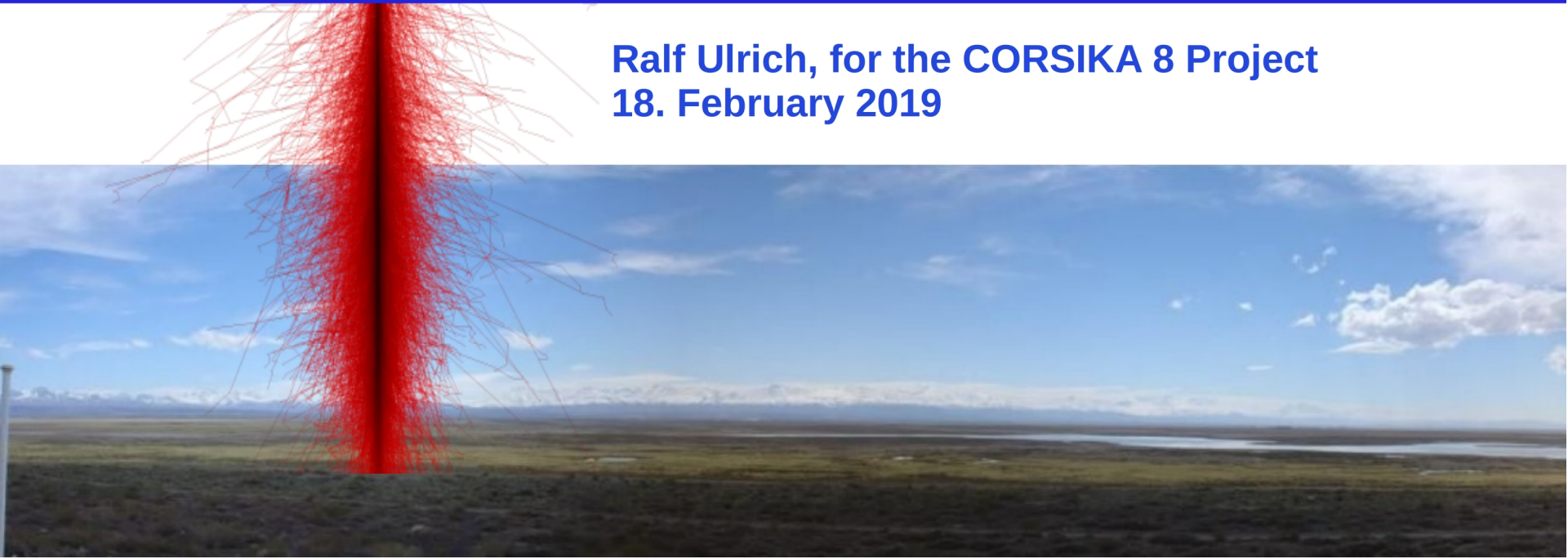
2nd CORSIKA 8 Focus Week

Simulating particle cascades for astroparticle physics

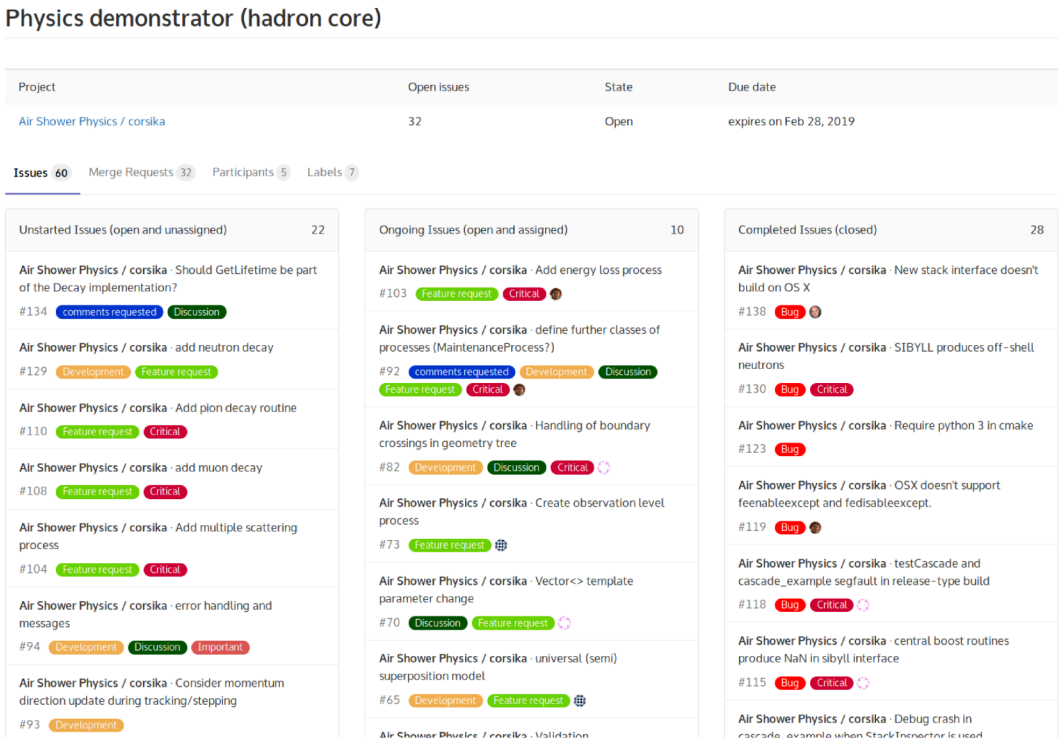
Ralf Ulrich, for the CORSIKA 8 Project

18. February 2019



Main goal this week

- **Milestone „hadron-core physics demonstrator“** (link)
  - 61% complete today
  - Decide today, what we want to include and what to shift to future release
  - Work on missing functionality
- **Discussing and planning next steps.**



Physics demonstrator (hadron core)

Project	Open issues	State	Due date
Air Shower Physics / corsika	32	Open	expires on Feb 28, 2019

Issues 60 | Merge Requests 32 | Participants 5 | Labels 7

Unstarted Issues (open and unassigned) 22

- **Air Shower Physics / corsika** · Should GetLifetime be part of the Decay implementation? #134 comments requested, Discussion
- **Air Shower Physics / corsika** · add neutron decay #129 Development, Feature request
- **Air Shower Physics / corsika** · Add pion decay routine #110 Feature request, Critical
- **Air Shower Physics / corsika** · add muon decay #108 Feature request, Critical
- **Air Shower Physics / corsika** · Add multiple scattering process #104 Feature request, Critical
- **Air Shower Physics / corsika** · error handling and messages #94 Development, Discussion, Important
- **Air Shower Physics / corsika** · Consider momentum direction update during tracking/stepping #93 Development

Ongoing Issues (open and assigned) 10

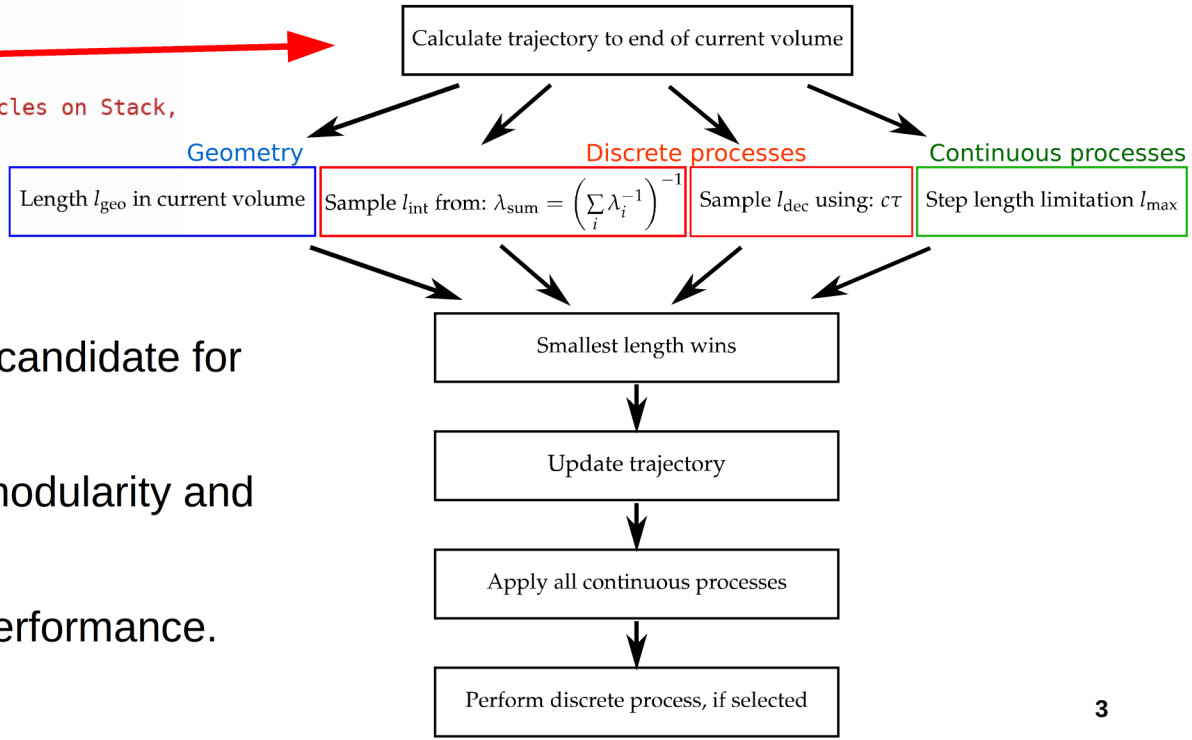
- **Air Shower Physics / corsika** · Add energy loss process #103 Feature request, Critical
- **Air Shower Physics / corsika** · define further classes of processes (MaintenanceProcess?) #92 comments requested, Development, Discussion, Feature request, Critical
- **Air Shower Physics / corsika** · Handling of boundary crossings in geometry tree #82 Development, Discussion, Critical
- **Air Shower Physics / corsika** · Create observation level process #73 Feature request
- **Air Shower Physics / corsika** · Vector<> template parameter change #70 Discussion, Feature request
- **Air Shower Physics / corsika** · universal (semi) superposition model #65 Development, Feature request
- **Air Shower Physics / corsika** · Validation

Completed Issues (closed) 28

- **Air Shower Physics / corsika** · New stack interface doesn't build on OS X #138 Bug
- **Air Shower Physics / corsika** · SIBYLL produces off-shell neutrons #130 Bug, Critical
- **Air Shower Physics / corsika** · Require python 3 in cmake #123 Bug
- **Air Shower Physics / corsika** · OSX doesn't support feenableexcept and fedisableexcept. #119 Bug
- **Air Shower Physics / corsika** · testCascade and cascade_example segfault in release-type build #118 Bug, Critical
- **Air Shower Physics / corsika** · central boost routines produce NaN in sibyll interface #115 Bug, Critical
- **Air Shower Physics / corsika** · Debug crash in cascade_example when StackInspector is used

Spotlight on a few solutions: internal main loop

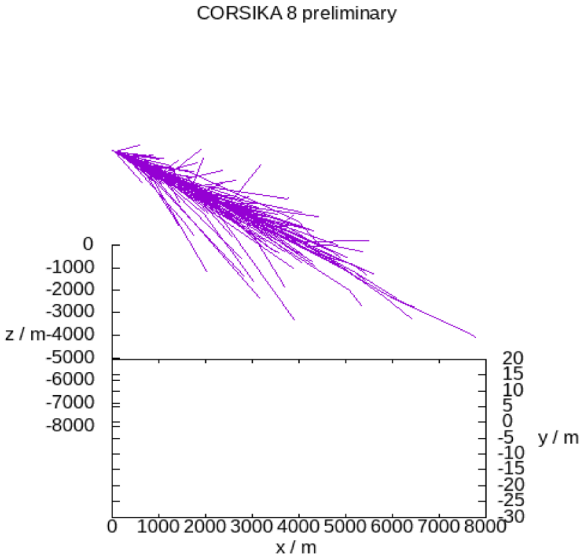
```
void Run() {
  while (!fStack.IsEmpty()) {
    while (!fStack.IsEmpty()) {
      auto pNext = fStack.GetNextParticle();
      Step(pNext);
    }
    // do cascade equations, which can put new particles on Stack,
    // thus, the double loop
    // DoCascadeEquations();
  }
}
```



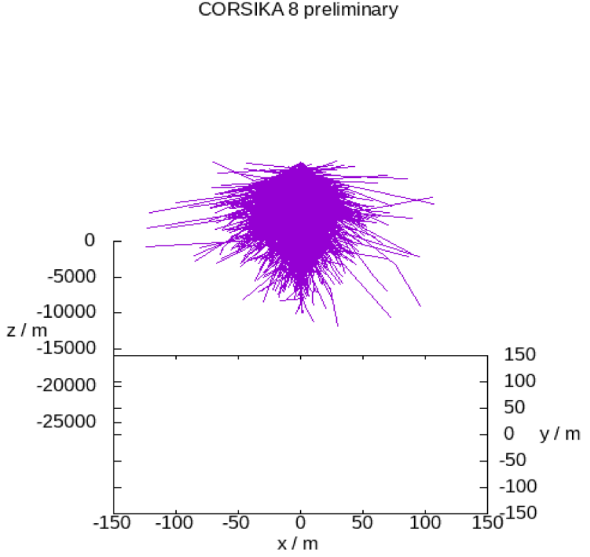
- As expected CORSIKA is ideal candidate for very clear framework structure
- This should result in excellent modularity and flexibility
- as well as high efficiency and performance.

First results

Proton primary, 100TeV, 45deg



Iron primary, 1PeV, 0deg



…

```
auto sequence = sibyll << sibyllNuc << decay << cut << trackWriter;
cascade::Cascade EAS(environment, tracking, sequence, stack);
EAS.Init();
EAS.Run();
```

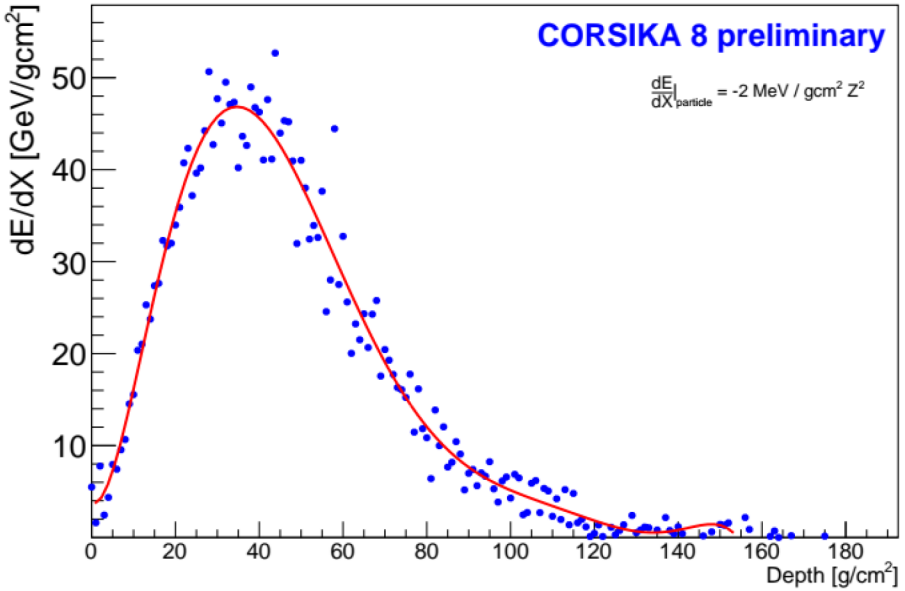
Spotlight on a few solutions: physics process

Demonstration of how to add additional physics into the cascade:

$$\frac{\mathrm{d}E}{\mathrm{d}X} = -2\,\mathrm{MeV\,g/cm^2}\,Z^2$$

```
class EnergyLoss : public process::ContinuousProcess<EnergyLoss> {

  MeVgcm2 fdEdX;

public:
  EnergyLoss(MeVgcm2 const vdEdX)
    : fdEdX(vdEdX) {}

  process::EProcessReturn DoContinuous(Particle& vP, Track& vT, Stack&) {
    GrammageType const dX =
      vP.GetNode()->GetModelProperties().IntegratedGrammage(vT, vT.GetLength());
    HEPEnergyType dE = -dX * fdEdX * pow(vP.GetChargeNumber(), 2);
    vP.SetEnergy(vP.GetEnergy() + dE);
    MomentumUpdate(vP);
    FillHistogram(vP, dE);
    return process::EProcessReturn::eOk;
  }

  void MomentumUpdate(corsika::setup::Stack::ParticleType& vP) {
    HEPMomentumType Pnew = elab2plab(vP.GetEnergy(), vP.GetParticleMass());
    auto pnew = vP.GetMomentum();
    vP.SetMomentum(pnew * Pnew / pnew.GetNorm());
  }
};
```

First ~longitudinal profile



…

```
auto sequence = sibyll << sibyllNuc << decay << EnergyLoss(2_MeV/1_g*square(1_cm)) << cut << trackWriter;
cascade::Cascade EAS(env, tracking, sequence, stack);
EAS.Init();
EAS.Run();
```

Upcoming steps

- 2nd CORSIKA 8 Focus Week: **18. - 22. February 2019**

	10th - 14th June	17th - 21st June	1st - 5th July	8th - 12th July	15th - 19th July
8 participants +	✓4	✓8	✓6	✓5	✓4
Maximilian Reining...		✓	✓		
felix		✓			
Tim Huege, KIT	✓	✓	✓	✓	
Johan Bregeon, LUPM		✓	✓	✓	✓
Dieter Heck	✓	✓	✓	✓	✓
Lukas Nellen		✓			
Ralf Ulrich, KIT	✓	✓	✓	✓	✓
Ralf Ulrich, KIT	✓	✓	✓	✓	✓

- Release of hadron core physics demonstrator: **February 2019**
- Next general workshop: **17-21 June 2019**
- Release of ICRC 2019 version: **June 2019**
- **ICRC 2019**: 4 contributions (2 oral, 2 poster) for the CORSIKA 8 project, plus several related contributions
- **~end of 2019**: consolidation discussion and steps towards physics release

Main challenges ahead

- Continue to build a worldwide collaboration around CORSIKA 8
  - Plan next technical journal articles, think about first physics articles
- Run-time configuration infrastructure
- Particle data output interface and definition
- Logging, also for parallel runs etc.
- Full physics implementation: hadrons plus mu/e/gamma
- Physics validation
- Seamless integration of cascade equations
- Profiling, optimization, vectorization and multi-threading solutions where useful

…. and many more