PARTONS tutorial (user's perspective)

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Prospects for extraction of GPDs from global fits of current and future data

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Outline

- what's PARTONS?
- architecture - basic information
- reference sources

- exercise

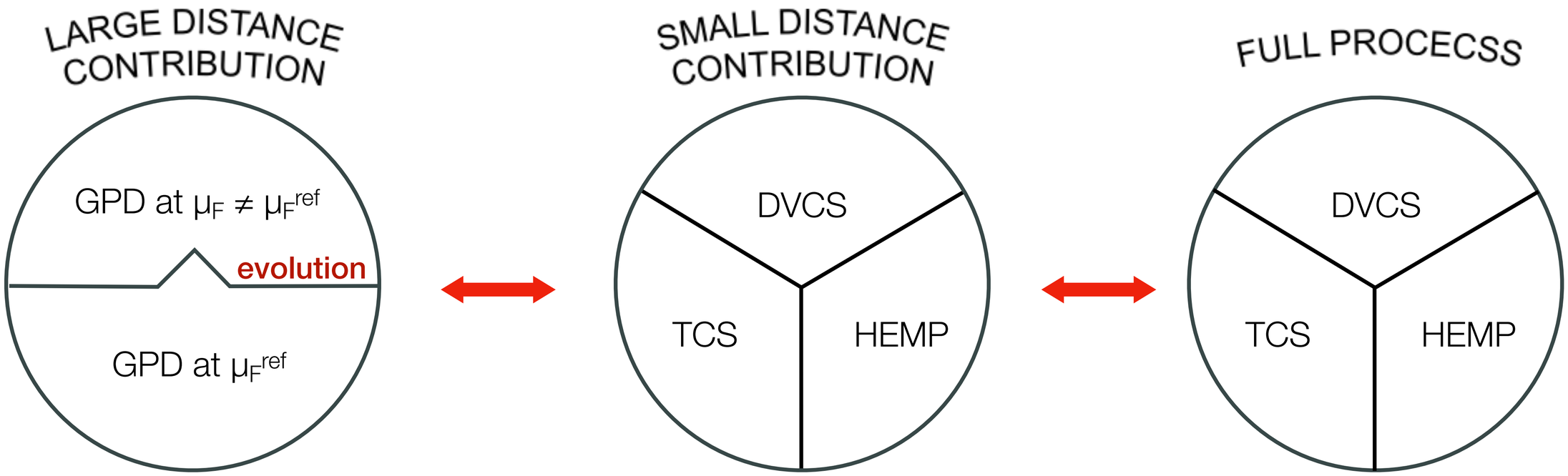
PARTONS

PARTONS - PARtonic Tomography Of Nucleon Software

- dedicated to the phenomenology of GPDs
- bridge between models of GPDs and experimental data
- can be used by both experimentalists and theoreticians
- aggregation point for GPD-related developments
- collaborative tool to support the effort of whole GPD community in a long run

- see Herve's talk for "The need for a computing framework for GPDs"

Typical GPD-related computation



First principles and fundamental properties

Computation of amplitudes

Experimental data and phenomenology

- physical models
- perturbative approximations

- many observables
- numerical methods

- accuracy and speed
- fits

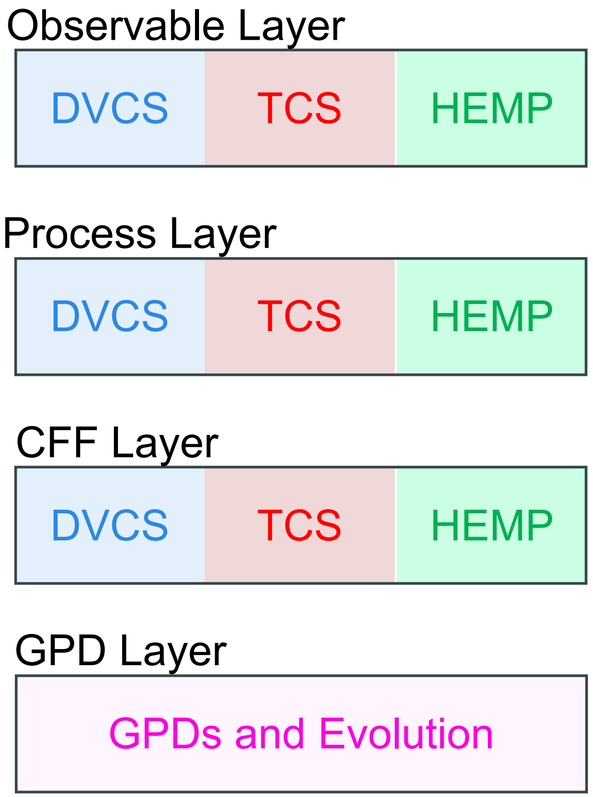
Layered structure

- one layer = collection of objects designed for common purpose
- one module = one physical development
- operations on modules provided by Services, e.g. for GPD Layer

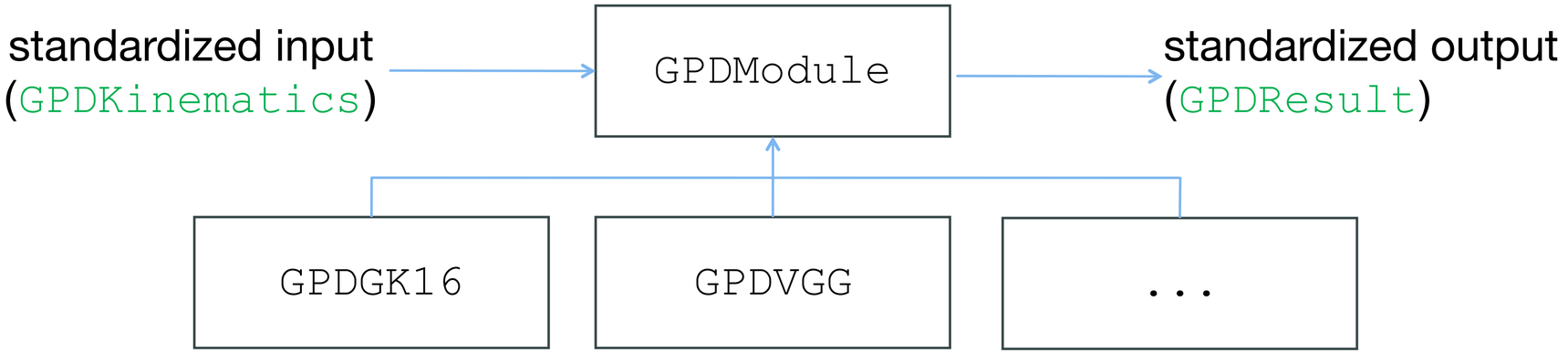
```
GPDResult computeGPDModel (const GPDKinematic& gpdKinematic,
        GPDModule* pGPDModule, const List<GPDType>& gpdType);

List<GPDResult> computeManyKinematicOneModel (
        const List<GPDKinematic>& gpdKinematicList,
        GPDModule *pGPDModule, const List<GPDType>& gpdType);
...
```

- what can be automated is automated
- features improving calculation speed

  e.g. threads



Standardised objects



- benefiting from C++ inheritance and polymorphism mechanisms
- reduction of mistake probability
- adding new modules as easy as possible (tutorials and templates available online)

Interface - xml

```
<?xml version="1.0" encoding="UTF-8" standalone="yes" ?>

<!-- Scenario starts here -->
<scenario date="2018-01-23" description="Example: evaluation of GPD model">

    <!-- Indicate service and its methods to be used -->
    <task service="GPDService" method="computeGPDModel" storeInDB="0">

        <!-- Define GPD kinematics -->
        <kinematics type="GPDKinematic">
            <param name="x" value="1.E-1" />
            <param name="xi" value="1.E-2" />
            <param name="t" value="-0.1" />
            <param name="MuF2" value="2." />
            <param name="MuR2" value="2." />
        </kinematics>

        <!-- Define physics assumptions -->
        <computation_configuration>
             <module type="GPDModule" name="GPDGK16">
            </module>
        </computation_configuration>
    </task>
</scenario>
```

Interface - c++

```
// Retrieve GPD service
GPDService* pGPDService =
        Partons::getInstance()->getServiceObjectRegistry()->getGPDService();

// Load GPD module with BaseModuleFactory
GPDModule* pGPDModel =
        Partons::getInstance()->getModuleObjectFactory()->newGPDModule(
                GPDGK16::classId);

// Create GPDKinematic(x, xi, t, MuF2, MuR2) to compute
GPDKinematic gpdKinematic(1.E-1, 1.E-2, -0.4, 2., 2.);

// Perform the calculation
GPDResult gpdResult = pGPDService->computeGPDModel(
        gpdKinematic, pGPDModel);

// Print result
std::cout << gpdResult.toString() << std::endl;
```

Database and threads

Database

- result computed by each layer can be stored/retrieved from database

```
...
<task service="GPDService" method="computeGPDModel" storeInDB="1">
...
```

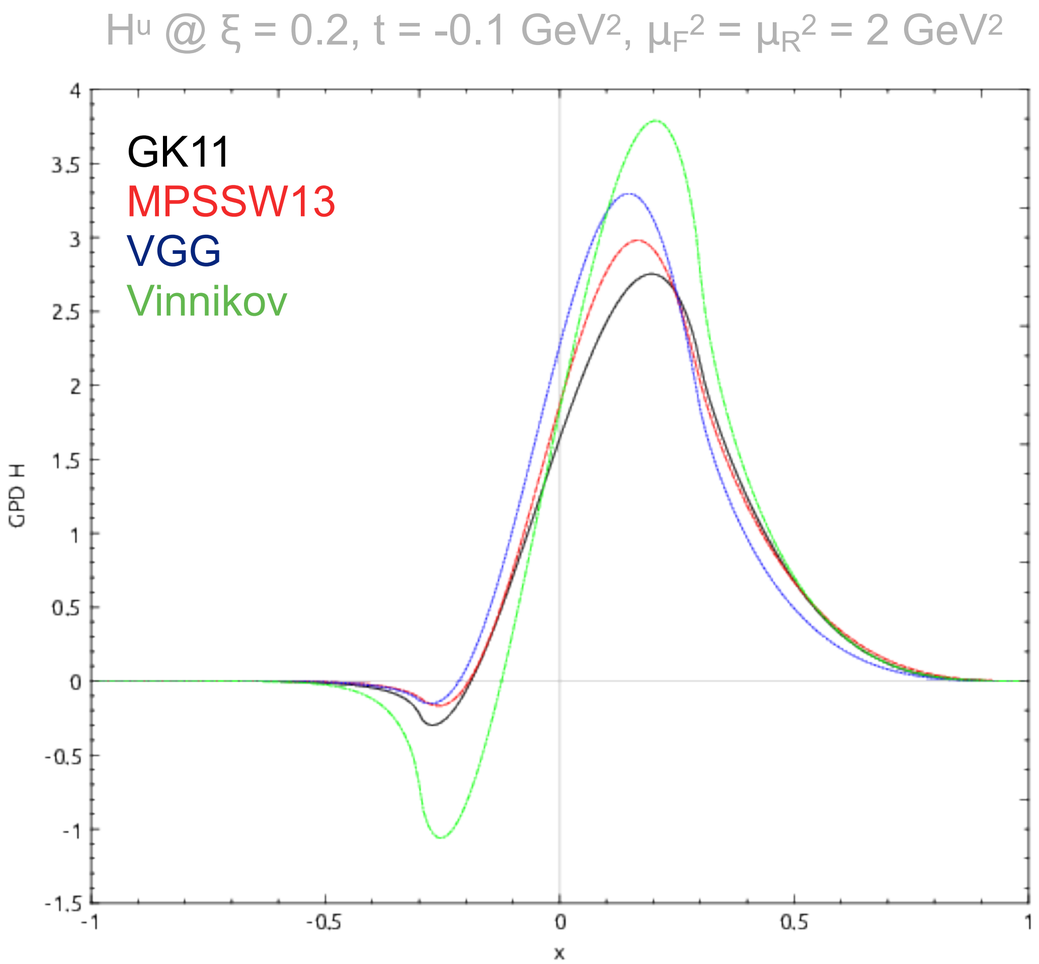
- MySQL support
- rollback mechanism and optimisation for large transactions
- database also to store experimental data → Fits

Threads

- to speed up calculation
- also used by Logger

Existing modules

- GPD: GK, VGG, Vinnikov, MPSSW, MMS, HM
- Evolution: Vinnikov's code
- CFF (DVCS only): LO, NLO (gluons and light (+heavy) quarks)
- Cross Section (DVCS only): VGG, BMJ, GV



Useful information

PARTONS is open source project distributed under following licenses (per subproject):

- elementary-utils: Apache
- numa, partons and partons-example: GPL

To download and for tutorials, useful information, reference documentation see:

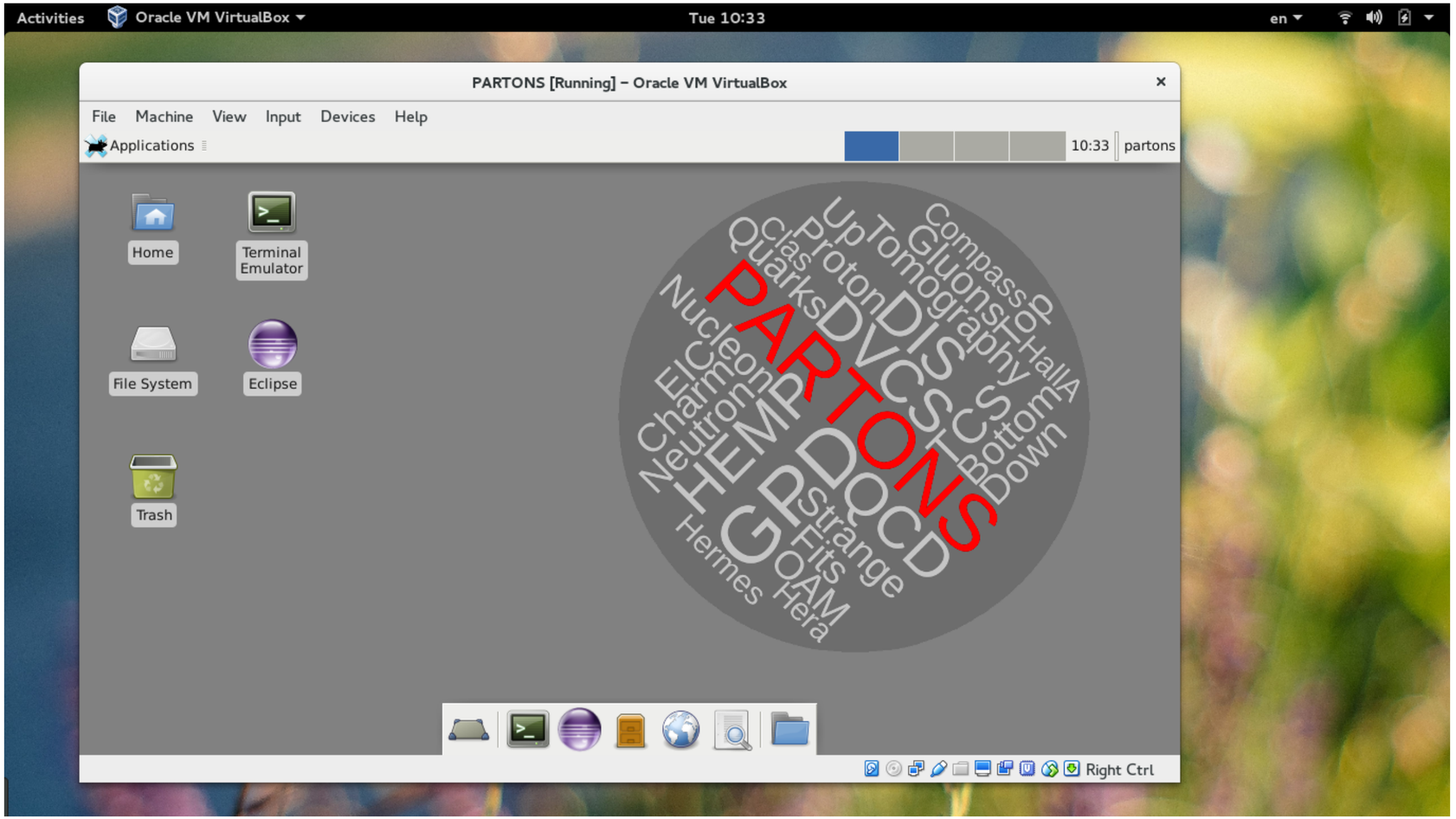
http://partons.cea.fr

For detail description of architecture see:

Eur. Phys. J. C78 (2018) 6, 478

Distribution

Compile PARTONS from scratch or use provided Virtual Machine (recommended)



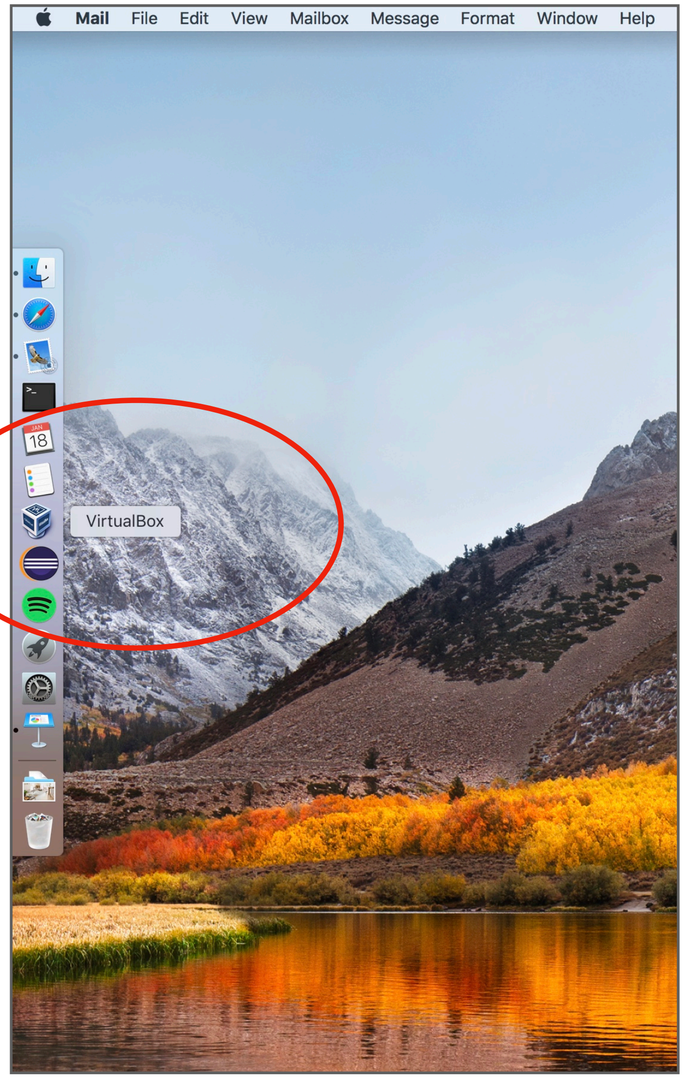
Agenda for exercise session

- run simple XML scenario
- create txt file for plotting

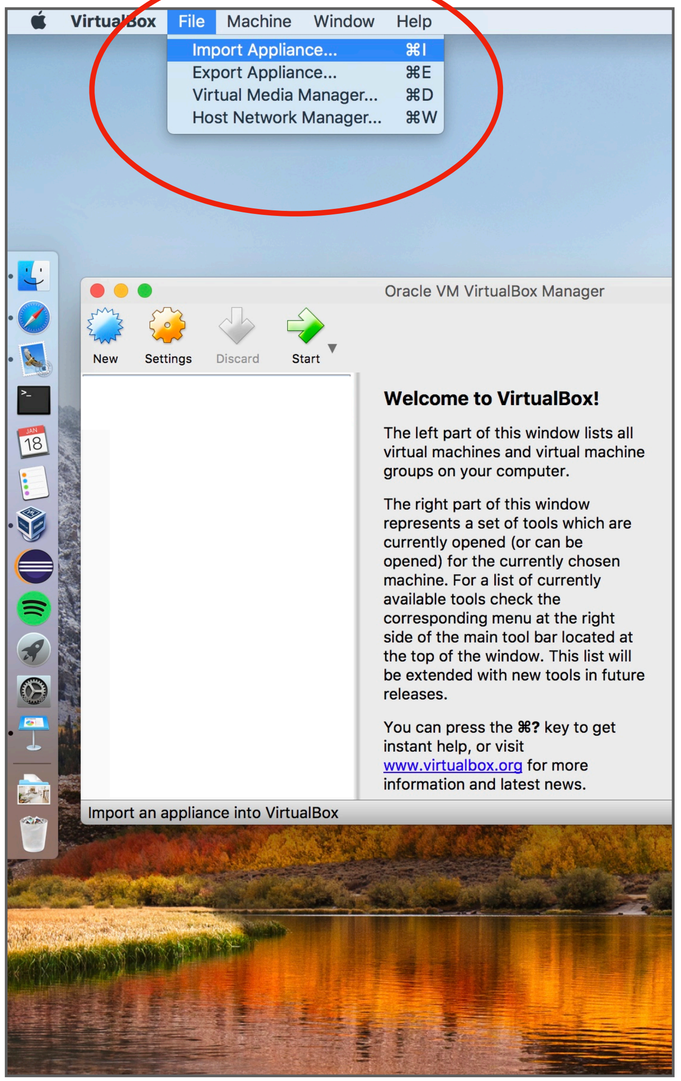
- basics of c++ “interface”
- addition of new module

Exercise - run PARTONS VM

(1) Open your VirtualBox



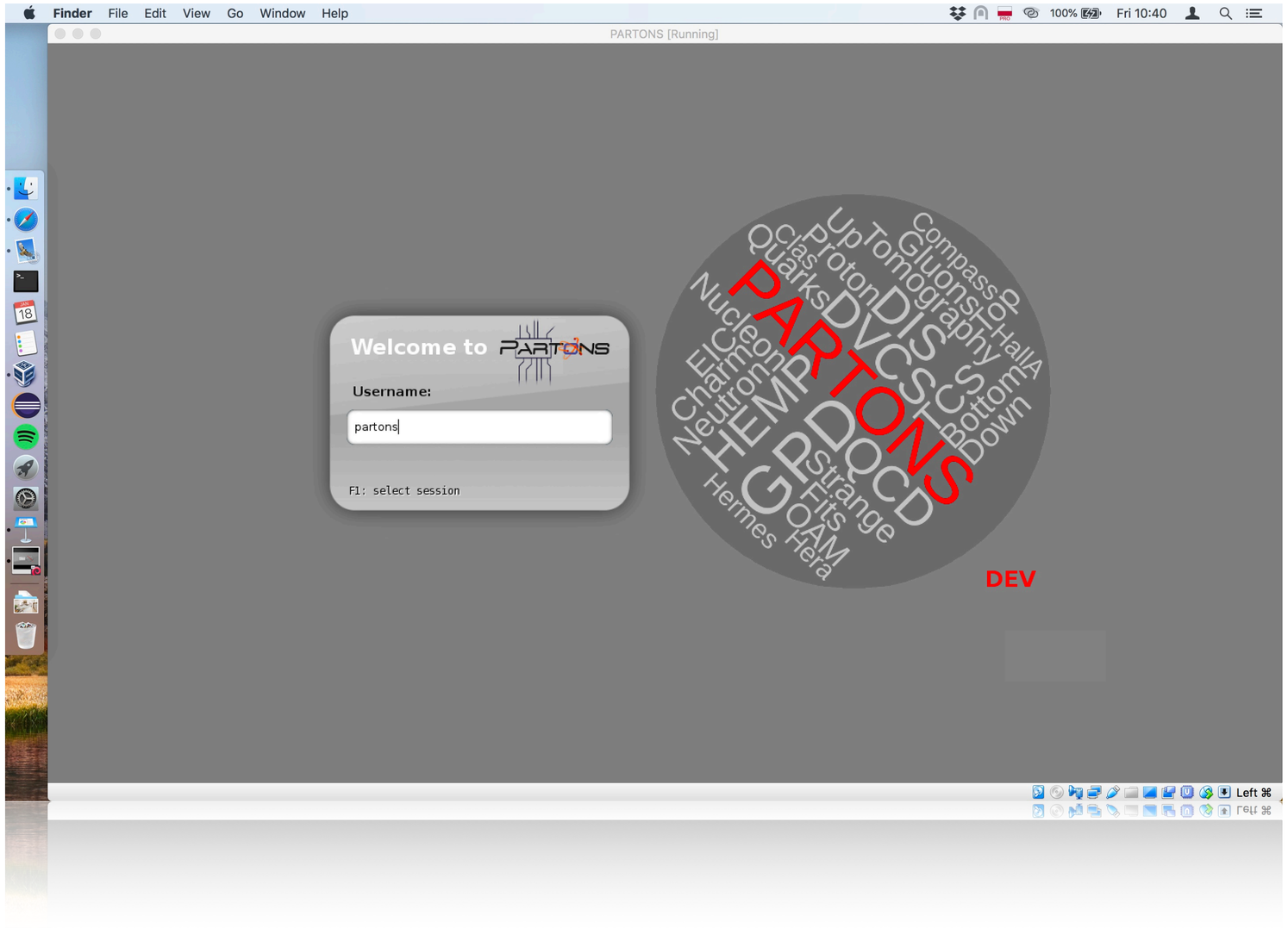
(2) Import PARTONS VM



(3) Open PARTONS VM

Exercise - run PARTONS VM

(4) Log in



Login: partons
Password: partons

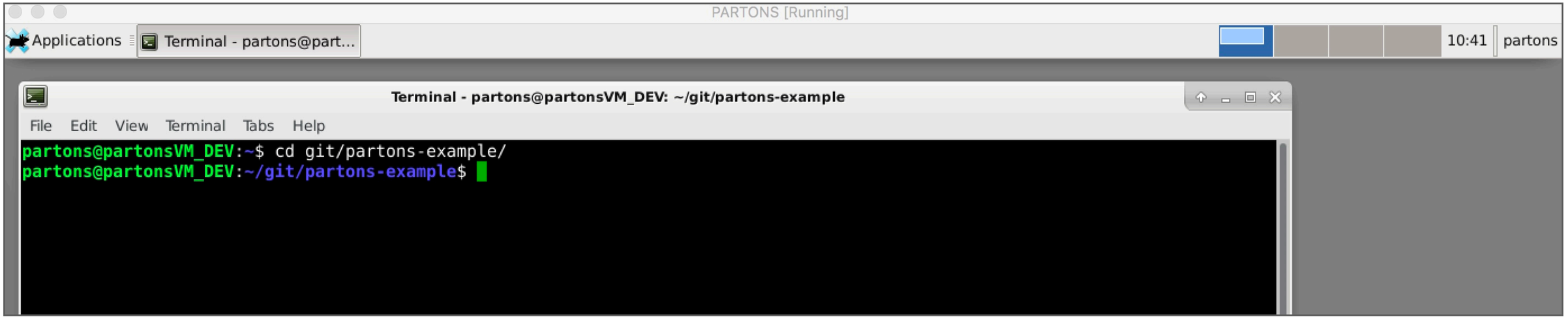
- OS of this VM is Linux/Debian 9.1
- root password to this VM is partons (useful, if you want to install your own software → apt-get)

- two versions of VM available
- user version with runtime env. (Eclipse CDT, g++, Qt, SFML, MySQL, …)
- developer version with extra dev. env. (gdb, ROOT, doxygen, …)

Exercise - run basic example

(5) Open Terminal and go to partons-example directory

```
$ cd git/partons-example
```



(6) Play scenario

```
$ ./bin/PARTONS_example data/examples/
  gpd/computeSingleKinematicsForGPD.xml
```

Exercise - what I've done?

(7) Open scenario

```
$ mousepad data/examples/gpd/computeSingleKinematicsForGPD.xml &
```

XML file

```
<?xml version="1.0" encoding="UTF-8" standalone="yes" ?>

<!--
This scenario demonstrates …
-->

<!-- Scenario starts here -->
<!-- For your convenience and for bookkeeping provide creation date and unique description -->
<scenario date="2018-01-23" description="GPD evaluation for single kinematics example">

   <!-- First task: evaluate GPD model for a single kinematics -->
   <!-- Indicate service and its methods to be used and indicate if the result should be stored
   in the database -->
   <task service="GPDService" method="computeGPDModel" storeInDB="0">

      <!-- Define GPD kinematics -->
      <kinematics type="GPDKinematic">
         <param name="x" value="0.1" />
         <param name="xi" value="0.2" />
         <param name="t" value="-0.1" />
         <param name="MuF2" value="2." />
         <param name="MuR2" value="2." />
      </kinematics>

      <!-- Define physics assumptions -->
      <computation_configuration>

         <!-- Select GPD model -->
         <module type="GPDModule" name="GPDGK16Numerical">
         </module>

      </computation_configuration>

   </task>

   <!-- Second task: print results of the last computation into standard output -->
   <task service="GPDService" method="printResults">
   </task>

</scenario>
```

terminal

```
. . .

[GPDKinematic]
m_className = GPDKinematic - m_objectId = 203 indexId = -1
m_x = 0.1 m_xi = 0.2 m_t = -0.1 m_MuF2 = 2(Gev2) m_MuR2 = 2(Gev2)
[PartonDistributionList]
GPD_H
[PartonDistribution]
m_className = PartonDistribution - m_objectId = 408 indexId = -1
GluonDistribution = 1.21356419769634
u = 5.1
u(+) = 5.01601
u(-) = 5.18398
d = 3.25071
d(+) = 3.71356
d(-) = 2.78785
s = 0.532688
s(+) = 1.06538
s(-) = 0

. . .
```

Exercise - what next?

(8) What can be done from here?

- add exact GPD evolution
  → see data/examples/other/makeUseOfGPDEvolution.xml
- change integration routine used in GPD module
  → see data/examples/other/changeIntegrationRoutine.xml

- replace single kinematics by list of kinematic points
  → see data/examples/gpd/computeManyKinematicsForGPD.xml
- create text file for 1D plot
  → see data/examples/gpd/makePlotFileFromDatabaseForGPD.xml

(9) Open scenario

```
$ mousepad data/examples/gpd/
  computeManyKinematicsForGPD.xml &
```

XML file

```
<?xml version="1.0" encoding="UTF-8" standalone="yes" ?>

<!--
This scenario demonstrates …
-->

<!-- Scenario starts here -->
<!-- For your convenience and for bookkeeping provide creation date and unique description -->
<scenario date="2018-01-23" description="GPD evaluation for single kinematics example">

   <!-- First task: evaluate GPD model for a single kinematics -->
   <!-- Indicate service and its methods to be used and indicate if the result should be stored
   in the database -->
   <task service="GPDService" method="computeManyKinematicOneModel" storeInDB="1">

      <!-- Define GPD kinematics -->
      <kinematics type="GPDKinematic">

      <!-- Path to file defining kinematics -->
         <param name="file" value="data/examples/gpd/kinematics_gpd.csv" />
      </kinematics>

      <!-- Define physics assumptions -->
      <computation_configuration>

         <!-- Select GPD model -->
         <module type="GPDModule" name="GPDGK16Numerical">
         </module>

      </computation_configuration>

   </task>

   <!-- Second task: print results of the last computation into standard output -->
   <task service="GPDService" method="printResults">
   </task>

</scenario>
```

(10) Open file with kinematic points

```
$ mousepad data/examples/gpd/
  kinematics_gpd.csv &
```

text file

```
-0.9|0.2|-0.1|2.|2.
-0.8|0.2|-0.1|2.|2.
-0.7|0.2|-0.1|2.|2.
-0.6|0.2|-0.1|2.|2.
-0.5|0.2|-0.1|2.|2.
-0.4|0.2|-0.1|2.|2.
-0.3|0.2|-0.1|2.|2.
-0.2|0.2|-0.1|2.|2.
-0.1|0.2|-0.1|2.|2.
  0.|0.2|-0.1|2.|2.
 0.1|0.2|-0.1|2.|2.
 0.2|0.2|-0.1|2.|2.
 0.3|0.2|-0.1|2.|2.
 0.4|0.2|-0.1|2.|2.
 0.5|0.2|-0.1|2.|2.
 0.6|0.2|-0.1|2.|2.
 0.7|0.2|-0.1|2.|2.
 0.8|0.2|-0.1|2.|2.
 0.9|0.2|-0.1|2.|2.
```

(11) Play scenario (result will be stored in DB)

```
$ ./bin/PARTONS_example data/examples/
  computeManyKinematicsForGPD.xml &
```

terminal

```
. . .

18-01-2019 04:58:39 [INFO] (GPDService::computeManyKinematicOneModel)
Results have been stored with computation_id = 1

. . .
```

(12) Open scenario (and play as any other one)

```
$ mousepad data/examples/gpd/
  makePlotFileFromDatabaseForGPD.xml &
```

XML file

```
<?xml version="1.0" encoding="UTF-8" standalone="yes" ?>

<!--
This scenario illustrates …
-->

<!-- Scenario starts here -->
<!-- For your convenience and for bookkeeping provide creation date and unique description -->
<scenario date="2019-01-23" description="Get GPD result from database">

   <!-- Task: generate file with data matching indicated criteria -->
   <task service="GPDService" method="generatePlotFile">

      <!-- Variables selected to be stored in the output file -->
      <task_param type="select">
         <param name="xPlot" value="x" />
         <param name="yPlot" value="quark_distribution" />
      </task_param>

      <!-- Applied requirements -->
      <task_param type="where">
         <param name="computation_id" value="1" />
         <param name="gpd_type_short_name" value="H" />
         <param name="quark_flavor_short_name" value="u" />
      </task_param>

      <!-- Path to the output file -->
      <task_param type="output">
         <param name="filePath" value="output.dat" />
      </task_param>
   </task>
</scenario>
```

(13) Open file with kinematic points

```
$ mousepad output.dat &
```

text file

```
-0.9    -9.08563583105145e-07
-0.8    -4.43918240093008e-05
-0.7    -0.000467371293683796
-0.6    -0.00260782941003755
-0.5    -0.0103670654791854
-0.4    -0.0340508850674199
-0.3    -0.104012279739543
-0.2    -0.400055115045195
-0.1     0.0839847034256669
  0      2.9565855609031
0.1      5.09999881970055
0.2      3.64307713422744
0.3      2.09945473777934
0.4      1.25081754859321
0.5      0.701862636656223
0.6      0.352627698561263
0.7      0.147010013190538
0.8      0.0432378242375268
0.9      0.0053805450793825
```

Exercise - evaluate observable

(14) Open scenario (and play as any other one)

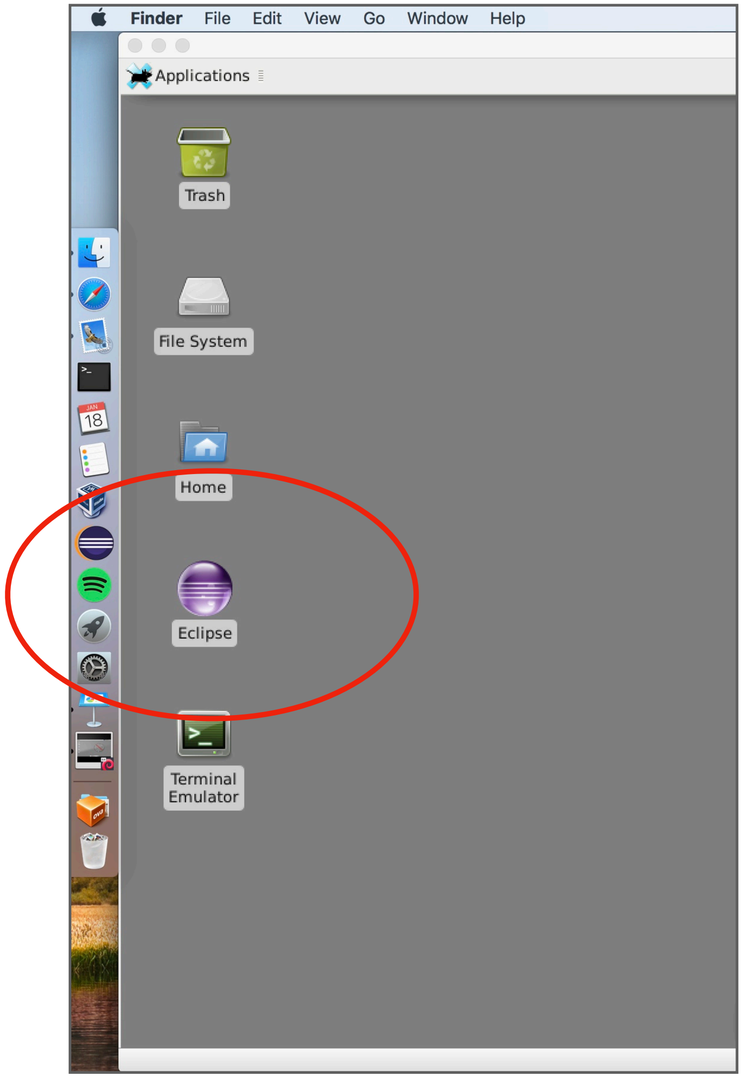
```
$ mousepad data/examples/observable/
  computeSingleKinematicsForDVCSObservable.xml &
```

XML file

```
<?xml version="1.0" encoding="UTF-8" standalone="yes" ?>

<!--
This scenario demonstrates …
-->

<!-- Scenario starts here -->
<!-- For your convenience and for bookkeeping provide creation date and unique
description -->
<scenario date="2019-01-23" description="DVCS observable evaluation for single
kinematics example">

   <!-- First task: evaluate DVCS observable for a single kinematics -->
   <!-- Indicate service and its methods to be used and indicate if the result
   should be stored in the database -->
   <task service="ObservableService" method="computeObservable" storeInDB="0">

      <!-- Define DVCS observable kinematics -->
      <kinematics type="ObservableKinematic">
         <param name="xB" value="0.2" />
         <param name="t" value="-0.1" />
         <param name="Q2" value="2." />
         <param name="E" value="6." />
         <param name="phi" value="20." />
      </kinematics>

      <!-- Define physics assumptions -->
      <computation_configuration>

         <!-- Select DVCS observable -->
         <module type="Observable" name="DVCSAllMinus">

            <!-- Select DVCS process model -->
            <module type="ProcessModule" name="DVCSProcessBMJ12">

               <!-- Select scales module -->
               <!-- (it is used to evaluate factorization and renormalization
               scales out of kinematics) -->
               <module type="ScalesModule" name="ScalesQ2Multiplier">

                  <!-- Configure this module -->
                     <param name="lambda" value="1." />
                  </module>

                  <!-- Select xi-converter module -->
                  <!-- (it is used to evaluate GPD variable xi out of kinematics) -->
                  <module type="XiConverterModule" name="XiConverterXBToXi">
                  </module>

                  <!-- Select DVCS CFF model -->
                  <module type="ConvolCoeffFunctionModule" name="DVCSCFFStandard">

                     <!-- Indicate pQCD order of calculation -->
                     <param name="qcd_order_type" value="NLO" />

                     <!-- Select GPD model -->
                     <module type="GPDModule" name="GPDGK16Numerical">
                     </module>

                  </module>

               </module>

            </module>

         </computation_configuration>

      </task>

      <!-- Second task: print results of the last computation into standard
      output -->
      <task service="ObservableService" method="printResults">
      </task>

   </scenario>
```

Exercise - c++ “interface” - Eclipse

(15) Open Eclipse



Why Eclipse? (and not e.g. vim):

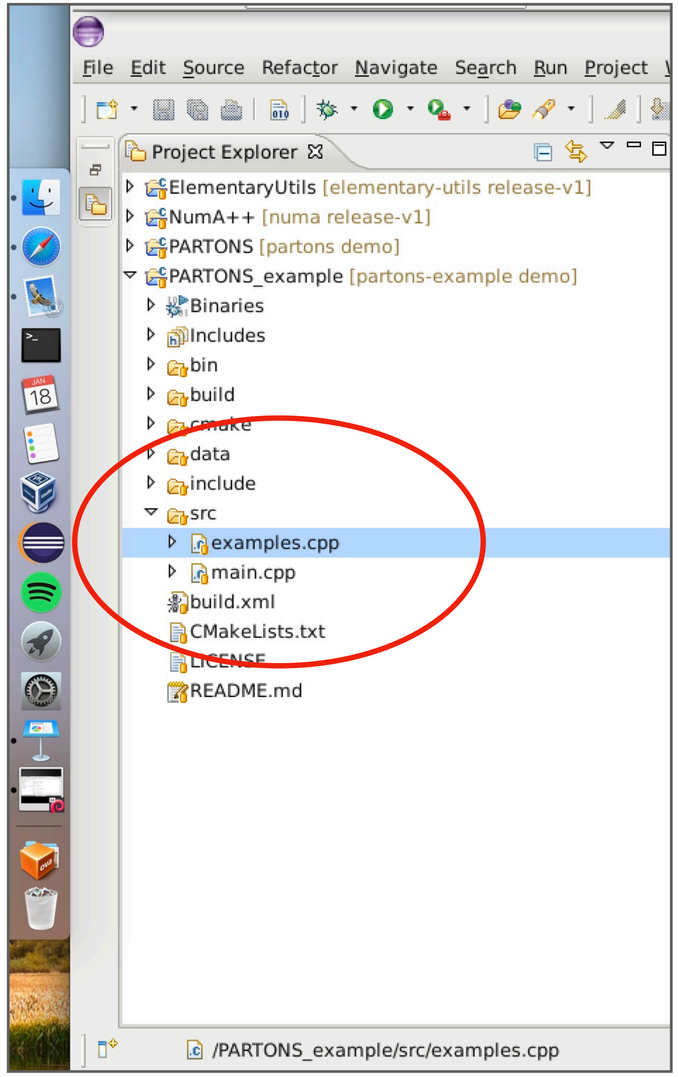
- very convenient for large projects
- the same env. for all developers
- in-flight error detection
- you can run PARTONS via Eclipse (also in debugging mode)
- git manager

Tips (for Linux):

- toggle between header and src files → ctrl + tab
- goto a given element → ctrl + left click
- auto-completion → ctrl + space
- auto-formatting of code → ctrl + shift + f
- auto-organisation of includes → ctrl + shift + o

Exercise - c++ “interface” - PARTONS_example/src/examples.cpp

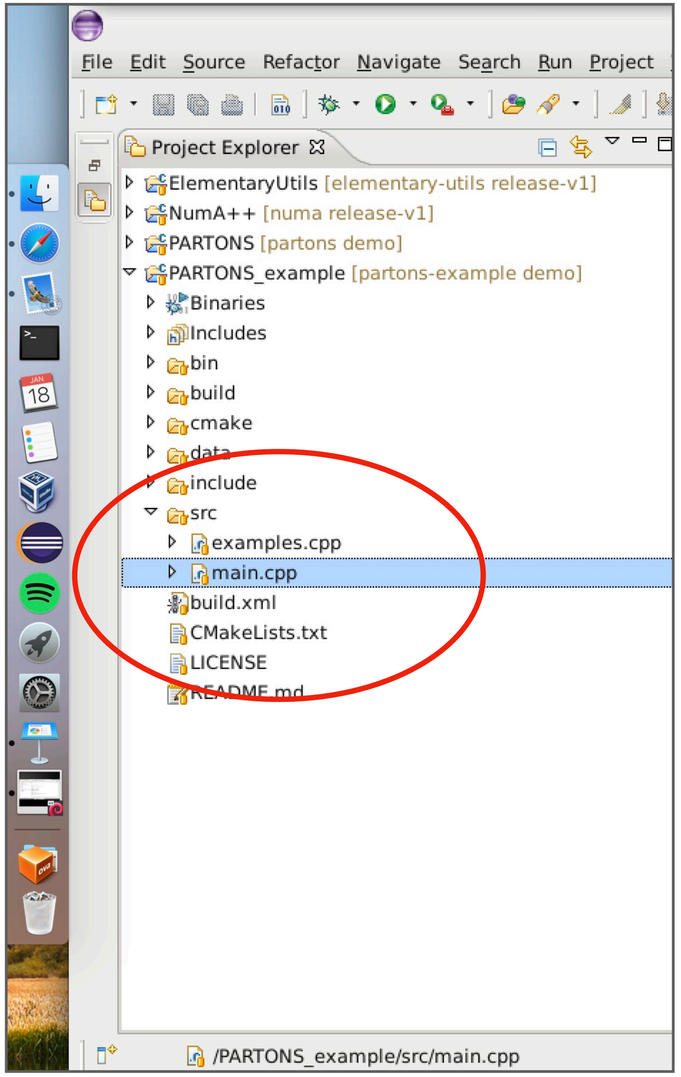
(16) Open examples.cpp in Eclipse




```
void computeSingleKinematicsForGPD() {

    // Retrieve GPD service
    PARTONS::GPDService* pGPDService =
            PARTONS::Partons::getInstance()->getServiceObjectRegistry()->getGPDService();

    // Create GPD module with the BaseModuleFactory
    PARTONS::GPDModule* pGPDModel =
            PARTONS::Partons::getInstance()->getModuleObjectFactory()->newGPDModule(
                    PARTONS::GPDGK16Numerical::classId);

    // Create a GPDKinematic(x, xi, t, MuF2, MuR2) to compute
    PARTONS::GPDKinematic gpdKinematic(0.1, 0.2, -0.1, 2., 2.);

    // Run computation
    PARTONS::GPDResult gpdResult = pGPDService->computeGPDModel(gpdKinematic,
            pGPDModel);

    // Print results
    PARTONS::Partons::getInstance()->getLoggerManager()->info("main", __func__,
            gpdResult.toString());

    // Remove pointer references
    // Module pointers are managed by PARTONS
    PARTONS::Partons::getInstance()->getModuleObjectFactory()->updateModulePointerReference(
            pGPDModel, 0);
    pGPDModel = 0;
}

void computeManyKinematicsForGPD() {

    // Retrieve GPD service
    PARTONS::GPDService* pGPDService =
            PARTONS::Partons::getInstance()->getServiceObjectRegistry()->getGPDService();

    // Create GPD module with the BaseModuleFactory
    PARTONS::GPDModule* pGPDModel =
            PARTONS::Partons::getInstance()->getModuleObjectFactory()->newGPDModule(
```

Exercise - c++ “interface” - PARTONS_example/src/main.cpp

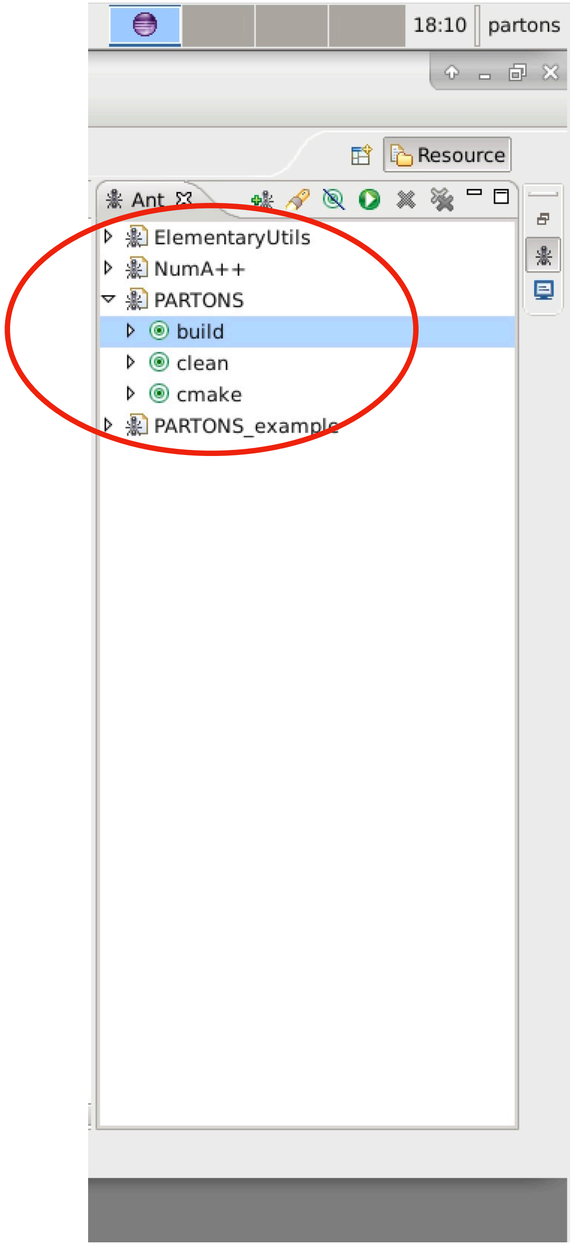
(17) Open main.cpp in Eclipse




```
        // ******************************************************
        // RUN XML SCENARIO *************************************
        // ******************************************************

        // You need to provide at least one scenario via executable argument
        if (argc <= 1) {

            throw ElemUtils::CustomException("main", __func__,
                    "Missing argument, please provide one or more than one XML scenario file.");
        }

        // Parse arguments to retrieve xml file path list.
        std::vector<std::string> xmlScenarioFilePathList = parseArguments(argc,
                argv);

        // Retrieve automation service parse scenario xml file and play it.
        PARTONS::AutomationService* pAutomationService =
                pPartons->getServiceObjectRegistry()->getAutomationService();

        for (unsigned int i = 0; i < xmlScenarioFilePathList.size(); i++) {
            PARTONS::Scenario* pScenario = pAutomationService->parseXMLFile(
                    xmlScenarioFilePathList[i]);
            pAutomationService->playScenario(pScenario);
        }

        // ******************************************************
        // RUN CPP CODE *****************************************
        // ******************************************************

        // You can put your own code here and build a stand-alone program based on PARTONS library.
        // To learn how you can use PARTONS library study provided examples of functions to be found in
        // include/examples.h (header) and src/examples.cpp (source) files.
        // To run these examples just call them here, e.g.:

        // computeSingleKinematicsForGPD();

        // Note, that you may need to comment out the part responsible for the running of XML scenarios.

    }
```

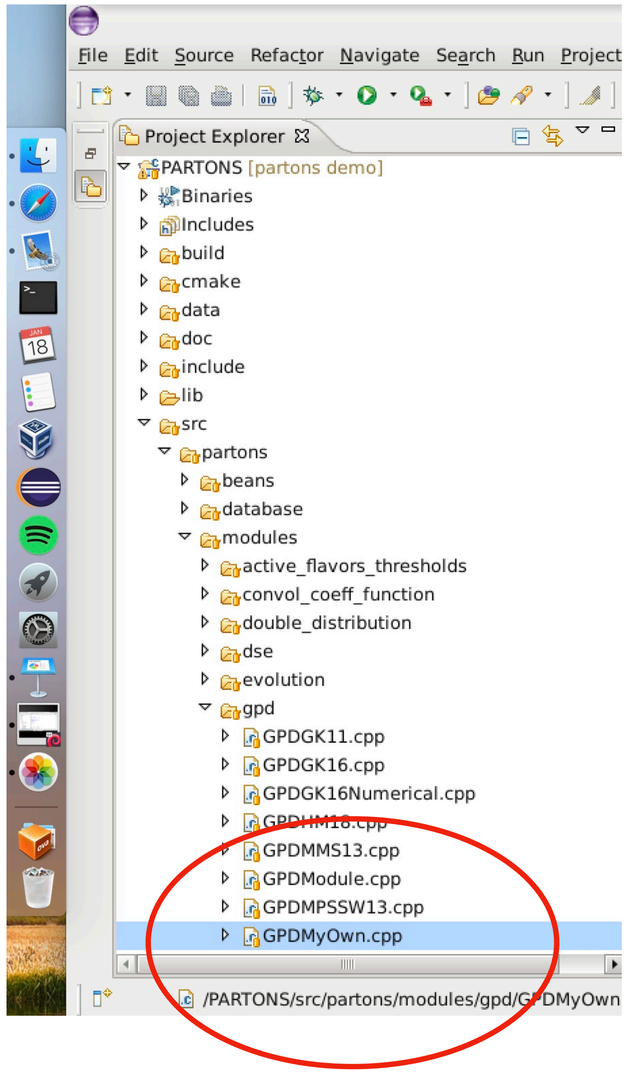
Exercise - c++ “interface” - compilation

- We use Ant to manage all build tasks
- You will find Ant icon on the right side of the Eclipse window
- For execution double click on a given task name



Exercise - c++ “interface” - PARTONS/src/partons/modules/gpd/GPDMyOwn.cpp

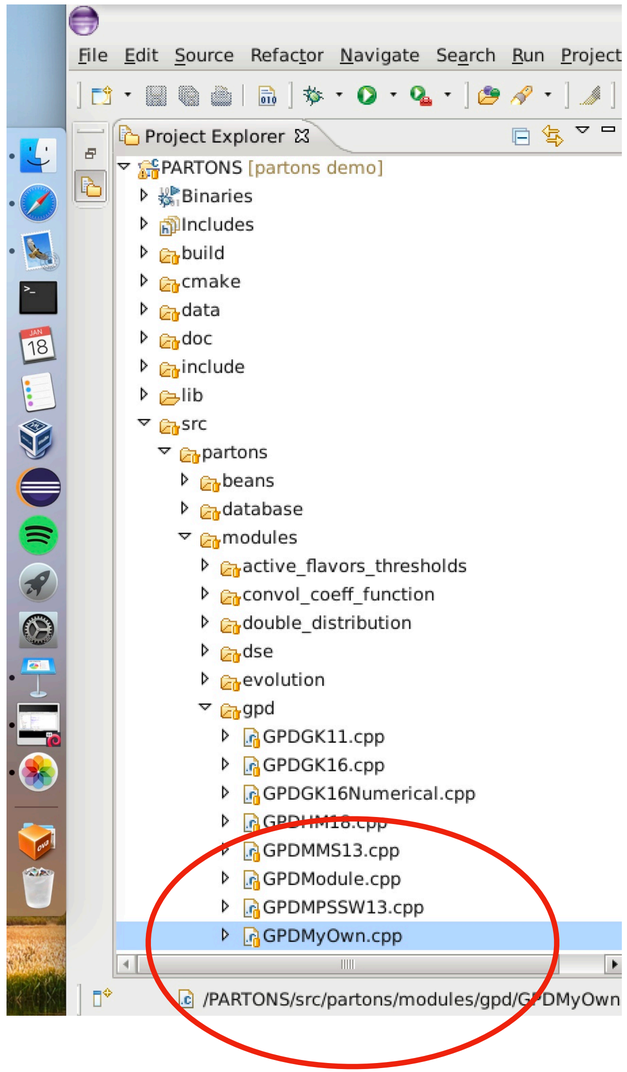
(18) Open GPDMyOwn.cpp in Eclipse




```cpp
const unsigned int GPDMyOwn::classId =
        BaseObjectRegistry::getInstance()->registerBaseObject(
                new GPDMyOwn("GPDMyOwn"));

GPDMyOwn::GPDMyOwn(const std::string &className) :
        GPDModule(className) {

    m_MuF2_ref = 4.;

    m_listGPDComputeTypeAvailable.insert(
            std::make_pair(GPDType::H, &GPDModule::computeH));

    m_listGPDComputeTypeAvailable.insert(
            std::make_pair(GPDType::E, &GPDModule::computeE));
}
```

Exercise - c++ “interface” - PARTONS/src/partons/modules/gpd/GPDMyOwn.cpp

(18) Open GPDMyOwn.cpp in Eclipse




```cpp
PartonDistribution GPDMyOwn::computeH() {

    //variables to be used:
    //m_x, m_xi, m_t, m_MuF2, m_MuR2

    //store
    QuarkDistribution quarkDistribution_u(QuarkFlavor::UP);
    QuarkDistribution quarkDistribution_d(QuarkFlavor::DOWN);
    QuarkDistribution quarkDistribution_s(QuarkFlavor::STRANGE);

    quarkDistribution_u.setQuarkDistribution(3.);
    quarkDistribution_d.setQuarkDistribution(4.);
    quarkDistribution_s.setQuarkDistribution(5.);

    quarkDistribution_u.setQuarkDistributionPlus(1.);
    quarkDistribution_d.setQuarkDistributionPlus(2.);
    quarkDistribution_s.setQuarkDistributionPlus(3.);

    quarkDistribution_u.setQuarkDistributionMinus(5.);
    quarkDistribution_d.setQuarkDistributionMinus(6.);
    quarkDistribution_s.setQuarkDistributionMinus(7.);

    GluonDistribution gluonDistribution(10.);

    PartonDistribution partonDistribution;

    partonDistribution.setGluonDistribution(gluonDistribution);
    partonDistribution.addQuarkDistribution(quarkDistribution_u);
    partonDistribution.addQuarkDistribution(quarkDistribution_d);
    partonDistribution.addQuarkDistribution(quarkDistribution_s);

    //return
    return partonDistribution;
}
```