Introduction to ILC-LDC Simulation and Reconstruction Software

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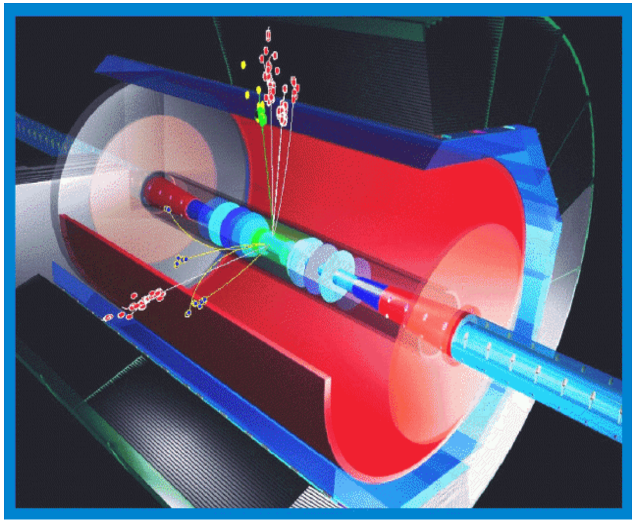
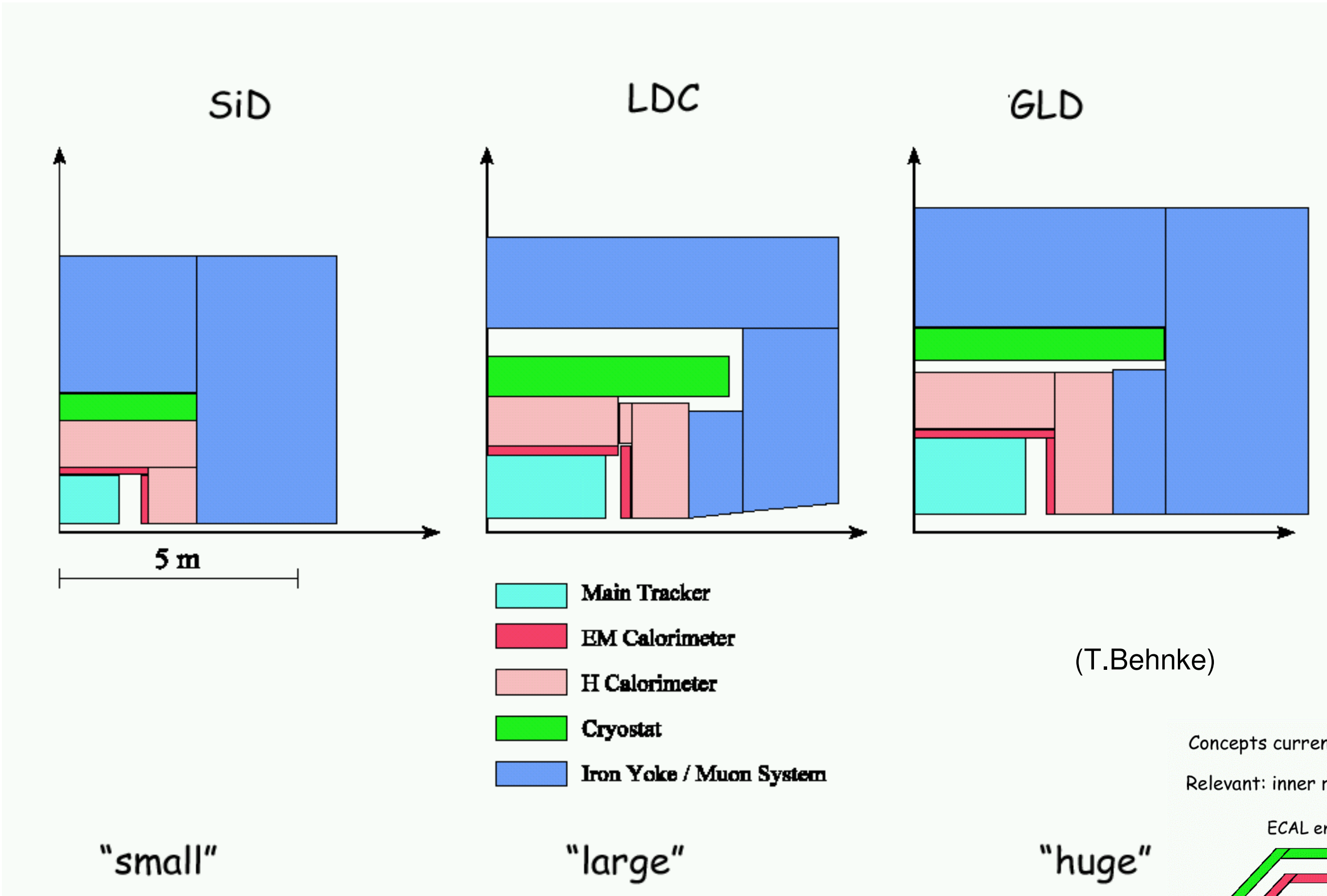
Outline

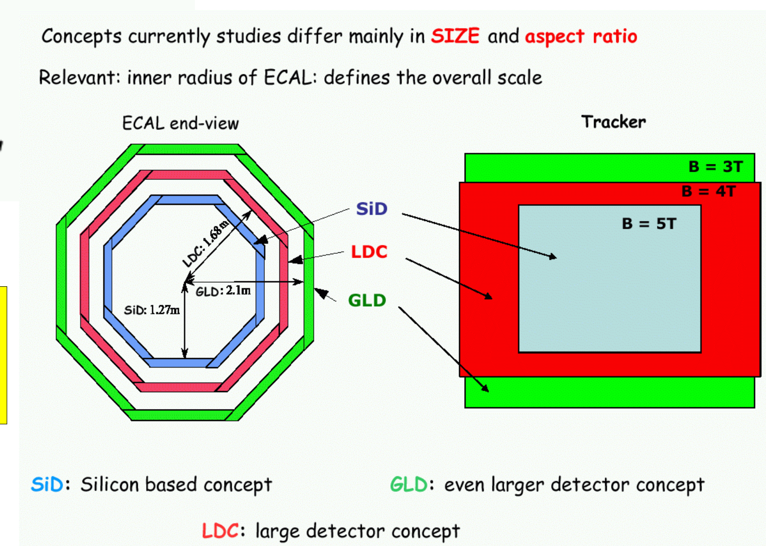
- Introduction - overview international software
- Central tools for LDC study
  - LCIO – data model & persistency
  - Simdet – fast simulation
  - Brahms – geant3 full simulation and reconstruction
  - Mokka – geant4 full simulation
  - Marlin – C++ reconstruction framework
  - LCCD - conditions data toolkit
  - GEAR – geometry description
- Summary & Outlook



Detector Concept Study



three interregional detector concept studies ongoing



Need (common?) **Simulation** and **Reconstruction** software to study detector concepts' performance !

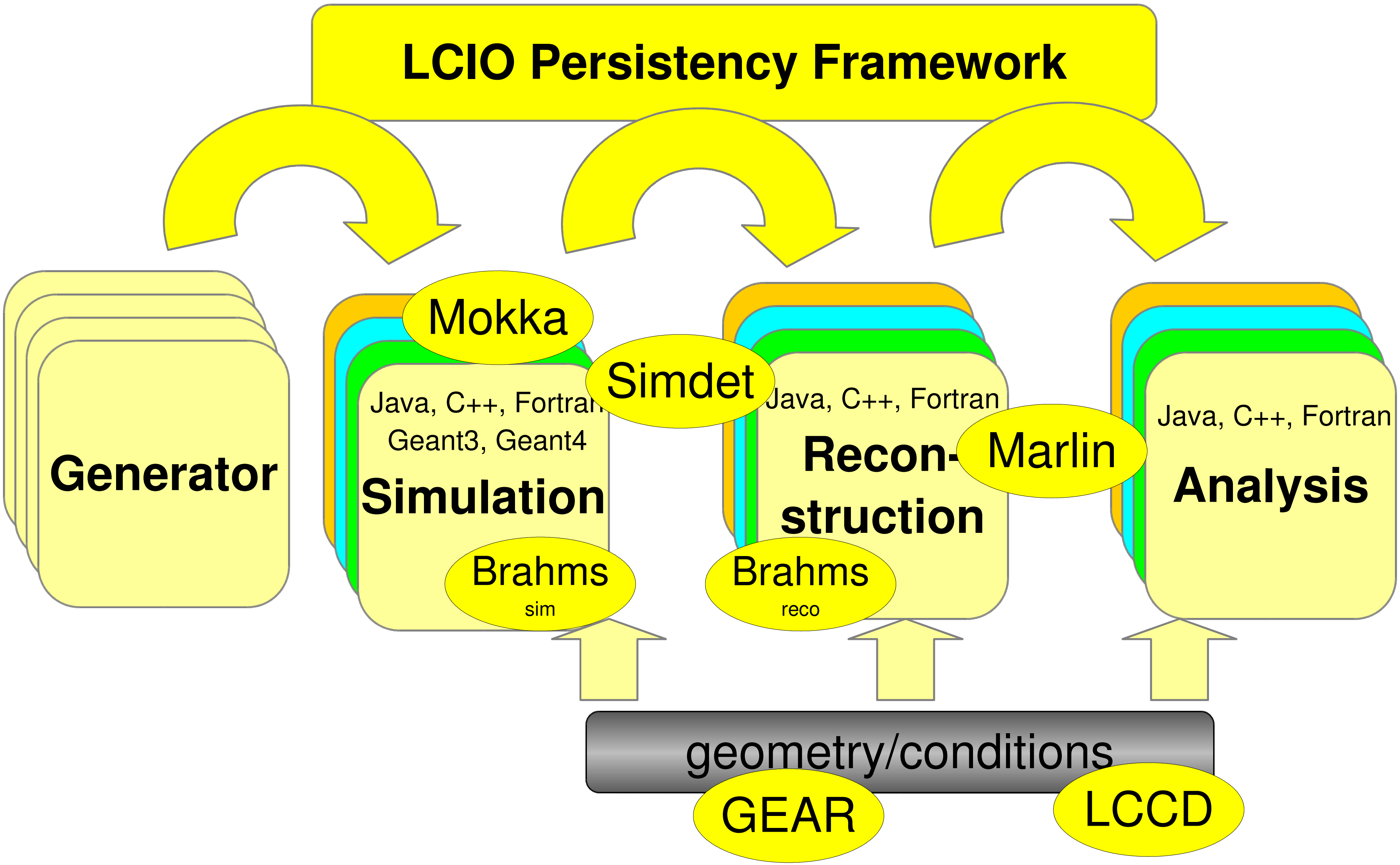
ILC software packages

	Description	Detector	Language	IO-Format	Region
Simdet	fast Monte Carlo	TeslaTDR	Fortran	StdHep/LCIO	EU
SGV	fast Monte Carlo	simple Geometry, flexible	Fortran	None (LCIO)	EU
Lelaps	fast Monte Carlo	SiD, flexible	C++	SIO, LCIO	US
Mokka	full simulation – Geant4	TeslaTDR, LDC, flexible	C++	ASCI, LCIO	EU
Brahms-Sim	Geant3 – full simulation	TeslaTDR	Fortran	LCIO	EU
SLIC	full simulation – Geant4	SiD, flexible	C++	LCIO	US
LCDG4	full simulation – Geant4	SiD, flexible	C++	SIO, LCIO	US
Jupiter	full simulation – Geant4	JLD (GDL)	C++	Root (LCIO)	AS
Brahms-Reco	reconstruction framework (most complete)	TeslaTDR	Fortran	LCIO	EU
Marlin	reconstruction and analysis application framework	Flexible	C++	LCIO	EU
hep.lcd	reconstruction framework	SiD (flexible)	Java	SIO	US
org.lcsim	reconstruction framework (under development)	SiD (flexible)	Java	LCIO	US
Jupiter-Satelite	reconstruction and analysis	JLD (GDL)	C++	Root	AS
LCCD	Conditions Data Toolkit	All	C++	MySQL, LCIC	EU
GEAR	Geometry description	Flexible	C++ (Java?)	XML	EU
LCIO	Persistency and datamodel	All	Java, C++, Fortran	-	AS,EU,US
JAS3/WIRED	Analysis Tool / Event Display	All	Java	xml,stdhep, heprep,LCIO,	US,EU

A Common Software Framework for the ILC ?

- a common software framework for the ILC that is flexible and easy to use would be highly desirable
  - (also for detector concept study!)
- but:
  - ILC emerged out of three regional studies
  - all groups have developed their own software as needed for the R&D
  - different languages used: C++, Java, f77
  - ...
- aim:
  - develop modular software and define interfaces so that packages can coexist/cooperate - **(and eventually converge !?)**
- common basis: **LCIO**

Overview of LDC software tools



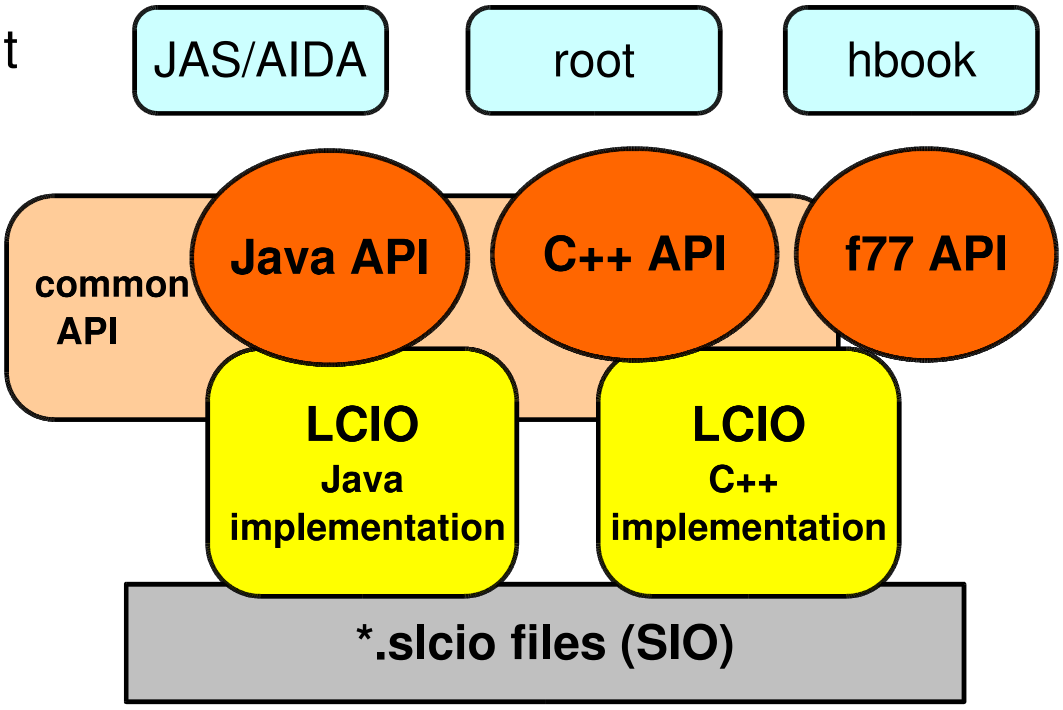
LCIO overview

- DESY and SLAC joined project:
  - provide common basis for ILC software
- Features:
  - Java, C++ and f77 (!) API
  - extensible data model for current and future simulation and testbeam studies
  - user code separated from concrete data format
  - no dependency on other frameworks

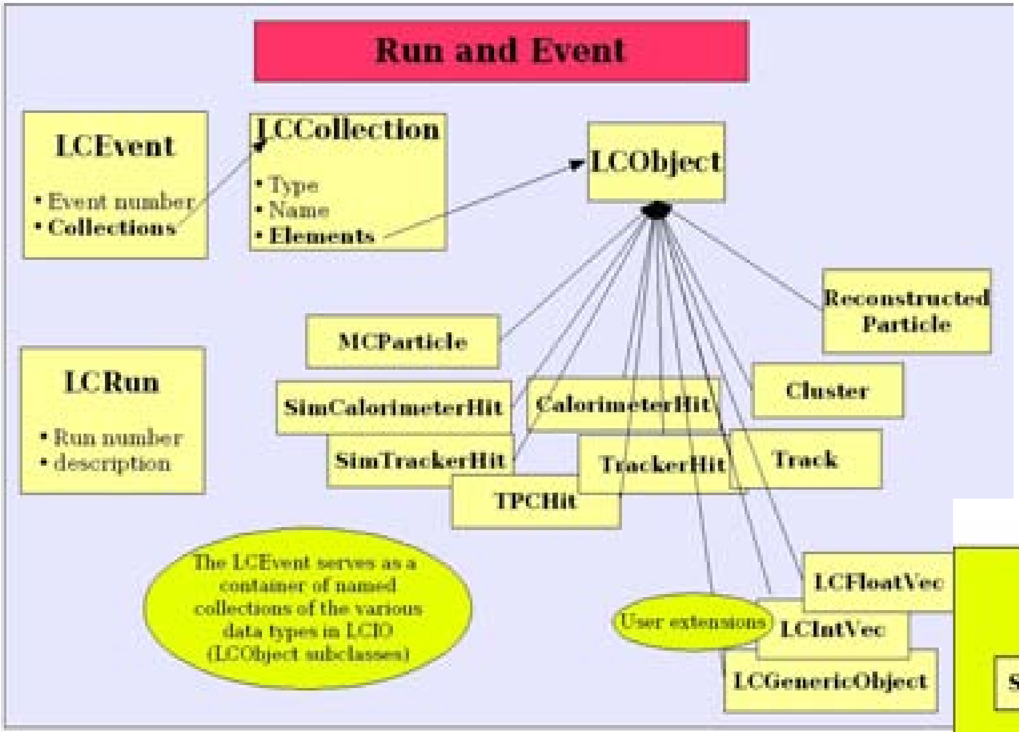
  simple & lightweight

now de facto standard for ILC software

SW-Architecture

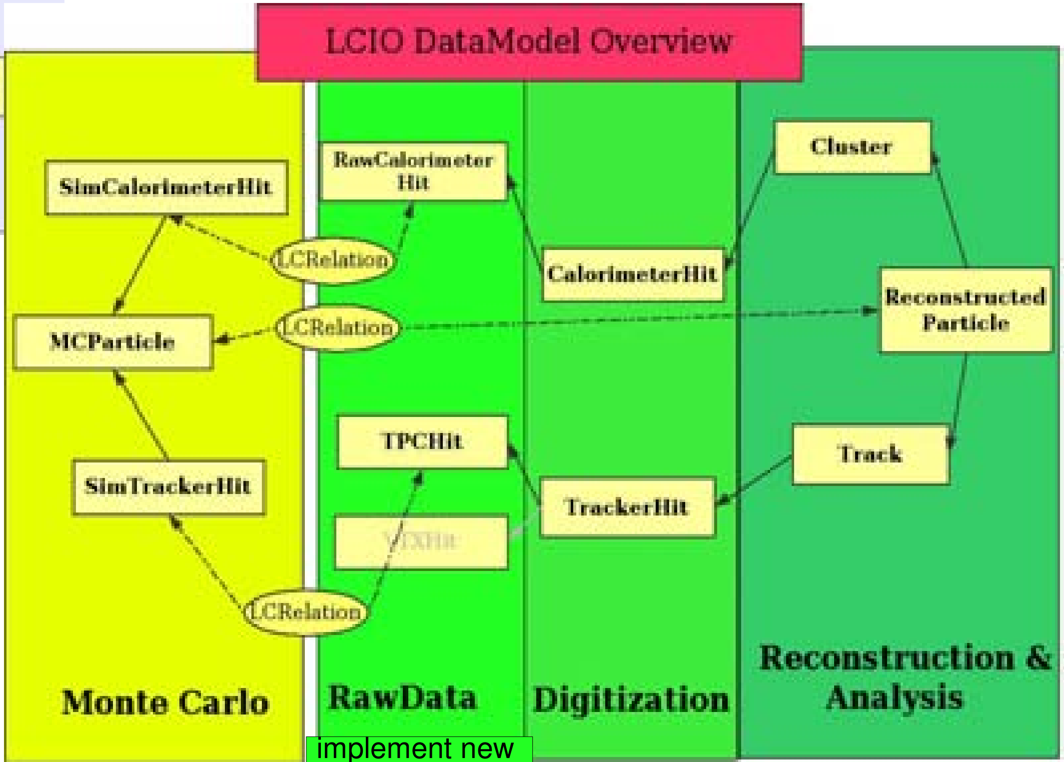


LCIO data model



event serves as container of untyped collections

hierarchy of data objects in the event

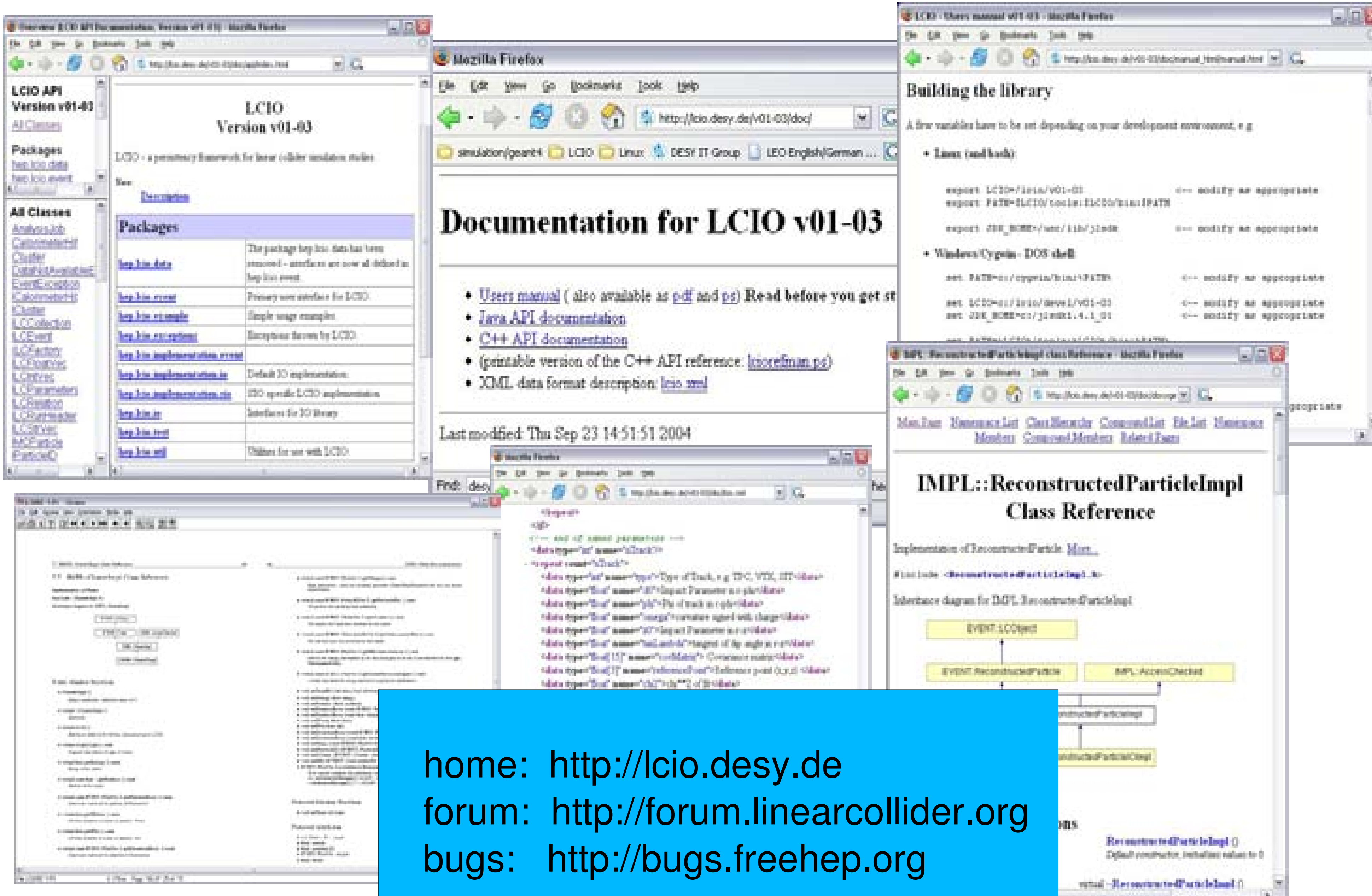


implement new classes as needed for testbeams !

LCIO status [v01-05]

- changed return values of E, P, m to double for MCParticle and ReconstructedParticle
  - stored are still floats
  - requires some trivial changes (float->double) in code where indicated by the compiler !
- new template UTIL::LCTypedVector<T> for creating std::vector<LCObjectType> from LCCollections
  - allows to use iterators and STL algorithms, e.g. std::for_each()
- added first implementations of generic tracker raw data classes (TPC, VTX, SiliconStrip,...)
  - TrackerRawData, TrackerData, TrackerPulse
- files are downward compatible with LCIO 1.4
- bug fixes
- see $LCIO/doc/versions.readme for more

LCIO on the web



home: http://lcio.desy.de
forum: http://forum.linearcollider.org
bugs: http://bugs.freehep.org

LCIO Future Plans

- current data model fairly complete
  - check usability of data model, e.g. track parameters
    - ongoing through development of reconstruction code !
  - need to define conventions on how to use LCIO
    - collection names, object types, collections to be present in event
- need to make LCIO more convenient (and efficient)
  - decoding of MCParticle information (parent/daughter, ...)
  - inverse relations (get all tracks for one MCParticle)
  - attach user information to LCObjects
- would like to make C++ version more C++ like, e.g. allow to use STL algorithms (templates in general)

- -> will have LCIO meeting here at snowmass

Simulation tools: Simdet, Brahms

- **SIMDET**

  writes LCIO

  - parameterized fast Monte Carlo (f77)
  - tracks + cov. matrix and clusters
  - hard coded geometry: TESLA TDR Detector

- **Brahms**

  reads + writes LCIO

  - geant3 full simulation (f77)
  - hard coded geometry: TESLA TDR Detector
  - full standalone reconstruction part (pflow)
    - tracking based on LEP reconstruction code

for download (cvs web interface)
and more information:
http://www-zeuthen.desy.de/linear_collider

Simulation tools: Mokka

- geant4 based full detector simulation for the ILC
- developed at LLR-Ecole Polytechnique (P. Mora de Freitas, G. Musat)
- http://polywww.in2p3.fr/geant4/tesla/www/\mokka/mokka.html
- some features:
  - steering files for configuration
  - all geant4 physics lists available
  - writes LCIO
  - reads StdHep / ASCII HepEvt
- Geometry
  - MySQL databases
    - geometry parameters
    - one database per subdetector
  - C++ Geometry Drivers
    - one for each subdetector type (e.g. TPC, HCAL)
    - define material and sensitive detector
  - abstract geometry layer: CGA

new features: (v05-01)
- SID detector model
- scalable detector models

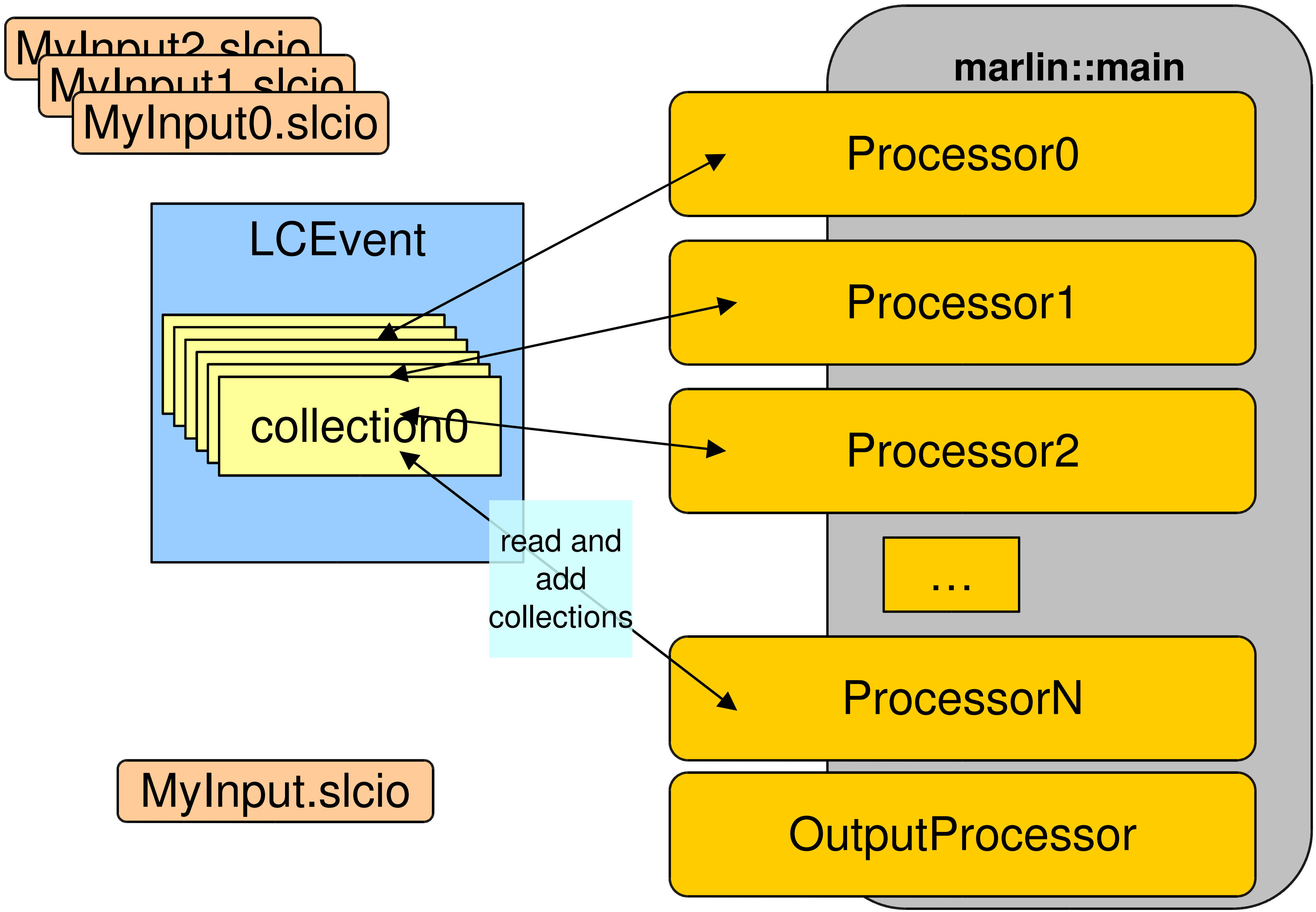
Marlin - Introduction

Modular **A**nalysis & **R**econstruction for the **L I N**ear Collider

- modular C++ application framework for the analysis and reconstruction of LCIO data
- uses LCIO as transient data model
- similar to US org.lcsim Java framework

- Application framework:
  - set of classes that provide the core functionality needed in problem domain and provide hooks (callbacks) for specific user code
  - provides main program
  - note: most current experiments that use OO (C++) have application frameworks

Marlin – schematic overview



Marlin Processor

- provides main user callbacks
- has own set of input parameters
  - int, float, string (single and arrays)
  - parameter description
- naturally modularizes the application
- order of processors is defined via steering file:
  - easy to exchange one or several modules w/o recompiling
  - can run the same processor with different parameter set in one job
- processor task can be as simple as creating one histogram or as complex as track finding and fitting in the central tracker

```
marlin::Processor
init()
processRunHeader(LCRunHeader* run)
processEvent( LCEvent* evt)
check( LCEvent* evt)
end()
```

```
UserProcessor
processEvent( LCEvent* evt){
  // your code goes here...
}
```

Marlin features

- core processors
  - AIDAProcessor
    - for easy creation of histograms, clouds, ntuples
  - OutputProcessor
    - writes current event or subset thereof
  - MyProcessor
    - simple example – serves as template for user code
  - ConditionsProcessor New
    - read conditions transparently with LCCD
  - DataSourceProcessor New
    - read non LCIO input, e.g. StdHepReader
  - SimpleFastMCProcessor New
    - fast smearing Monte Carlo
    - needs testing

- fully configurable through steering files:
  - program flow
  - input parameters
    - processor based and global

- self-documenting:
  - MyApplication -l

    will print all available processors with their parameters and example/default values

Marlin - new features I

- v00-09 (details in $MARLIN/doc/release.notes)
- new optional XML steering files
  - based on TinyXml (open source) – included in Marlin
  - same basic structure as old ASCII steering files
  - additional features:
    - allows conditional execution of processEvent() method based on boolean flags set by processors
    - allows grouping of processors with shared parameters
  - 'Marlin -x > steer.xml' creates example steering file with all available processors
- XML can be used in Marlin for other input files

Marlin – example XML steering


```
- <marlin>
  - <execute>
      <processor name="MyAIDAProcessor"/>
      <processor name="MyEventSelection"/>
    - <if condition="MyEventSelection">
        <group name="Tracking"/>
        <processor name="MyClustering"/>
        <processor name="MyPFlow"/>
        <processor name="MyLCIOOutputProcessor"/>
      </if>
    </execute>
  - <global>
      <parameter name="LCIOInputFiles"> simjob.slcio </parameter>
      <parameter name="MaxRecordNumber" value="5001"/>
      <parameter name="SupressCheck" value="false"/>
    </global>
  - <processor name="MyLCIOOutputProcessor" type="LCIOOutputProcessor">
      <parameter name="LCIOOutputFile" type="string">outputfile.slcio </parameter>
      <parameter name="LCIOWriteMode" type="string">WRITE_NEW</parameter>
    </processor>
  - <group name="Tracking">
      <parameter name="NTPCLayers" value="200"/>
      <processor name="MyTrackfinder" type="Trackfinder"/>
    - <processor name="MyTrackfitter" type="Trackfitter">
        <parameter name="Algorithm" value="DAF"/>
      </processor>
    </group>
    <!-- ... -->
  </marlin>
```

- ActiveProcessors replaced by <execute>...</execute> section
- Reconstruct only events that pass the event selection

- Parameters defined as content of <parameter/> tag or as its value attribute

- Processors can be enclosed by <group/> tag
- Parameters in <group/> joined by all processors

Marlin - new features II

- Exceptions (subclasses of lcio::Exception):
  - uncaught Exceptions terminate program with error message (given in constructor)
  - ParseException
    - thrown if steering has wrong syntax
  - SkipEventException
    - can be thrown by any processor
    - skips processEvent() for all subsequent processors
    - printout at end of program (#evts skipped by processor)
  - StopProcessingException
    - can be thrown by any Processor
    - ends program gracefully by calling all end() methods
  - others ?

Marlin - new features III

- improved Makefiles
  - make it easier to build against an installed version of Marlin:
    - INCLUDE += `. $(MARLIN)/bin/marlin_includes.sh`
    - LIBS += `. $(MARLIN)/bin/marlin_libs.sh`
    - ensures same optional dependencies are used (LCCD, CLHEP, CondDBMySQL,...)
  - USERINCLUDES, USERLIBS to define additional dependencies
  - global GNUmakefile:
    - allows to build marlin with several packages of processors
    - links all packages in $MARLIN/packages directory
    - packages need to follow $MARLIN/examples/mymarlin structure
  - see workshop DVD

MarlinReco

- **Marlin serves as a framework for the distributed development of a full suite of reconstruction algorithms !**

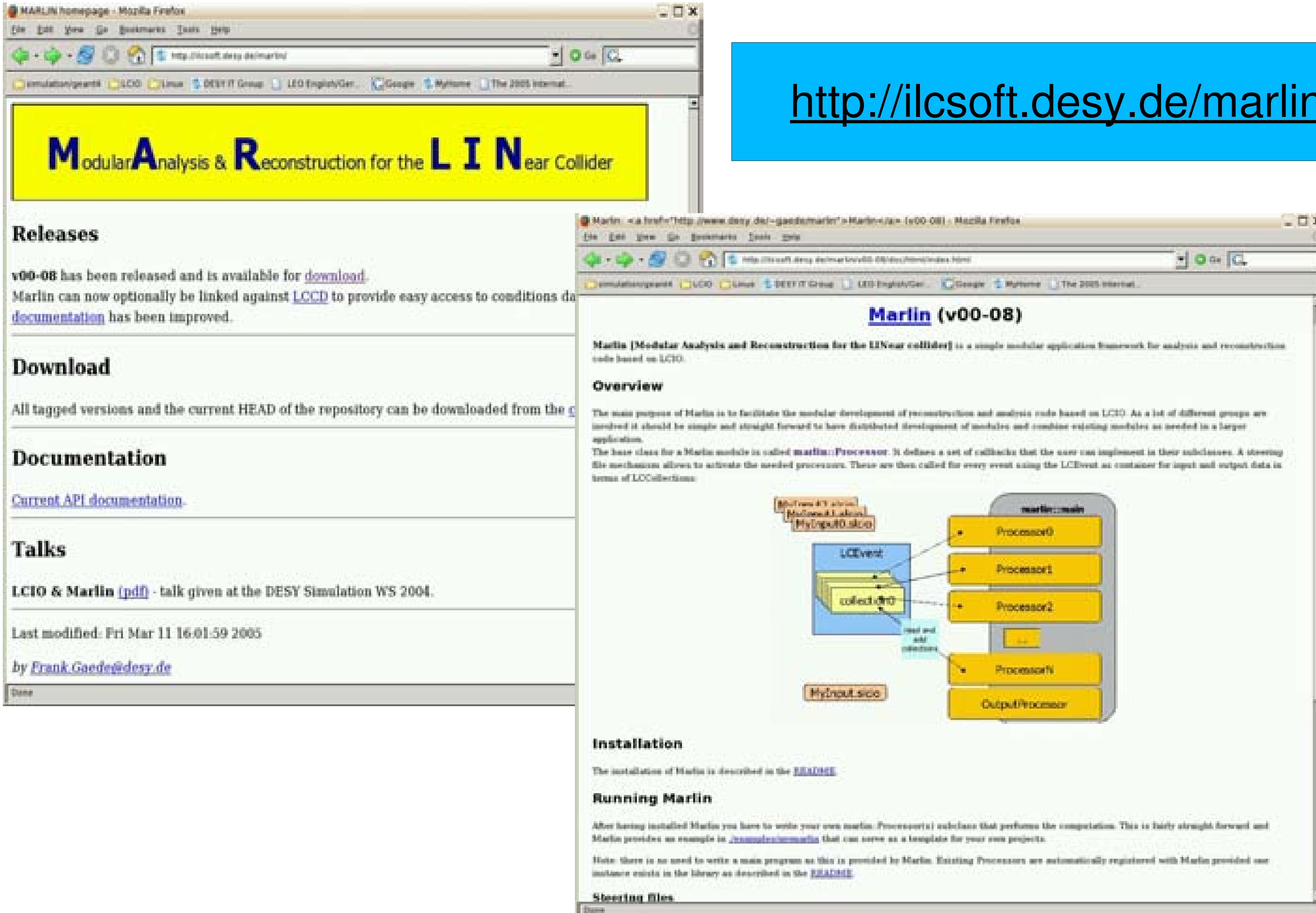
  -> your input is welcome !

- **(almost) complete set of standard reconstruction in Marlin available: MarlinReco** (see talk by S. Aplin)
  - first version available on DVD "ILC software for LDC"

- uses first implementation of GEAR geometry description
  - Marlin v00-09-01

Marlin on the web

http://ilcsoft.desy.de/marlin



LCCD Motivation

- fairly complete software chain for simulation and reconstruction for the ILC exists (or is under development)
- can be also used for the simulation of upcoming subdetector testbeam studies
- one important ingredient is missing:

conditions database

-> LCCD

LCCD

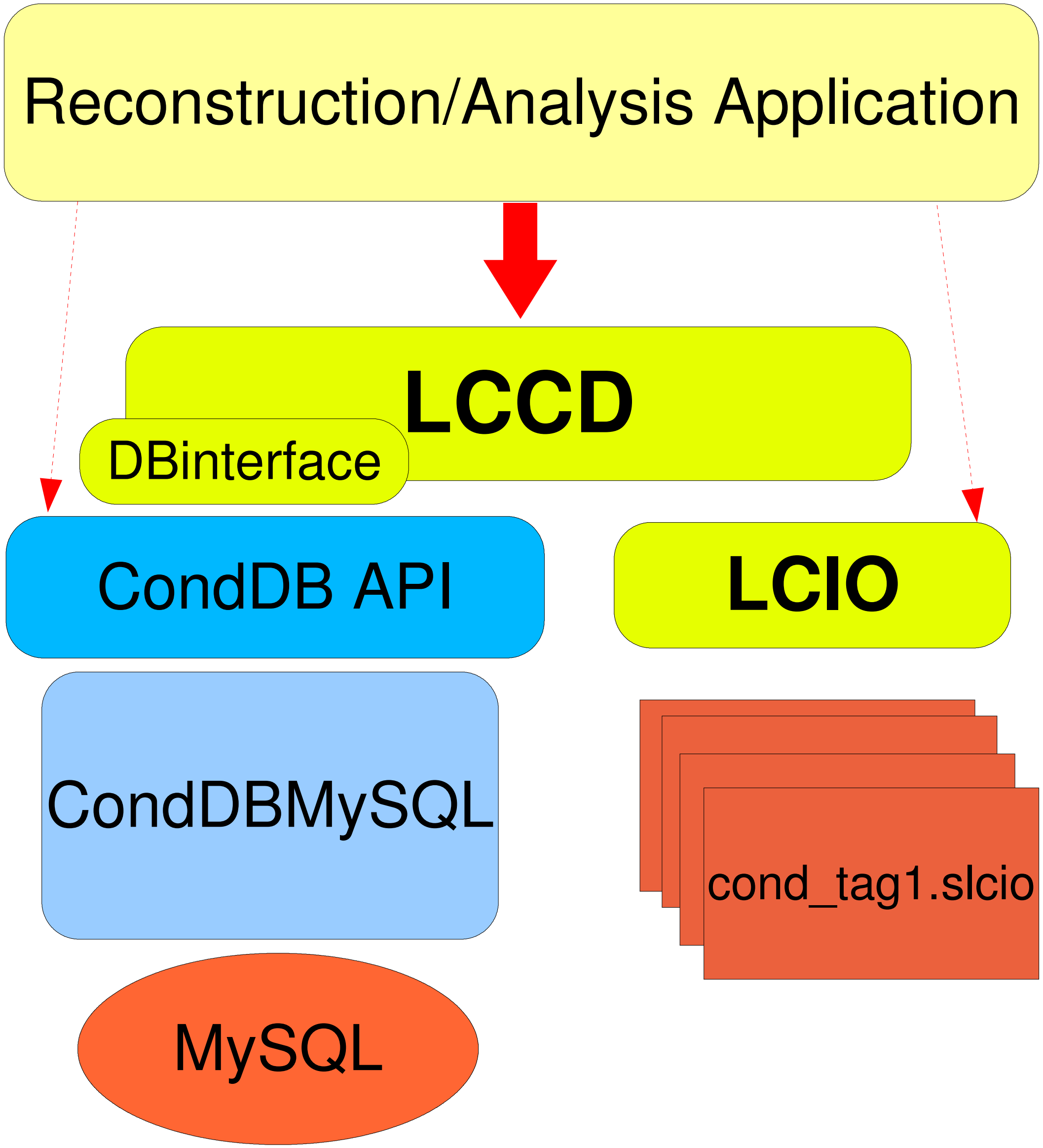
Linear **C**ollider **C**onditions **D**ata Toolkit

- handles access to conditions data transparently from
  - conditions database (CondDBMySQL (by Lisbon Atlas group))
  - LCIO files

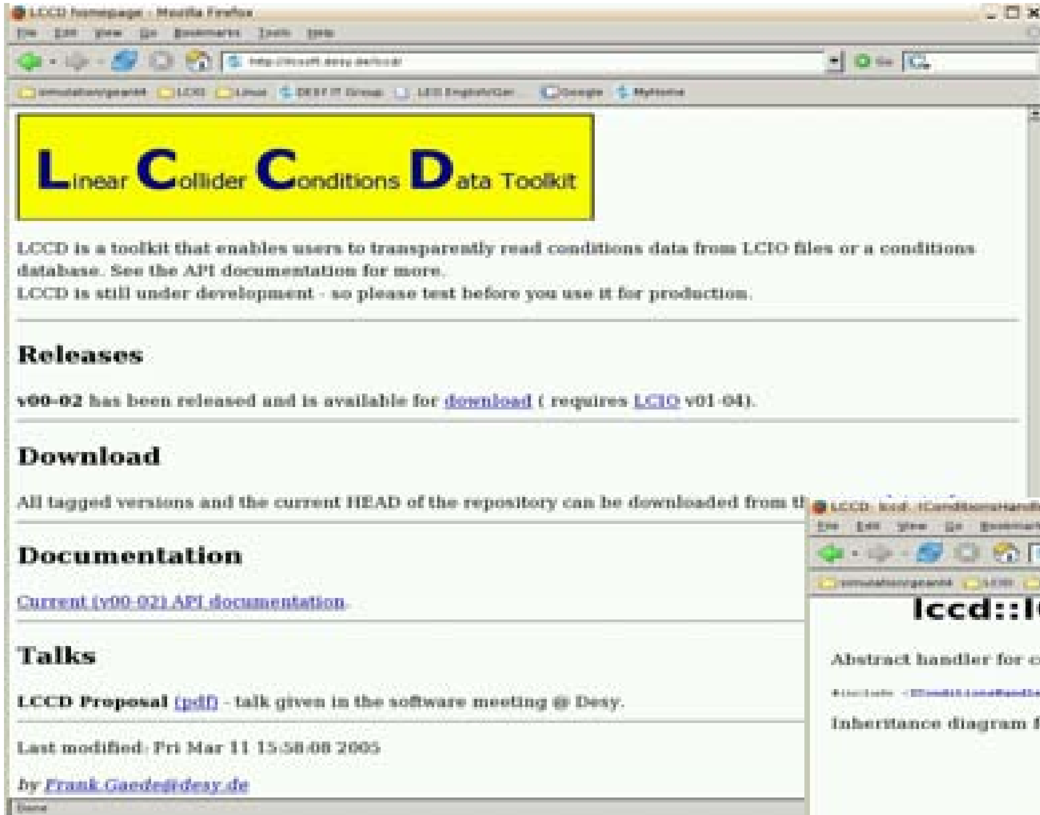
- Conditions Data:
  - all data that is needed for analysis/reconstruction besides the actual event data
    - typically has lifetime/validity range longer than one event
      - can change on various timescales, e.g. seconds to years
    - need for versioning (tagging) (changing calibration constants)
    - also 'static' geometry description (channel mapping, positions,...)

LCCD features

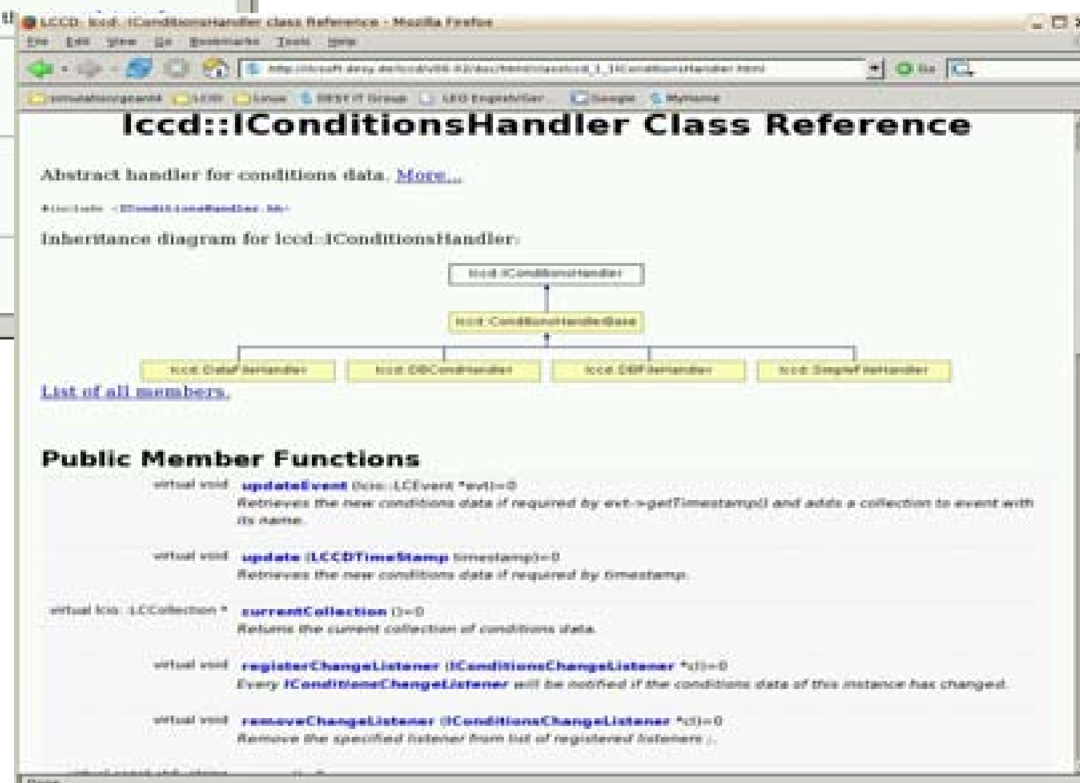
- Reading conditions data
  - from conditions database
    - for given tag
  - from simple LCIO file
    - (one set of constants)
  - from LCIO data stream
    - e.g. slow control data
  - from dedicated LCIO-DB file
    - has all constants for given tag
- Writing conditions data
  - as LCGenericObject collection
  - in folder (directory) structure
  - tagging
- Browsing the conditions database
  - through creation of LCIO files
    - vertically (all versions for timestamp)
    - horizontally (all versions for tag)



LCCD on the web



http:/ilcsoft.desy.de/lccd



GEAR Overview

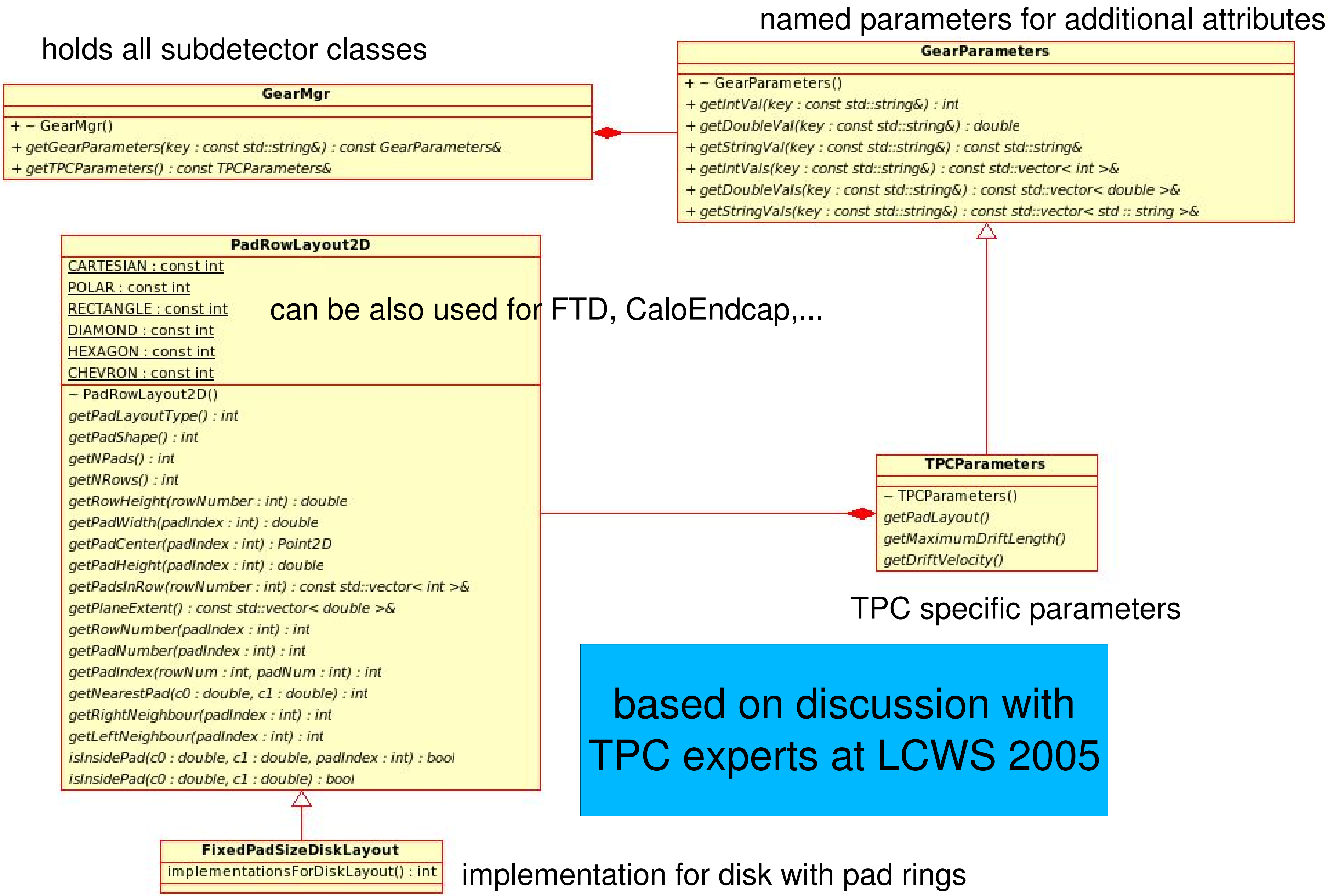
GEometry **A**PI for **R**econstruction

- Motivation:
  - need well defined geometry definition that
    - is flexible w.r.t different detector concepts
    - has high level information needed for reconstruction
      (different from detailed local description for simulation !)
    - supports 'plug & play' philosophy of processors implementing different algorithms
    - provides access to material properties (radiation/interaction lengths)
- Idea:
  - define abstract interface (a la LCIO C++ and Java ?)
  - concrete implementation based on XML files and CGA

GEAR – Classes

- Subdetector description
  - high level description of detector shape and readout geometry – one class for every subdetector type, e.g.
    - TPC, Ecal, Hcal (MainCalorimeter), FTD, VTX, SIT, ...
    - defines required attributes - as detailed as necessary but as abstract as possible
    - allows to add additional named attributes
  - use XML files
- Material properties
  - point properties (density, material, radlen,...)
  - distance properties integrated along (straight!?) path
  - use Mokka-CGA interface to geant4 geometry

GEAR – TPC description



based on discussion with TPC experts at LCWS 2005

GEAR – material properties


```
GearDistanceProperties
------------------------------------------------------------
– GearDistanceProperties()
getMaterialNames(p0 : const Point3D&, p1 : const Point3D&) : const std::vector< std :: string >&
getMaterialThicknesses(p0 : const Point3D&, p1 : const Point3D&) : const std::vector< double >&
getNRadlen(p0 : const Point3D&, p1 : const Point3D&) : double
getNIntlen(p0 : const Point3D&, p1 : const Point3D&) : double
getBdL(pos : const Point3D&) : double
getEdL(pos : const Point3D&) : double
```

integrated along path:

- straight line or
- true path in B-Field ?

```
GearPointProperties
------------------------------------------------------------
– GearPointProperties()
getCellID(pos : const Point3D&) : int
getMaterialName(pos : const Point3D&) : const std::string&
getDensity(pos : const Point3D&) : double
getTemperature(pos : const Point3D&) : double
getPressure(pos : const Point3D&) : double
getRadlen(pos : const Point3D&) : double
getIntlen(pos : const Point3D&) : double
getLocalPosition(pos : const Point3D&) : Point3D
getB(pos : const Point3D&) : double
getE(pos : const Point3D&) : double
getListOfLogicalVolumes(pos : const Point3D&) : std::vector< std :: string >
getListOfPhysicalVolumes(pos : const Point3D&) : std::vector< std :: string >
getRegion(pos : const Point3D&) : std::string
isTracker(pos : const Point3D&) : bool
isCalorimeter(pos : const Point3D&) : bool
```

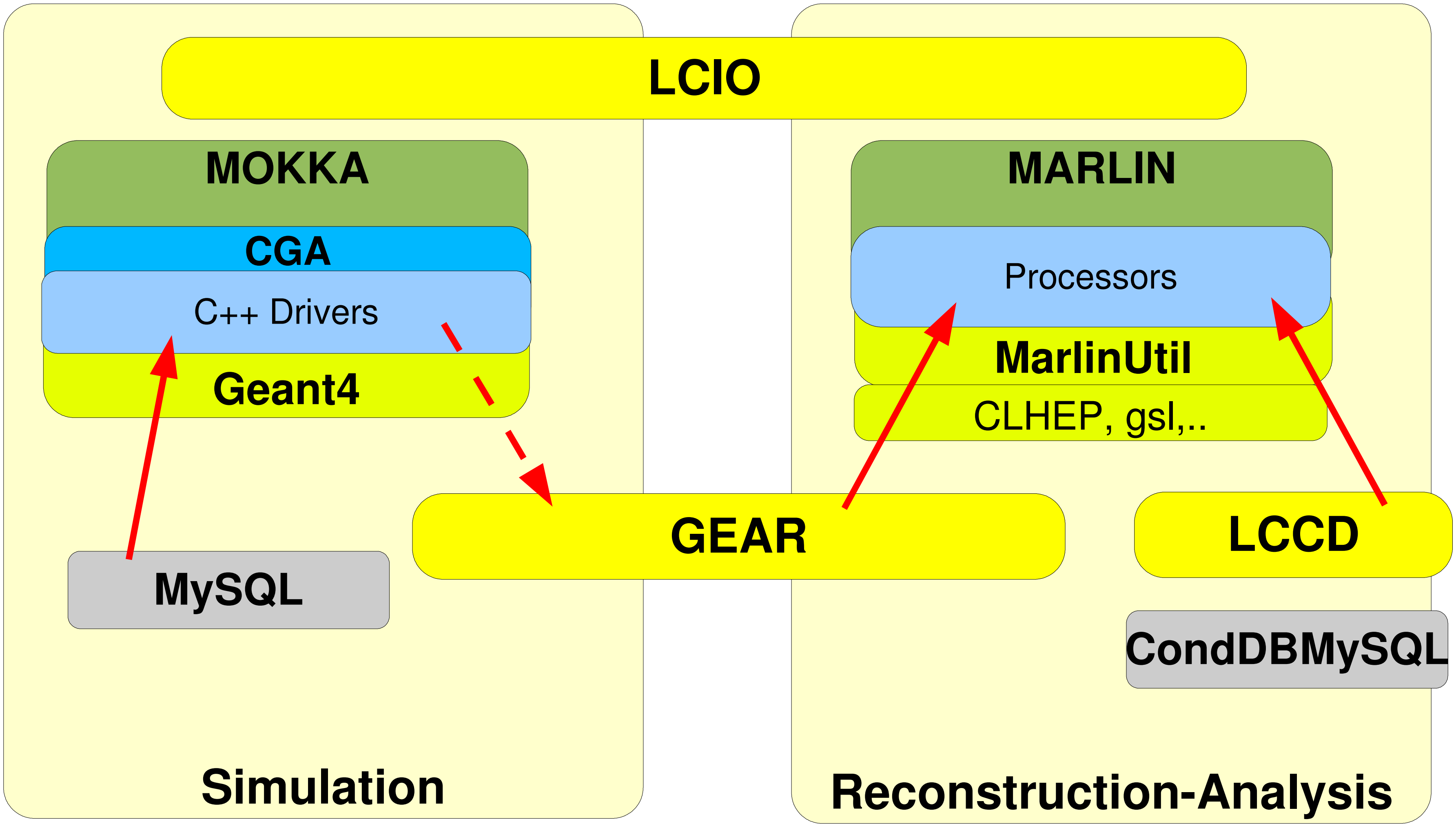
properties at point from geant4 (CGA)

based on discussions at Argonne Simulation Meeting 2004

GEAR status and outlook

- first mini implementation with XML files for current MarlinReco: TPC, Ecal, Hcal
  - XML format 'compatible' with US compact description
  - integrated in Marlin v00-09-01 (see DVD)
  - soon to be released !
- Plans:
  - have discussions at snowmass with other subdetector groups about abstract interface needed
  - see if other groups are interested in collaborating !?
  - provide implementation of material properties based on CGA/Mokka
  - investigate option of creating GEAR XML files in Mokka geometry drivers:
    - the information is there
    - have only one source of geometry

LDC simulation framework



Summary & Outlook

- a fairly complete OO-software framework exists for the LDC study based on Mokka, Marlin, LCIO, LCCD and GEAR
  - ready to start using it for detector concept study !

current version of this software can be found on the DVD "ILC software for LDC "

- has been used to produce LDC events on "International ILC Event DVD" on the DESY – computing **Grid !**
  - LCIO files for SID, LDC, GLC of Zpole, Zh and ttbar events
  - also at http://www-flc.desy.de/snowmassdatadvd

To Do:
• investigate interoperability with other frameworks
• apply software to other comcepts
• exchange ideas and collaborate
improve software ...

all software (will be) available at portal:
http://www-flc.desy.de/ilcsoft