WG4 Summary
-Intense Muon Physics-

Conveners
Y. Semertzdis (BNL), M. Grassi (Pisa), K. Ishida (RIKEN)

summary-1 for muon applications
by K. Ishida
Muon Physics (the Standard Model and beyond)

LFV

g-2 and EDM

Life time

Michel parameters

Muon Applications (Physics with muons)

$\mu^- :$ heavy electron

muonic atom, nuclear capture

muonic atoms and molecules

muon catalyzed fusion

$\mu^+ :$ light proton

$\mu$SR (muon spin rotation/relaxation/resonance)

muonium (atomic physics)

muon as beam

radiography

summary by Y. Semertzdis

summary by K. Ishida
Muon for unstable nuclear physics

P. Strasser

X-RAY SPECTROSCOPY of MUONIC ATOMS!

- Powerful tool to probe the NUCLEAR CHARGE DISTRIBUTION.

How to produce exotic $\mu A^*$ atoms of unstable nuclei?

<table>
<thead>
<tr>
<th>Implantation:</th>
<th>20x</th>
<th>10x</th>
<th>5x</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance:</td>
<td>50µm</td>
<td>100µm</td>
<td>200µm</td>
</tr>
</tbody>
</table>

$\mu H + A_z^* \rightarrow \mu A_z^* + H$

TRANSFER RATE: $\lambda_z \approx C_z Z \times 10^{10} \text{ s}^{-1}$

HIGH TRANSFER RATE & HIGH EFFICIENCY

Single $D_2$ Layer

Total $\gamma$-Ray Energy Spectra

- ~2 ppm
- ~1 ppm
- ~0.5 ppm
Muon catalyzed fusion

K. Ishida

rich in few body physics problems
muon catalyzing more than 120 fusions
progress and plans for increasing $\mu$CF
$\alpha\mu$ reactivation process
high density, high temperature target
control of molecule states

$\omega_s = (1-R)\omega_s^0$

14MeV neutron

17.6MeV $\times Y_n$
energy output

nuclear fusion

K$_{\alpha}$/K$_{\beta}$
X-ray

effective sticking

transfer to He

injected muon
µSR (muon spin rotation/relaxation/resonance)

materials science with muons

example:
\(\sigma\) (muon spin relaxation) as probe of superconducting (s.c.) pair density classification of s.c. systems and study of s.c. mechanism

Y. J. Uemura
E. Morenzoni in plenary

\(\sim 1000\) A for 1 kG

3d superfluid density
Low energy (or ultra slow) muon beam

E. Morenzoni in plenary
Y. Matsuda

surface science
thin layer/multilayers
depth profile of field penetration

beam intensity
rapid progress at RIKEN-RAL
1000/s x 7 expected at PSI this year
Radiography with high energy muon beam  K. Nagamne

TeV Cosmic ray probing a volcano

Energy loss and scattering angle vs thickness and Z-dep.

Compact muon source for advanced muon radiography nuclear inspection, industrial machinery …
For more muon beams

Axial focusing surface muon beam transportation, 1.3sr

Axisymmetric $\mu$-e separator

<table>
<thead>
<tr>
<th></th>
<th>Proton Current</th>
<th>Target Thickness</th>
<th>Muon Intensity</th>
<th>$\mu^+$ / pulse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dai Omega</td>
<td>500MeV 5 $\mu$A</td>
<td>4mm</td>
<td>$4 \times 10^5 \mu^+ / s$</td>
<td>$2 \times 10^4$</td>
</tr>
<tr>
<td>KEK-MSL I</td>
<td>500MeV 5 $\mu$A</td>
<td>30mm</td>
<td>$2.5 \times 10^4 \mu^+ / s$</td>
<td>$1.3 \times 10^3$</td>
</tr>
<tr>
<td>RAL</td>
<td>800MeV 200$\mu$A</td>
<td>10mm</td>
<td>$\sim 10^6 \mu^+ / s$</td>
<td>$\sim 2 \times 10^4$</td>
</tr>
</tbody>
</table>
Future muon beams for muon science

MLF (Materials and Life Science) at J-PARC 3GeV
MLF Muon Facility has started construction
To be realized in 4 years

Y. Miyake

Muon Facility 3GeV 333μA

Surface Muon
(4MeV) 4 Ports 10^7/s

Decay μ⁺/μ⁻
(10-50MeV) 2 Ports 10^7/s

Intense Surface & Negative muon port

Slow μ⁺
(eV-keV) 1 Ports 10^4-5/s

J-PARC
Muon Science **Phase 1**
Decay-Surface Muon Port
Surface Muon Port

Muon Science **Phase 2**
Curved Solenoid Port
For Ultra Slow Muon & Negative Muon Beams

Muon Science **Phase 2’**
High Momentum
Decay Muon Port

Beam shift along path calculated by Ishida
Muon Facility for Particle Physics at J-PARC 50GeV

Fast extraction facility for
  muon physics: $\mu e$ conversion, edm, g-2
  anti-proton physics: antimatter etc
aim at $10^{11}$~$10^{12}$/s with PRISM for PRIME,
PRISM-II for g-2 and edm
LOIs to J-PARC
organization of global collaboration
Summary of muon applications part

Good progress in wide range of muon science

Steady increase (x10 or more) is expected in muon beam intensity of various characters (slow muon, pulsed muon)

Several orders magnitude increase of muon intensity aimed at neutrino-factory would have strong impact on muon application sciences (needs matching beam properties, beam slot, facilities) and also could open a new field of applications.