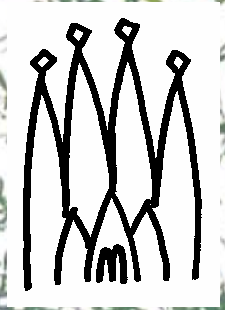

LoKi & Bender

Smart & transparent physics analysis

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Outline

- The easy and friendly environment for physics analysis
  - The dream or reality ?
- Code complexity, readability, easiness etc is not a property of language
  - C++ itself is not a shit

LoKi

- Set of C++ utilities atop of DaVinci to perform easy ('1 line') and readable physics analysis

Bender

- Set of Python's utilities for interactive physics analysis with full access to LoKi's functionality

Tool for physics analysis

- Selection/filtering of particles with certain criteria
- Looping over the various combinations
- Creation of composed particles
- Kinematical/topological constraints
- Access to MC truth
- Histograms & N-Tuples

The major design criteria

- Compact & Readable code
  - At most 1 line per each task
- Hide all technical details
- Concentrate on physical contents
- Friendly semantics

Is the goal achievable?

- The best example - KAL by genius Hartwig Albrecht
  - Script-like file
  - All technical details are well hidden from end-users
  - Transparent physical content of the code
  - Looping, histograms, N-tuples, MC truth - at most 1 line!
- Typical analysis program ~ 50-70 lines
- All senior person, including the spokesman successfully participated in physics analysis

```
HYPOTH E+ MU+ PI+ 5 K+ PROTON

IDENT PI+     PI+
IDENT K+      K+
IDENT E+      E+
IDENT PROTON  PROTON
IDENT MU+     MU+

SELECT K- pi+
 IF P > 2 THEN
  SAVEFITM D0 DMASS 0.040 CHI2 4
 ENDIF
ENDSEL

SELECT D0 pi+
  PLOT MASS L 2.0 H 2.1 NB 100 @
         TEXT ` mass D0 pi+ `
ENDSEL

GO 1000
```

Is the goal achievable with OO?

- Majority (but me) is convinced that C++ features (verbosity, static nature etc) do not allow to use it as friendly language for physics analysis

Pattern package by T.Glebe (HERA-B)

- Native C++
- Easy, readable and very efficient

```
TrackPattern PiMinus =
  pi_minus.with ( pt > 0.1 & p > 1 ) ;
TrackPattern PiPlus  =
  pi_plus.with  ( pt > 0.1 & p > 1 ) ;
TwoProngDecay kShort =
  K0S.decaysTo  ( PiMinus & PiPlus ) ;
kShort.with ( vz > 0   ) ;
kShort.with ( pt > 0.1 ) ;
```

Try to merge the best ideas : LoKi

- KAL by Hartwig Albrecht
  - '1-line' semantics
  - Predefined variables
- Pattern and GCombiner by Thorsten Glebe
  - Cuts and patterns
- HepChooser and HepCombiner from obsolete CLHEP
  - Combinations, loops
- Loki by Andrei Alexandresku
  - Functions, name and spirit

```
select ( "K-"  , ID == "K-"  && CL > 0.01 && P > 5 * GeV ) ;
select ( "PI+" , ID == "pi+" && CL > 0.01 && P > 5 * GeV ) ;

for ( Loop D0 = loop( "K- PI+" , "D0" ) ; D0 ; ++D0 )
   {
       if( P( D0 ) > 10 * GeV ) { D0->save( "D0" ) ; }
   }
for ( Loop Dstar = loop( "D0 PI+" , "D*+" ) ; Dstar ; ++Dstar )
   {
       plot ( "Mass of D0 pi+", M(Dstar) / GeV , 2.0 , 2.1 , 100 ) ;
   }
```

LoKi: major design ideas

- Compact, easy to read and transparent code
- Hide all technicalities
- Implement all 'everyday idioms' as 1-line functions
- Locality:
  - Declare, create and use the objects only 'locally'
  - 1 analysis = 1 short file
- High CPU performance
  - Reuse of the most modern C++ techniques
  - Paradigm of templated compile time metaprogramming

- Implement everything as reusable components
  - LoKi functions are compatible with Loki, STL, boost, CLHEP
  - LoKi functions are used with cuts, other functions, histograms, tuples, MC truth, etc
- Weak coupling with concrete Event model, tools, etc
- Extendable

LoKi versus native DaVinci

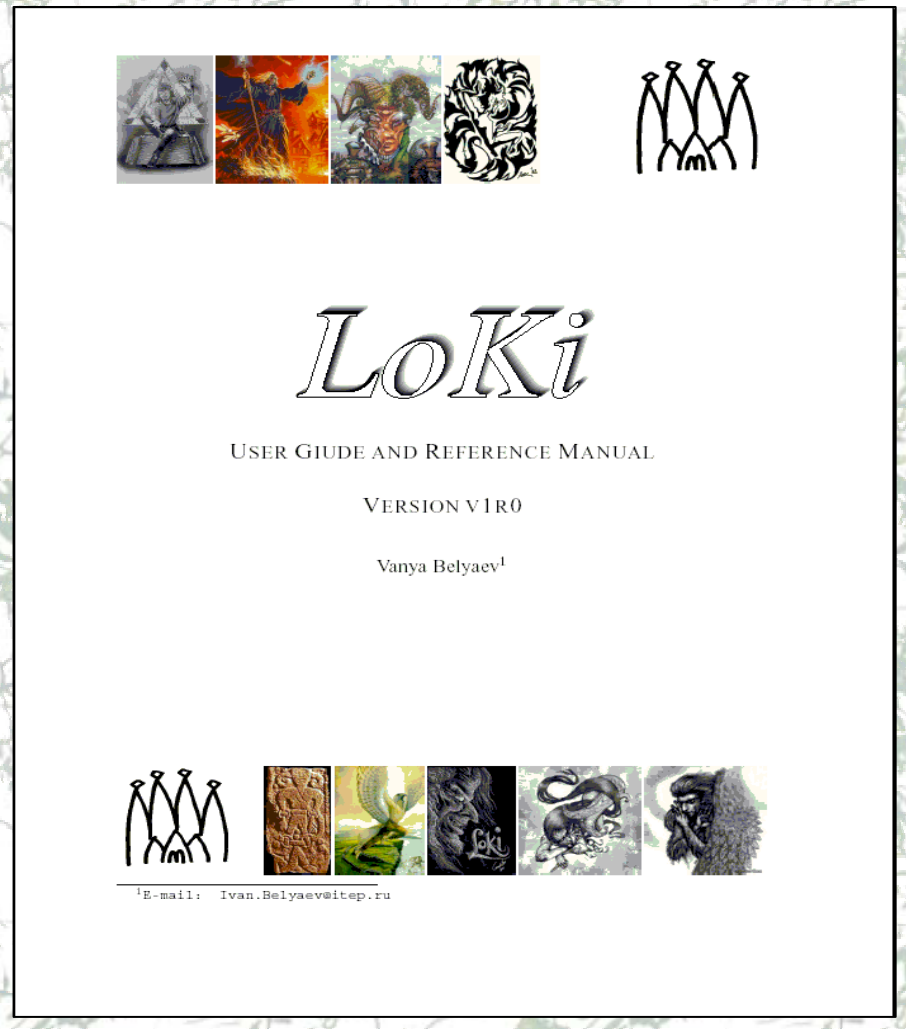
COCOMO model SLOCCount by David A.Wheeler

Selection	SLOC	Person-month	Cost [k$]
B2DD	2.6 k	6.5	73
B2HH	362	0.8	9
Bd2D0Kstar	1.1 k	2.3	30
Bd2JpsiKstar	1.5 k	3.6	40
Bd2MuMuKstar	1.4 k	3.4	38
Bs2DsH	3.2 k	8.0	91
Bs2MuMu	530	1.2	14
Bd2JpsiKs	1.0 k	2.3	30
Bd2KstarGamma	128	0.3	2

LoKi: Status of current version v1r2

- LoKi is used by Galina, Andrey, Sergey and Benoit for their studies of radiative and gluon penguins
- Tools/LoKi v1r1 is semi-officially released as part of DaVinci v8r0
- Few released physics (pre)selection packages use LoKi
- Package of examples is provided: LoKiExamples
- Detailed documentation (65 pages) is available

~ibelyaev/doc/GaudiDoc/LoKi.ps



LoKi: selection of particles

- Simple selection of particles & vertices from TES, LoKi internal storages, already selected particles or any other sources according to kinematical and/or topological criteria

all kaons (no cuts)

```
select("Kaon" , ID=="K-" || ID=="K+" ) ;
```

Positive pions with Confidence Level in excess of 1% and p_T > 100 MeV/c^2

```
select("Pi+" , ID=="pi+" && CL>0.01 && PT>100*MeV );
```

Positive muons with χ^2_{IP} with respect to the primary vertex in excess of 4

```
const Vertex* pv = … ;
select("MyMu" , ID=="mu+" && IPCHI2(point(pv))>4);
```

LoKi: functions and cuts

Large set (>50) of predefined *functions*

- Simple properties of particles
  - `P,PT,PX,M,CL,ID,Q,LV01,M12,DMASS,DMCHI2,….`
- Simple properties of Vertices
  - `VCHI2,VTYPE,VX,VZ,VDOF,VPRONGS,VTRACKS,…`
- Topological properties of Particles and Vertices
  - `IP,IPCHI2,VDCHI2,VDTIME,VDSIGN,DDANG,…`
- Operations with Functions - other Functions
  - `+ - * / sin cos tan abs pow min max …`

Cuts/predicates are formed from functions

LoKi: multiparticle loops

Loops over particle combinations, selects combinations according to kinematical and topological criteria

simple loop over all $K^- \pi^+ \pi^+ \pi^-$ combinations

```
for( Loop D0 = loop( "K- pi+ pi+ pi-" , "D0") ; D0 ; ++D0 )
{
```

Require p_T of combination in excess of 1 GeV/c and χ^2_{VX} < 49

```
  if( PT( D0 ) > 1 * GeV && VCHI2( D0 ) < 49 )
   {
```

Book and fill (1 action!) the histogram

```
     plot( "K- pi+ pi+ pi- mass", M(D0)/GeV , 1.5 , 2.0 , 200 );
```

Save the combinations with $|\Delta M|$<30 MeV/c^2

```
     Cut dm = abs( DMASS("D0") ) < 30 * MeV ;
     if( dm( D0 ) ) { D0->save("D0") ; }
} }
```

LoKi: Histograms

- Histograms are local & booked on-demand
  - No need for pre-booking!
- Include variants for effective implicit loops

```
for( Loop D0 = loop( "K- pi+" , "D0") ; D0 ; ++D0 )
{
  plot( "K- pi+ mass", M(D0)/GeV , 1.7 , 2.0 , 150 );
}

plot( loop( "K- pi+", "D0" ) , "(2)K-pi+ mass" , M12 / GeV ,
   1.7 , 2.0 , 150 ) ;

plot( select("Kaons", ID == "K-" ) , "PT of kaons ", PT /GeV ,
   0 , 5 , 100 );
```

Book and fill the histogram

Make a loop, book and fill the histogram

Select particle, make a loop, book and fill the histogram

LoKi: N-tuples

- N-Tuples are local & booked on-demand
  - No need for pre-booking of N-Tuple and its items
- Include variants for effective implicit loops

Book N-tuple

```
Tuple tuple = ntuple("My N-Tuple for K- pi+ combinations");
for( Loop D0 = loop( "K- pi+" , "D0") ; D0 ; ++D0 )
{
```

Fill columns one-by-one

```
   tuple -> column( "M" , M(D0)/GeV);
   tuple -> column( "PT" ,PT(D0)/GeV);
```

Fill few columns at once

```
   tuple ->fill("PX,PY,PZ", PX(D0)/GeV, PY(D0)/GeV, PZ(D0)/GeV);
```

Commit N-Tuple row

```
   tuple->write() ;
}
```

LoKi: MC matching I

- The simplest basic formal question:
  - Does this reconstructed Particle originates from this MCParticle ?

```
const Particle*   p = … ;
const MCParticle* mcp = … ;
```

Create MC match object

```
MCMatch mcmatch = mctruth();
```

Use MC match object

```
bool match = mcmatch( p , mcp ) ;
```

LoKi: MC matching II

- Question 2
  - What MCParticle from the list correspond to this Particle?

```
const Particle*   p   = … ;
MCSEQ             mcps = … ;

MCMatch mcmatch = mctruth();

MCSEQ::iterator mcp =
   mcmatch->match( p , mcps.begin() ,mcps.end() ) ;
if ( mcps.end() != mcp )
   {
      const MCParticle* mc =  *mcp ;
   }
```

Arbitrary sequence of MCParticle objects

Use MC match object

MCParticle is found!

LoKi: MC matching III

- Question 3
  - What Particle from the list correspond to this MCParticle?

```
SEQ                    ps = … ;
const MCParticle*  mcp  = … ;

MCMatch mcmatch = mctruth();

SEQ::iterator ip =
  mcmatch->match( ps.begin() ,ps.end() , mcp ) ;
if ( ps.end() != ip )
{
const Particle* particle =  *ip ;
}
```

Arbitrary sequence of Particle objects

Use MC match object

Particle is found!

LoKi: MC matching IV

- Easy to combine with Olivier Dormond's beautiful tool

Find MC decays

Create MC cut

Does this D0 matches to one of the MC truth D0 ?

```
MCMatch finder = mctruth() ;
MCRange mcD0s   = finder->findDecays("D0 -> K- pi+");

Cut mccut = MCTRUTH( mctruth() , mcD0s );
for( Loop D0 = loop( "K- pi+" , "D0" ) ; D0 ; ++D0 )
{
  if( mccut( D0 ) )
   {
     plot("mass of true D0->K- pi+",
          M(D0)/GeV,1.7,2.0,150);
} }
```

LoKi: other utilities

- Event tag collections
  - Almost no difference to Tuples
- Expansion of decay trees (both MC and Reco)
- Extraction of `ProtoParticles`
- Easy extraction to decay tree products with indices:
  - `child ( B0 , 1 )`
  - `child ( B0 , 2 , 1 )`
  - `child ( child ( B0 , 1 ) , 4 )`
- Other utilities & tools beyond this presentation

LoKi + Python = Bender

- Python allows to make the code even more compact and readable
- Python allows to keep the code and the options together in one file
  - Improved locality
- Python allows to make analysis interactive
  - Invoke Bender from Panoramix prompt ?
- The only one executable for all persons and all their jobs
  - No private libraries, no compiler, linker etc
- 'Platform independent' (to some extent)
  - Develop and test algorithms on laptop (Win) and then send the script to 'large' center (Linux)
- Each separate analysis – 1 self-contained python file with code and options

Bender: Bs→ φφ (I)

φ selection part of `Analysis.py` file

```
#
from BenderModule import *

#
class PhiPhi(Bender):
    " My own analysis algorithm "
    def analyse ( self ) :

        kplus     = self.select  ( tag="K+" , cuts = ID == 'K+' )
        kminus    = self.select  ( tag="K-" , cuts = ID == 'K-' )
        primaries = self.vselect ( tag='PVs' ,cuts = VTYPE == VertexType.Primary )
        if primaries.empty() : return SUCCESS

        tuple = self.ntuple( name='myTuple' )
        phis  = self.loop( formula='K+ K-' , pid=333 )

        # MC truth information
        mc      = self.mctruth()
        mcphis  = mc.findDecay( decay = 'phi(1020) -> K+ K- ' );
        mccut   = MCTRUTH( self._mctruth('jshfalj') , mcphis )

        dm  = abs_( DMASS( "phi(1020)" ) ) < 10.
        for phi in phis :
            if M12( phi ) > 1050 : continue
            if not mccut( phi )  : continue
            self.plot     ( title=' phi mass '   , value= M(phi) , low= 1000. ,  high=1050. )
            tuple.column ( name='mass'      , value= M(phi) )
            tuple.column ( name='m12'       , value= M12(phi) )
            tuple.column ( name='p'         , value= P(phi) )
            tuple.column ( name='pt'        , value= PT(phi) )
            tuple.column ( name='cl1'       , value= CL(phi(1) ) )
            tuple.column ( name='cl2'       , value= CL(phi(2) ) )
            tuple.write()
            if dm( phi ) : phi.save('phi')
```

Bender : Bs→ φφ (II)

B_s selection part of `Analysis.py` file

```
tuple2 = self.ntuple( name='tuple for Bs' )
allBs  = self.loop(formula='phi phi' , pid=531 )
for Bs in allBs :
    if M12(Bs) < 3000 : continue
    tuple2.column( name='m12'   , value=M12(Bs) )
    tuple2.column( name='p'     , value=P(Bs) )
    tuple2.column( name='pt'    , value=PT(Bs) )
    tuple2.column( name='lv01' , value=LV01(Bs) )
    tuple2.write()

phis = self.selected('phi')
#print ' Numebr of selected  phis is ' , phis.size()

return SUCCESS
```

Bender: Bs→ φφ (III)

Configuration part of `Analysis.py` file

```
def property( tag ):    # temporary trick!
    return Service(tag)

#    create my algorithm
myAlg = PhiPhi('MyAnalysis')

# configure my algorithm
p1 = property('MyAnalysis')
p1.OutputLevel = 4
p1.TupleLUN    = 'TUPLES'
p1.TupleOffSet = 2000

# configure the desktop
desktop                  = property('MyAnalysis.PhysDesktop')
desktop.InputLocations   = ["/Event/Phys/Photons", "/Event/Phys/Charged"]
desktop.OutputLocation   =  "/Event/Phys/MyAlg"

# initialize the algorithms
myAlg.initialize()

# append it to the list of top level algorithms
g.topAlg = g.topAlg + [ 'MyAnalysis' ]

g.execute(400)
g.exit()
```

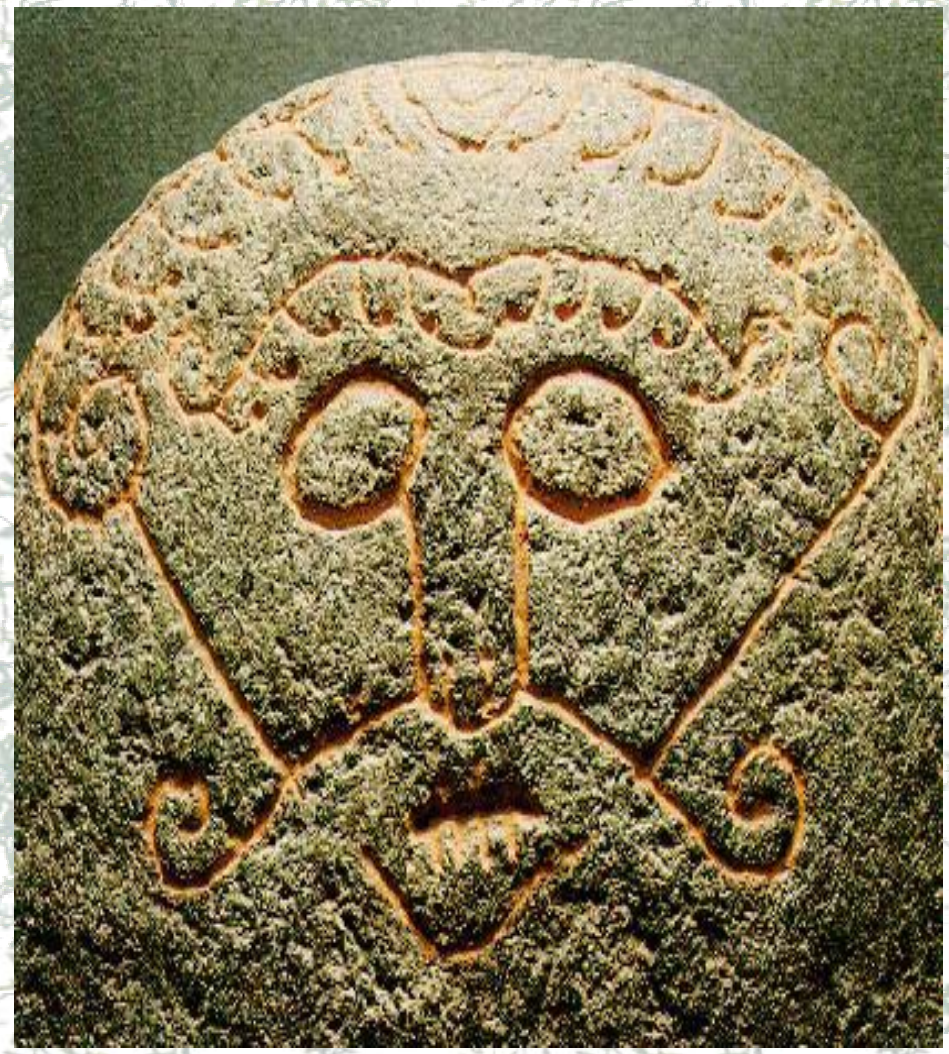
LoKi I

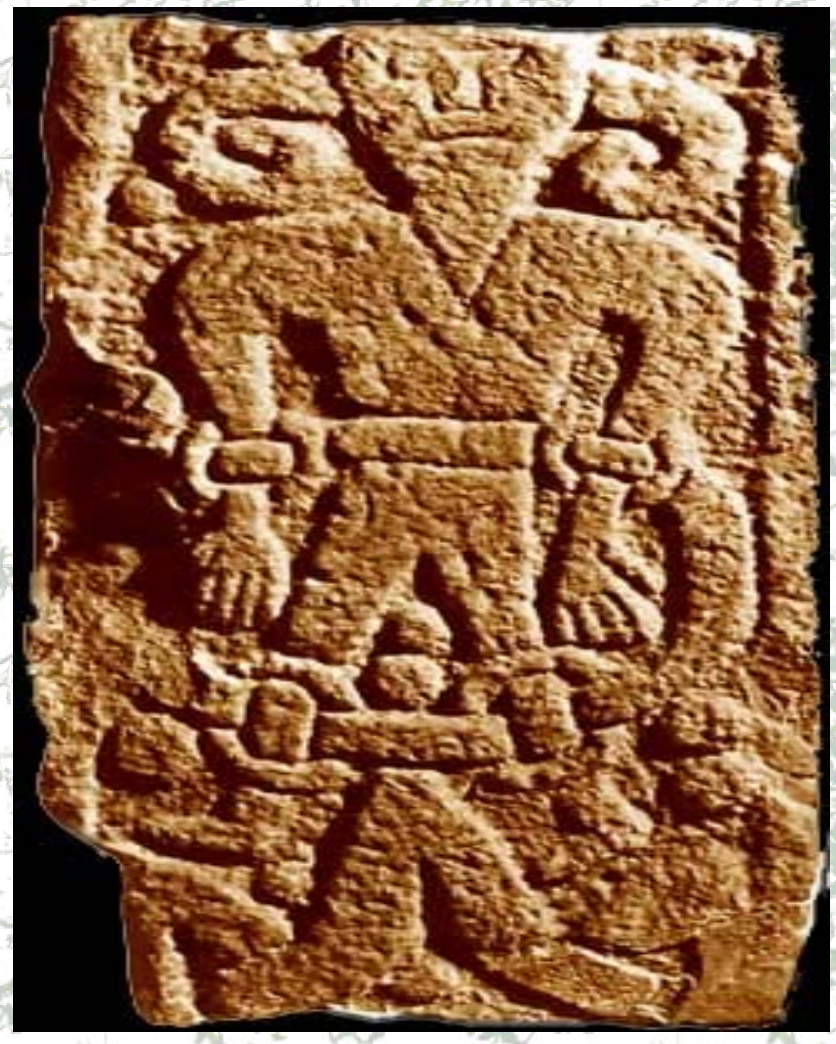
- Loki is a god of wit and mischief in Norse mythology
- Loops & Kinematics





LoKi II





LoKi III

Bender