Welcome to the workshop

Sven-Olaf Moch

Universität Hamburg

MITP workshop *Heavy-Quark Hadro Production from Collider to Astroparticle Physics*, Mainz, Sep 30, 2019

MITP workshop

- **Heavy-Quark Hadro Production from Collider to Astroparticle Physics**
  two weeks from September 30 to October 11, 2019

- Organizers
  - **Ralph Engel** *KIT*
  - **Maria Vittoria Garzelli** *Universität Tübingen & Universitá degli Studie die Firenze*
  - **Sven-Olaf Moch** *Universität Hamburg*

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- Compared to previous MITP programs we are a very interdisciplinary workshop
- Maybe, participants (you!) can hear talks on things that are completely new to them

Atmospheric leptons

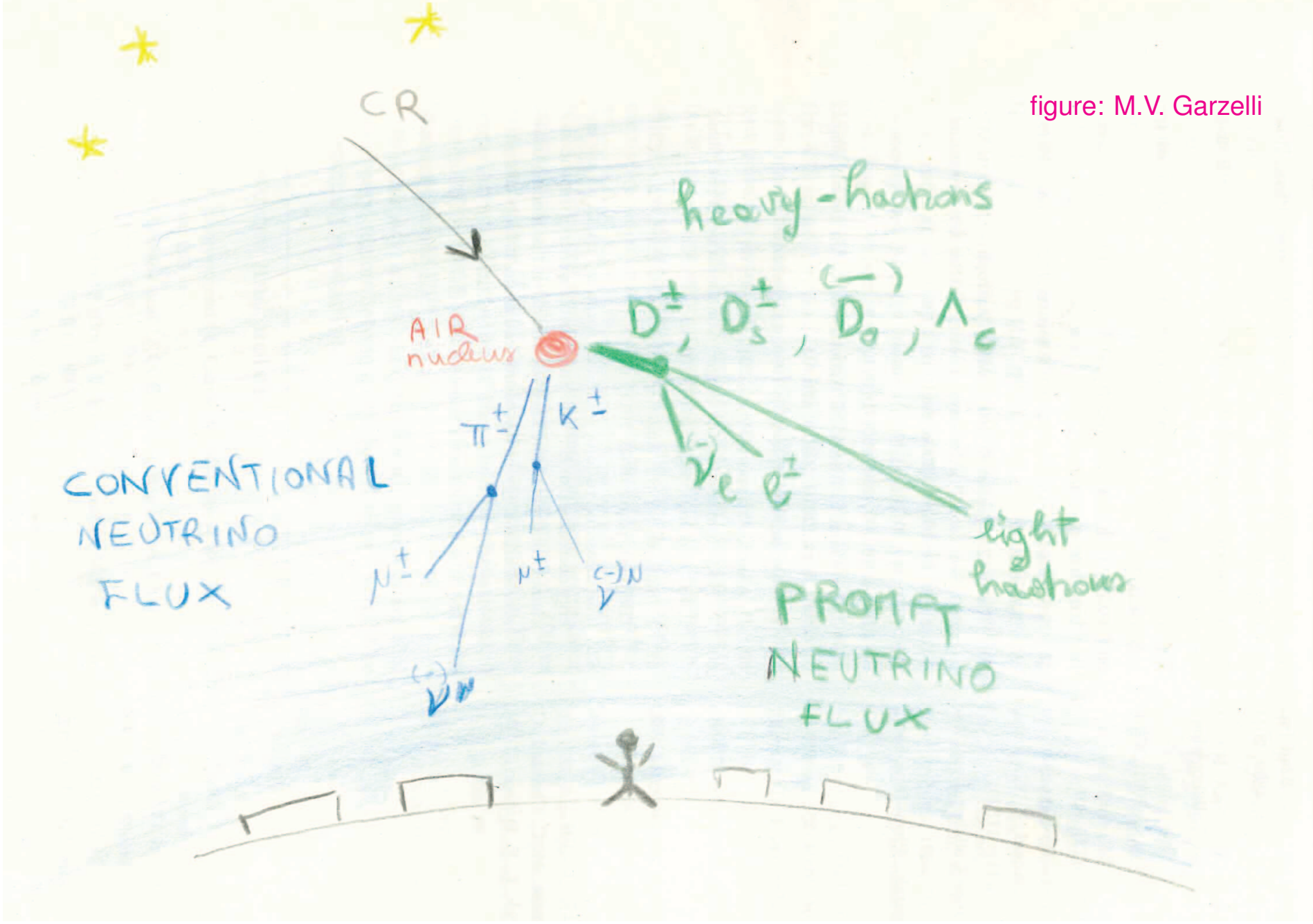
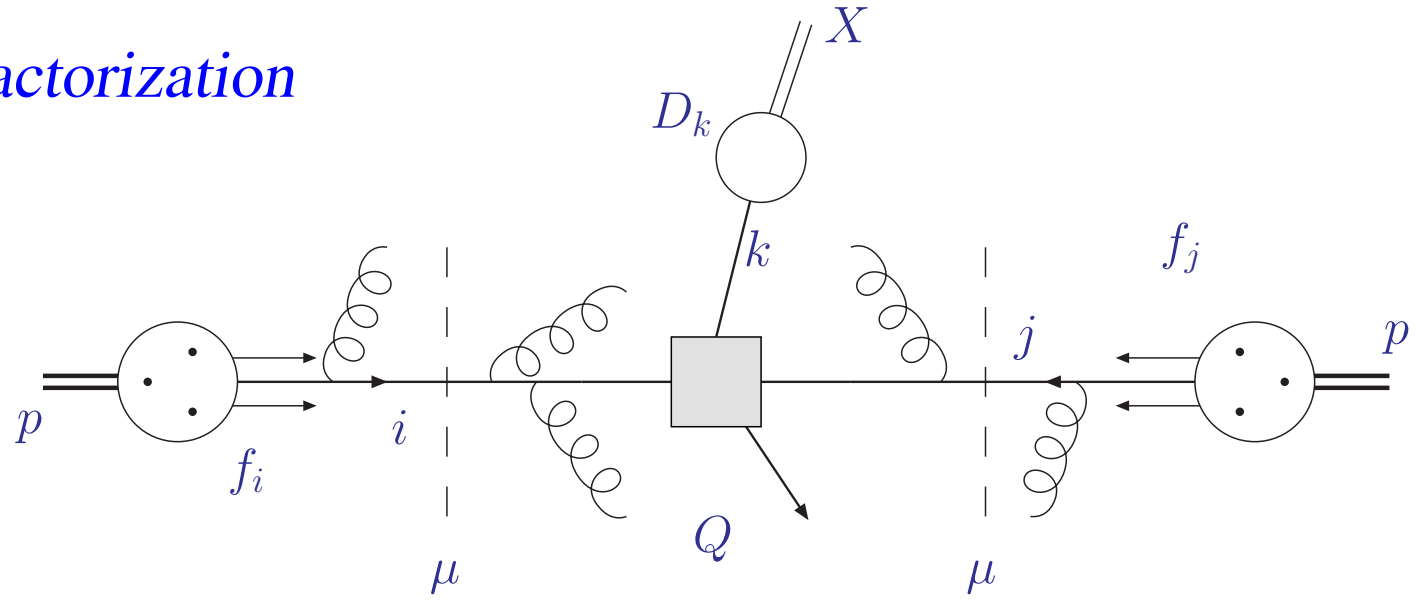


figure: M.V. Garzelli

Charm quark hadro-production

- Perturbative charm production contributes to prompt atmospheric neutrino flux

QCD factorization



$$\sigma_{pp\to X} = \sum_{ij} f_i(\mu^2) \otimes f_j(\mu^2) \otimes \hat{\sigma}_{ij\to X}\left(\alpha_s(\mu^2), Q^2, \mu^2, m_X^2\right)$$

- Hard parton cross section $\hat{\sigma}_{ij\to X}$ calculable in perturbation theory
  - cross section $\hat{\sigma}_{ij\to k}$ for parton types i, j and hadronic final state X
- Non-perturbative parameters: parton distribution functions f_i, fragmentation functions D_k, strong coupling α_s, particle masses m_X

Parton luminosity

- Long distance dynamics due to proton structure

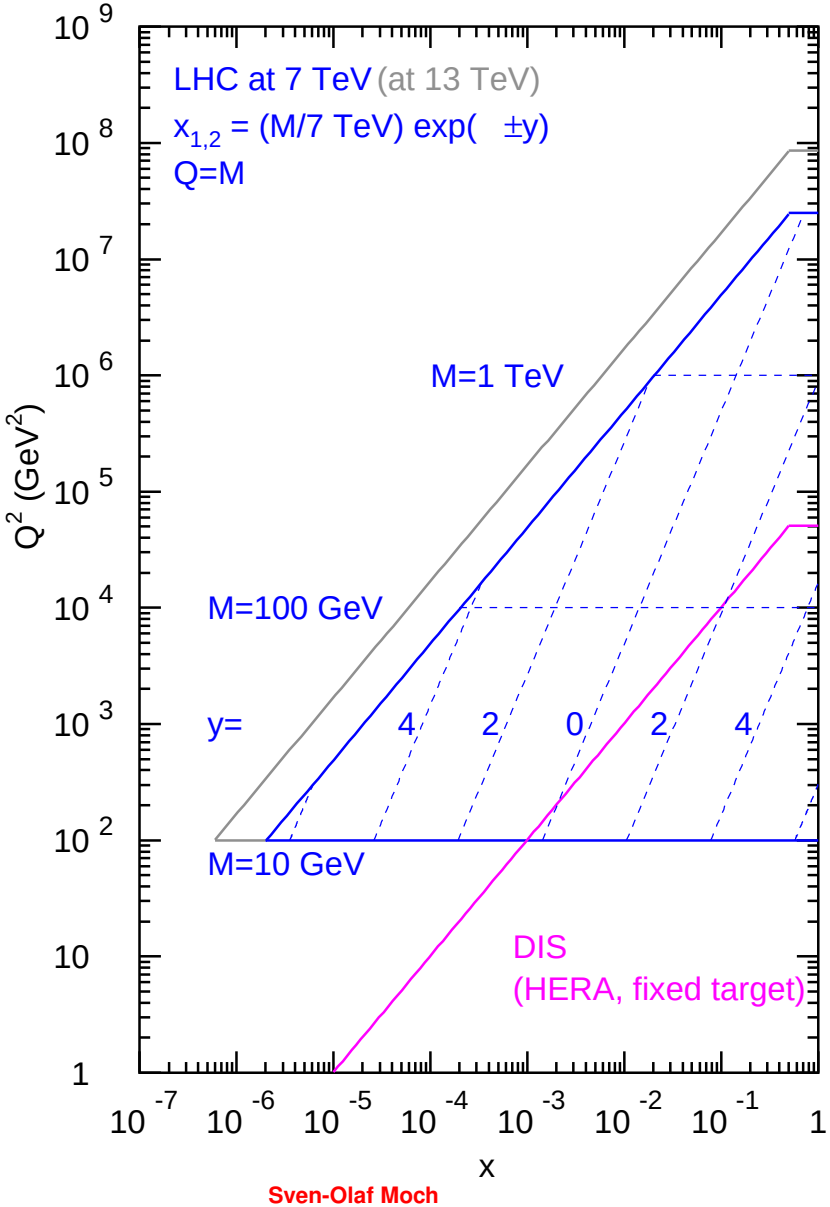
- Cross section depends on parton distributions f_i

$$\sigma_{pp\to X} = \sum_{ij} f_i(\mu^2) \otimes f_j(\mu^2) \otimes \left[\dots\right]$$

  - convolution of parton distributions
  - small-x part of f_i and large-x PDFs f_j
- Parton distributions in proton known from global fits to exp. data
  - high precision analysis to NNLO in QCD
  - information on proton structure depends on kinematic coverage

Parton kinematics

- Current kinematic coverage of proton structure driven by LHC



- LHC run at $\sqrt{s}$ = 7, 8 and 13 TeV
  - parton kinematics well covered by HERA and fixed target experiments
- Parton kinematics with $x_{1,2} = M/\sqrt{S}\mathrm{e}^{\pm y}$
  - forward rapidities sensitive to small-x
- Proton and neutron PDFs related by isospin symmetry
  - use $p \simeq n \simeq N$ at high-energies (small-x)

Week 1

- Monday

  M. Masip *Charm and muons in extensive air showers*

  F. Riehn *Heavy-quark production and further recent developments in SIBYLL*

  T. Pierog *Heavy-quark production and further recent developments in EPOS*

  S. Ostapchenko *Heavy-quark degrees of freedom, and further recent developments in QGSJET*

- Tuesday

  R. Ulrich *Measurements at accelerators particularly useful for High-Energy Astroparticle Physics: from fixed-target experiments to colliders*

  S. Turchikhin *Heavy-flavour production + selected news on forward physics in ATLAS*

  A. Grelli *Heavy-flavour production + selected news on forward physics in ALICE*

  A. Bursche *Heavy-flavour production + selected news on forward physics in LHCb*

- Wednesday

  C. Schwinn *Soft gluon and Coulomb resummation for top-quark pair production at hadron colliders*

  A. Broggio *Resummation techniques for heavy-quark production and Dark Matter annihilation*

Week 1 (cont'd)

- Thursday

  R. Coniglione *The KM3NeT and ANTARES Neutrino Telescopes: capabilities and issues at the highest energies*

  R. Gauld *Neutrino scattering at multi-TeV and PeV energies*

  A. Geiser *Heavy-flavour production in CMS + outlook on a combined treatment of heavy flavour measurements at HERA, LHC and elsewhere*

- Friday

  S. Plätzer *Heavy-flavour treatment in parton showers and (parton shower + hadronization) effects on heavy-quark hadroproduction*

  F. Prino *Phenomenological models of heavy-quark transport in Quark Gluon Plasma*

Week 2

- Monday

  M.-H. Reno, P.Lipari *Summary of Week 1*

  T. Gaisser/A. Fedynitch *Atmospheric fluxes and prompt neutrinos in IceCube*

  L. Fusco *Results on atmospheric fluxes and prompt neutrinos in ANTARES/Km3Net*

  C. Mascaretti *How can we disentangle prompt neutrinos from other components at neutrino telescopes? Comparison of theory predictions with experimental data*

- Tuesday

  O. Zenaiev *Constraints from heavy-quark production on proton PDF fits*

  S. Kulagin *From proton PDFs to nuclear PDFs*

  I. Schienbein *Nuclear PDFs and heavy-flavour production*

  S. Baranov J/ψ *polarization and* η_c *production puzzles: a possible way out*

  M. Barabanov *Probing of strong interactions and hadron matter in hadron and heavy ion collisions*

- Wednesday

  G. Ferrera *Heavy-quark mass effects on* q_T*-resummed distributions*

  F. Hautmann k_t*-factorization: open issues, with examples from collider physics*

  R. Maciula *Treatment of charm production in* k_t*-factorization*

  E. de Oliveira *Probing double parton scattering via associated open charm and bottom production in ultraperipheral pA collisions*

Week 2 (cont'd)

- Thursday

  G. Leontaris *String theory and GUT connections with cosmology/astrophysics*

  S. Brodsky *Novel QCD Physics of Heavy Quark Hadroproduction*

- Friday

  Key participants + Organizers *Conclusions*

Open questions

Event generators

- Heavy-quark degrees of freedom in Monte Carlo event generators at colliders:
  - What is the status ?
  - Are we satisfied with the present implementations ?
- Heavy-quark degrees of freedom in the event generators for high-energy Cosmic Ray Physics:
  - How do the predictions change after their implementation ?
  - Which models are used ?
  - Which connection with pQCD ?
- **Cross talk between the communities**
  - Up to which extent, can we use Monte Carlo codes at colliders to produce predictions for high-energy astroparticle physics ?
  - Which ingredients are missing ?
  - How do their predictions compare to those of the EAS codes ?

Open questions (cont'd)

Heavy-quark production

- Heavy-quark production in pQCD:
  - What are the various sources of uncertainties ?
  - Are they all considered in the theory predictions ?
  - How can we bring down theory uncertainties ?
  - What can calculations beyond collinear factorization for heavy-quark production in k_t-factorization provide ?
- Parton distributions for astroparticle physics:
  - What is implemented in EAS generators ?
  - Up to which extent can we use PDF andnuclear PDF fits extracted from collider physics there ?
  - What to do for processes initiated by other particles different (e.g. pions) ?
  - What to do with PDFs when describing scatterings with very low momentum transfer ?

Open questions (cont'd)

Heavy-quark production

- **Cross talk between the communities**
  - Can astroparticle physics help to put some constrain ?
  - Which further collider and/or fixed-target measurements would we suggest to decrease present uncertainties ?
- Cold nuclear matter effects and QGP effects on high-energy astroparticle observables:
  - How can we disentangle these two components ?
- Neutrino detectors:
  - How can we disentangle prompt neutrino fluxes from conventional and astrophysical fluxes ?
- BSM physics:
  - Can results from ultra-high-energy astroparticle physics can be used to constrain BSM physics ?

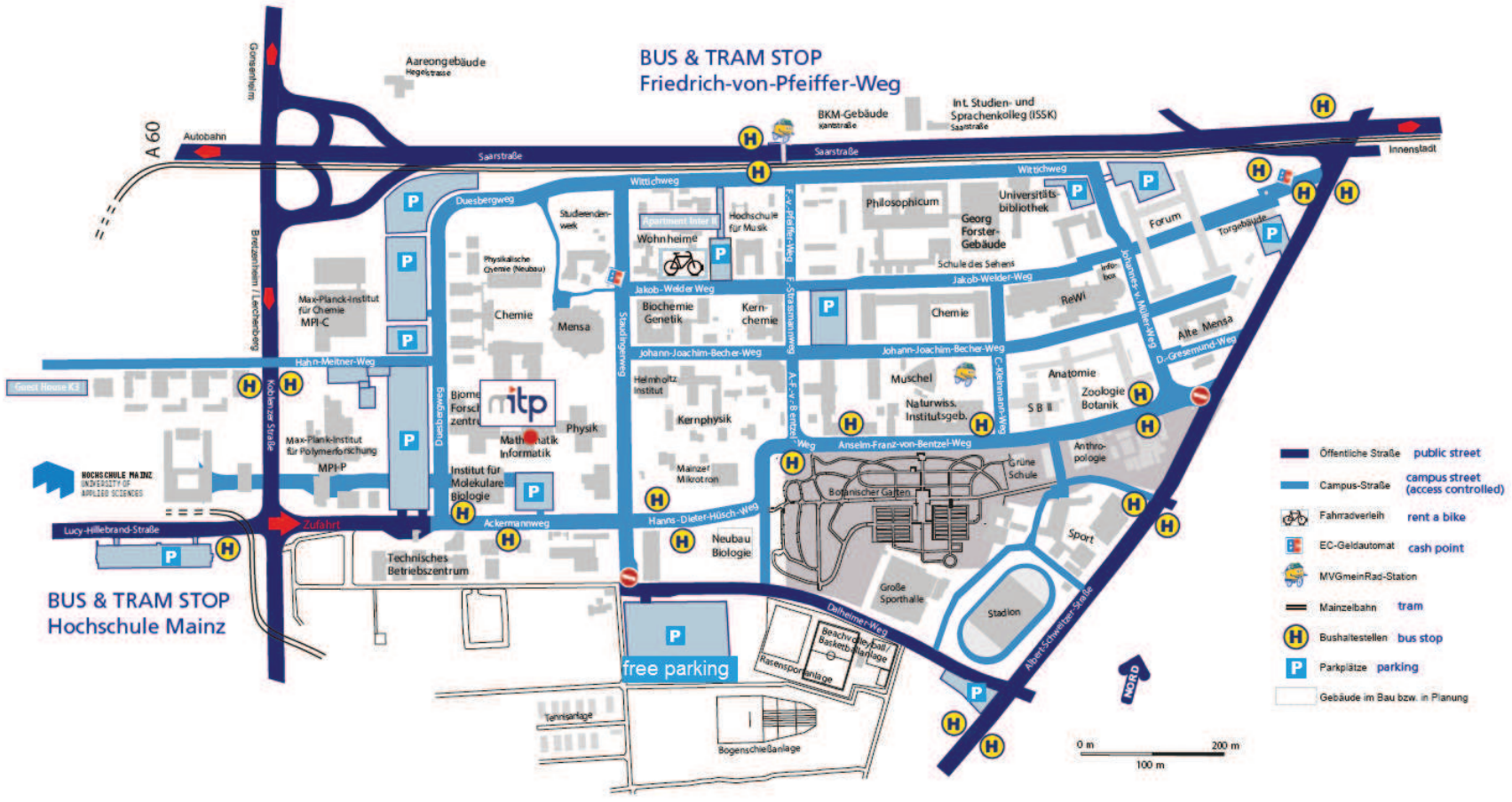
Practicalities (I)

Mainz Institute for Theoretical Physics

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

JG|U

CAMPUS MAP



Mainz Institute for Theoretical Physics

Practicalities (II)

- Lock your offices when you leave
- Timetable on indico web-site is developing
  https://indico.mitp.uni-mainz.de/event/186/
- Lunch break in Zentralmensa:
  (cafeteria in upper floor accepts cash payments)
- Coffee breakes at 10:30h and at 16:30h
  (coffee, tea and cakes/fruit free; espresso 50 cents)
- Social dinner during the week: Thursday evening at 19:00h at Eisgrub

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