Other facilities - upgraded & new

- **Second generation of JLab 12 GeV**
  - Rolf Ent, Or Hen

- **Belle II**
  - Carlos Marinas, Hue Ye, Gianluca Inguglia

- **PANDA @ FAIR**
  - Marc Pelizeaus

- **CBM @ FAIR**
  - Claudia Hoehne

- **Mu2e @ FNAL**
  - Luca Morescalchi

- **SHiP @ CERN**
  - Annarita Buonaura

- **LHC upgrades**
  - Magdalena Slawinska, Tomas Davidek, Thomas Peitzmann
A second generation of Jefferson Lab 12 GeV experiments – towards precision spatial and momentum imaging of hadrons

longitudinal momentum fraction $x$ and transverse momentum $k$

Transverse Momentum Imaging

Transverse Spatial Imaging

longitudinal momentum fraction $x$ at transverse location $b$
A second generation of Jefferson Lab 12 GeV experiments – towards precision spatial and momentum imaging of hadrons

* Up to FY17: 12-GeV Upgrade Project ongoing
* FY16: ongoing program in
  - Hall A: deeply-virtual Compton scattering & $p$ magnetic form factor
  - Hall B < 6 GeV science: heavy photon search & $p$ radius experiment
  - Hall C: Beam line/dump test
  - Hall D: GlueX engineering run
* FY17: official (DOE) start of 12 GeV science operations
  (typical lifetime of facility science program ~ 15 years)
EMC-SRC correlation

Tagged structure functions

(1) Perform DIS off forward going nucleon.
(2) Infer its momentum from the recoil partner.

Large Acceptance Detector
(LAD@Hall-C)

Backward Angle Neutron Detector
(BAND@Hall-B)
Belle II (KEK)

- High-resolution and large-coverage detector

- 40 times larger luminosity than previous Belle
- 50 ab$^{-1}$ by 2025

Ready for physics run in 2018
Belle II (KEK)

Belle II early physics program of bottomonia spectroscopy

Physics at B-factory

- CP Violation
  - CKM matrix elements: $V_{ub}$, $V_{cb}$.
  - CPV in charm sector
- Bottomonium spectroscopy
- Unanticipated New Particles
  - XYZ hadrons.
- Beyond the SM
  - $B \rightarrow X_s l^+ l^-$ probe the FCNC
  - Lepton flavor violating.
  - $B \rightarrow \tau \nu$, $D^{(*)}\tau \nu$ probe the charged Higgs.
  - Light dark matter particles and dark photon
  - ......

Potential of Belle II early physics on bottomonia

- Below $\Upsilon(4S)$: The $\Upsilon(3S)$ offers greatest access to lower bottomonium states, 200fb$^{-1}$ data set will give significant potential
  - Study of $\eta_b(1S,2S)$, $h_b(1P)$ and $\Upsilon(n^3D_1)$ Studies
  - Analyses with converted photons to improve resolution.
  - Hadronic/Radiative transitions.

- Above $\Upsilon(5S)$
  - Charged bottomonium-like states: $Z^\pm_b$

Large $\Upsilon(4S, 5S)$ data sets exist.
Leptonic and semileptonic B decays can be used to probe new physics at tree level and in loops.

- Anomalies already observed in data
- The dark photon is proposed in many BSM theories to introduce possible interactions between dark matter particles
- Can explain many anomalies observed in astrophysical if the mass in the few MeV- few GeV range
- With 50 ab$^{-1}$ collected at Belle II experiment one should be able to resolve the observed anomalies and measure rare decays with missing energy. In addition one will have a high discovery potential in searches for the dark photon.
**PANDA (FAIR)**

**pp annihilation**

- Gluon-rich environment
- **Uniqueness** of antiproton probe (no other facility in the corresponding energy range in the world)
- **Versatility** of physics program (if coupled with universal PANDA detector) addressing
  - hadron spectroscopy
  - nucleon structure
  - hadron interactions

**charmonium spectroscopy**

*e.g.* lineshape of $X(3872)$

\[
\begin{align*}
R &= \frac{G_E}{G_M} \\
&= \text{lineshape of } X(3872) \\
&= \text{(Hanhart, PRD76(2007))034007)}
\end{align*}
\]

**timelike e.m. $p$ form factors**

\[
p\bar{p} \to e^+e^-, \mu^+\mu^-
\]

\[
R = \frac{G_E}{G_M}
\]

**Diagram:**

- **Graph 1:** Shows the lineshape of $X(3872)$ with fit parameters.
- **Graph 2:** Displays various data points from experiments like BaBar, LEAR, FENICE+DM2, E835, BESIII, and PANDA simulations I and II.
- **Legend:** Indicating the different datasets.
Claudia Hoehne

CBM (FAIR)
(Compressed Baryonic Matter)

Explore & characterize high-baryon density matter in A+A collisions
- equation of state
- new forms of matter (quarkyonic, strange, hypernuclei …)
- phase transitions?

High precision experiment, high interaction rates, rare probes!

Complementary to heavy-ion experiments at LHC

K. Fukushima, T. Hatsuda,
Rept. Prog. Phys. 74, 014001 (2011)

FAIR “phase 0” prior to 2022

Install, commission and use CBM detector components in ongoing physics campaigns:
- BM@N (Dubna)
- HADES at GSI
- STAR at BNL
• Mu2e will search for the CLFV process:
  \[ \mu^- \text{Al} \rightarrow e^- \text{Al} \]
  (where the resulting e has an energy of 104.96 MeV)

• In 3 years of data taking we expect \(10^{18}\) stopped muons, to put an upper limit on
  \[ R_{\mu e} = \frac{\Gamma (\mu^- + N(A,Z) \rightarrow e^- + N(A,Z))}{\Gamma (\mu^- + N(A,Z) \rightarrow \text{all muon captures})} \]
  \(< 6 \times 10^{-17} @ 90\% \text{ C.L}\)

• If signal is found, it will be proof of new Physics and it will provide data complementar to LHC and to the other CLFV experiments

• If no signal is found, it will set constrains on mass scale up to thousands of TeV

✓ R&D phase is completed for all the subdetectors
✓ Test beams of first large scale prototypes are scheduled for this year

 Courtesy A. de Gouvea, B. Bernstein, D. Hitlin

Mu2e (Fermilab)
- New experiment proposed @ CERN SPS
  - 400 GeV proton spills (4 x 10^{13} \text{ p.o.t.}) from a dedicated beam line at the SPS accelerator
- Technical and Physics Proposal submitted in April 2015
- Decay volume 50m long equipped with detectors at the far end to explores Hidden Portals searching for *long-lived and very weakly interacting particles*
  - Vector portal (dark, hidden, para-photons)
  - Scalar portal
  - Neutrino portal
- **Neutrino physics with emulsion-based active neutrino target** (\(\mu\)m resolution) in a magnetic field.
  - Particular focus on identifying and distinguish \(\nu_\tau\) and anti-\(\nu_\tau\)
  - High statistics never reached before (8k \(\nu_\tau\) CC + 4k anti-\(\nu_\tau\) CC ) to:
    - Study \(\nu_\tau\) and anti-\(\nu_\tau\) cross sections
    - Estimate structure functions (\(F_4\) and \(F_5\)) from CC DIS of neutrino on nucleon
  - Study \(\nu\)-induced charm events
  - Study s-quark content of the nucleon

Positive recommendation from CERN SPS Committee
• High luminosity LHC physics prospects with the upgraded ATLAS detector (M. Slawinska, Thurs AM)

• ATLAS Tile Calorimeter, its performance at 13 TeV pp collisions, and its upgrades for the high luminosity LHC (T. Davidek, Thurs AM)

• Measurement of forward direct photon production in pA at the LHC with ALICE – a probe for nuclear PDFs and saturation (T. Peitzmann, Tues PM) (FoCal upgrade to ALICE)
LHC upgrades (CERN)

Magdalena Slawinska
Tomas Davidek
Thomas Peitzmann

HL-LHC upgrade

ATLAS detector upgrades (M. Slawinska, Thurs AM)
- Trigger and Data Acquisition
  - Two-Level hardware trigger with L0 up to 1MHz and L1 up to 400 kHz
  - High-Level Trigger with 10 kHz output (permanently recorded data)
  - “Custom hardware” triggers for data streaming at rates 1-40 MHz
- New Inner Tracker, Calorimeters and Muon Triggers
- Trigger and Data Acquisition
- Completely new, all-silicon tracker
- Extending Pixel Detector to $|\eta| < 4$
- Calorimeters
  - LAr forward electromagnetic calorimeter replaced with high-granularity
  - High Granularity Timing Detector installed in front of LAr Cal end-caps, $2.4 \leq |\eta| \leq 4.3$
- Readout electronics of LAr and Tile Calorimeters replaced
- Muon Spectrometer
  - Addition of RPCs in the barrel, $|\eta| < 1$


Much extended physics capabilities in EG. EWSB, BSM, ...

ATLAS TileCal upgrade (T. Davidek, Thurs AM)
Major electronics upgrade for HL-LHC 2023
upgrade with higher radiation tolerance, faster and more modern electronics

DEMONSTRATOR prototype built and tested in labs and testbeam; could be inserted in
ATLAS by end of year