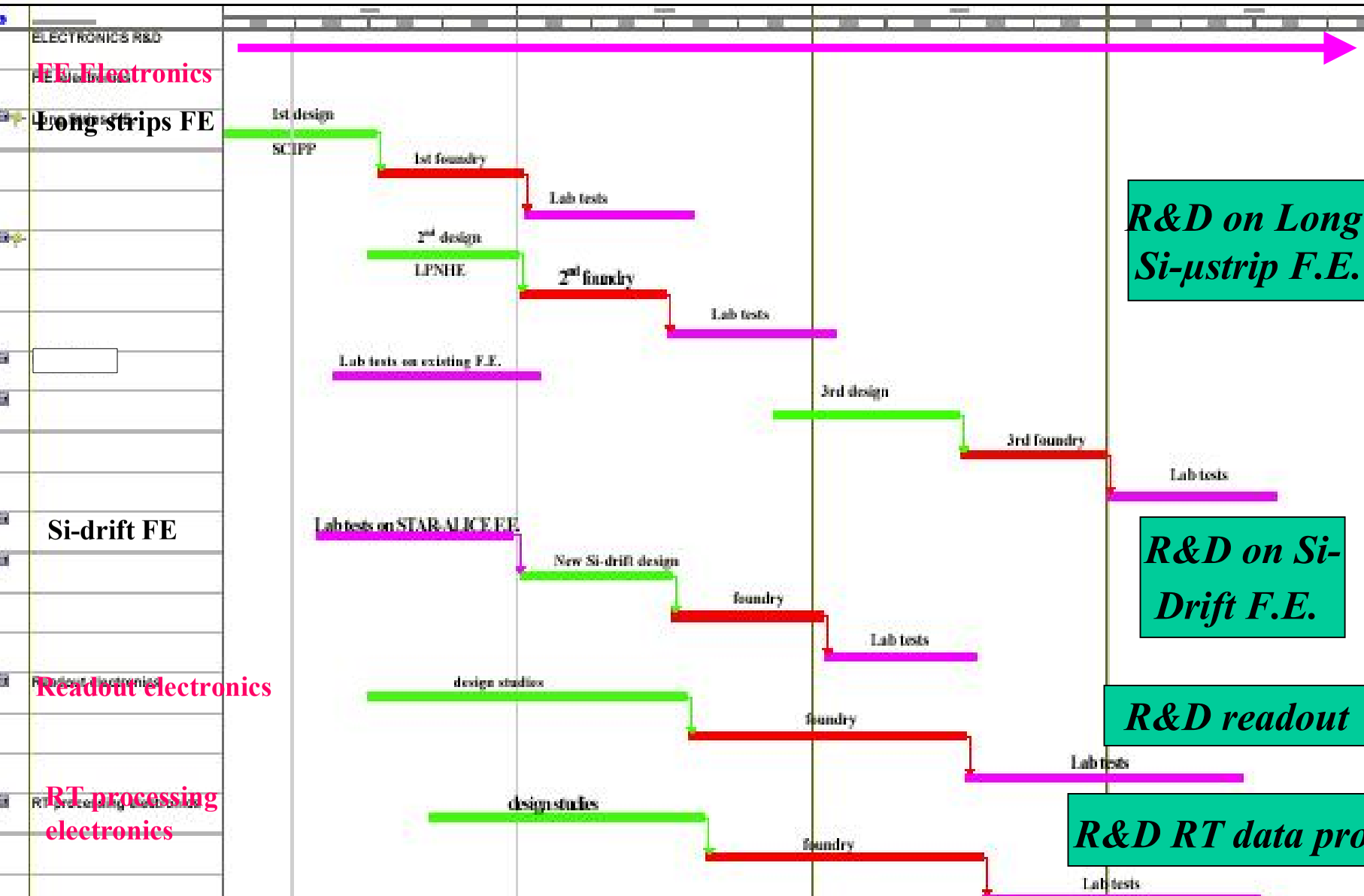
The sharing of responsibilities

The financing of the project

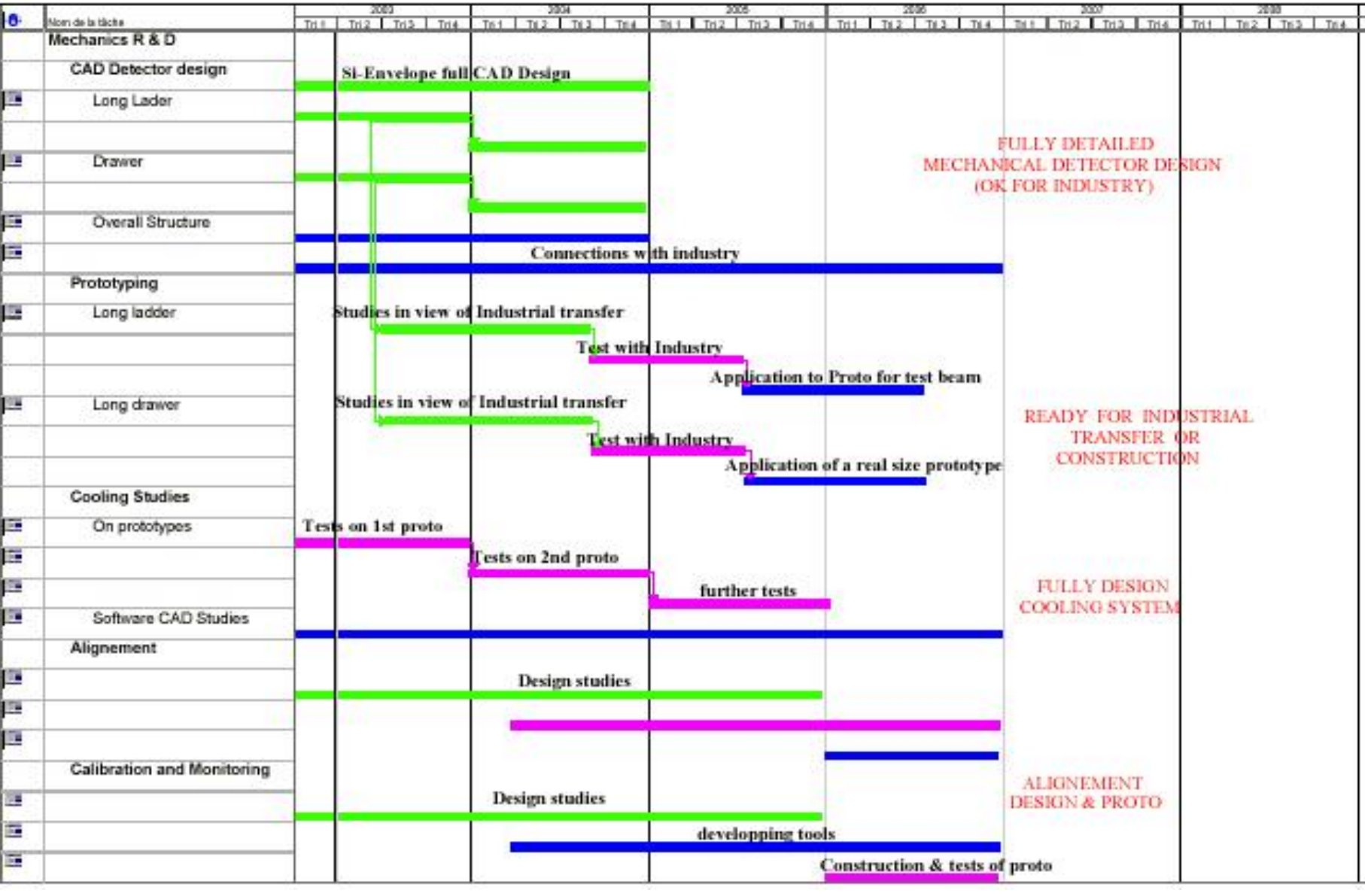
Schedule & Milestones for the Si-SENSOR R&D



Schedule/milestones for electronics R&D



Schedule/milestones for mechanics R&D



Sharing of responsibilities

Institutions	Sensor RD	Electronics	Mechanics	Simulations	Tests set-up
Michigan			**Yes**	**Yes**	**Yes**
IMB-CNM	**Yes**				**Yes**
BNL	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Geneva U.	**Yes**	**Yes**	**Yes**		**Yes**
Helsinki U.	**Yes**		**Yes**		**Yes**
IEKP	**Yes**			**Yes**	
Obninsk U	**Yes**			**Yes**	
LPNHE-P	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Sharing of responsibilities (cont'd)

INFN/Pisa	***to***	***be***	***def***	***in***	***ed***
Charles U.		**Yes**	**Yes**	**Yes**	**Yes**
Roma I	***to***	***be***	***def***	***in***	***ed***
SCIPP/SC	**Yes**	**Yes**		**Yes**	**Yes**
Korean U.	**Yes**	**Yes**	**Yes**		
Tokyo U.				**Yes**	**Yes**
Torino U.	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
IFIC-CSIC	***to***	***be***	***def***	***in***	***ed***
Wayne S.U	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
IfH-Wien	**Yes**	**Yes**			**Yes**

Finances

- *The US groups have been or are going to be funded by DOE and/or NSF, for their project for these 2 or 3 years (Santa Cruz proposal to the DOE Advanced Detector R&D Program, $90K, WSU NSF proposal [pending, positive review]: 2003-2005 for a total of $450K [$ 80, 170, 200K] & hardware contribution per year for BNL: $25, 50, 90K , and University of Michigan :joint UCLC/LCRD proposal [pending] for the alignment project)*

- *The European groups are R&D funded for a few of them for this present year (ex: IN2P3). They will submit an R&D proposal to get funded for the next fiscal year, by fall '03.*

- *The Asian groups are applying for funds to Korean and Japanese funding agencies (R&D proposal on Intermediate Silicon-tracker is pending).*

This organized R&D project should help in sharing among us the expertise and needed tools, and in getting the funds for the next coming years.

Cost estimate (very tentative, salaries not included)

Items	Individual cost	Subtotal cost
Silicon-sensor R&D		
Long Strips Silicon-Drift New sensors Mechanical Ladder	3 x (3 x 1.5) K Euros 4 x 1.5 K Euros 3 x 2 K Euros 5 x 1 K Euros	13.5 K Euros 6 K Euros 6 K Euros 5 K Euros
Total cost sensors		*30,5 K Euros*
Electronics R&D		
VFE electronics RO electronics	4 x 7,5 K Euros About 5 K Euros	30 K Euros About 5 K Euros
Total Cost Electronics		*35 K Euros*
Beam Test (prototype)		
Mechanics & Sensors Electronics	About 10 + 20 K Euros 15 K Euros/channel	About 30 K Euros 2048 x 15 = 30 K Euros
Total Cost of beam test		*60 K Euros*
Mechanics R&D		
Prototypes & tools Alignment	About 60 + 20 K Euros About 30 K Euros	About 80 K Euros About 30 K Euros
Total Cost Mechanics		*About 110 K Euros*