



NATIONAL  
ACCELERATOR  
LABORATORY



THE UNIVERSITY OF  
CHICAGO

# Optimization and Machine Learning for Particle Accelerators: organization of the course

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**Day 1**

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- Course website:  
[https://slaclab.github.io/USPAS\\_ML](https://slaclab.github.io/USPAS_ML)
- Gathers resources for the course:
  - Agenda
  - Lecture slides  
(posted just before each lecture)
  - Lab solutions (posted after  
corresponding labs)
  - Slack workspace

## Overview

This page gathers the class material for the winter 2022 U.S. Particle Accelerator School course on [Optimization and Machine Learning for Accelerators](#).

## Agenda

[Download](#)

## Lecture slides

- Organization
- Optimization 1: Introduction and local methods
- Optimization 2: More advanced methods
- Introduction to machine learning
- Gaussian processes
- Bayesian optimization
- Modern neural networks
- Uncertainty quantification in machine learning
- Unsupervised learning



# Agenda

| Time<br>(CST time zone) | Monday<br>January 24         | Tuesday<br>January 25        | Wednesday<br>January 26                    | Thursday<br>January 27              | Friday<br>January 28                   |
|-------------------------|------------------------------|------------------------------|--|-------------------------------------|--|
|                         |                              |                              | Return homework<br>from lab 1              |                                     | Return homework<br>from lab 3          |
| 10:00 AM                | Lecture 1:<br>Optimization 1 | Lecture 2:<br>Optimization 2 | Lecture 3:<br>Intro to<br>machine learning | Lecture 4:<br>Gaussian<br>processes | Lecture 5:<br>Bayesian<br>optimization |
| 11:00 AM                | Break                        | Break                        | Break                                      | Break                               | Break                                  |
| 12:00 PM                |                              |                              |  | Gaussian<br>processes               |  |
| 1:00 PM                 | Lab 1                        | Lab 2                        | Lab 3                                      | Lab 4                               | Lab 5                                  |
| 2:00 PM                 |                              |                              |  |                                     |  |

Homework  
from lab 1

Homework  
from lab 3

Homework  
from lab 5

| Monday<br>January 31                    | Tuesday<br>February 1                       | Wednesday<br>February 2                | Thursday<br>February 3                  | Friday<br>February 4                 |
|---|---|--|---|--------------------------------------|
| Return homework<br>from lab 5           |   | Return homework<br>from lab 6          |   | Return homework<br>from lab 8        |
| Lecture 6:<br>Modern neural<br>networks | Lecture 7:<br>Uncertainty<br>quantification | Lecture 8:<br>Unsupervised<br>learning | Lecture 9:<br>Reinforcement<br>learning | Exam                                 |
| Break                                   | Break                                       | Break                                  | Break                                   | Break                                |
| Lab 6                                   | Lab 7                                       | Lab 8                                  | Lab 9                                   | Lecture 10:<br>Current<br>challenges |

Homework  
from lab 6

Homework  
from lab 8

**Connect to Zoom during the colored areas of the planning  
(see Google Calendar invitations)**



# Labs and homework

- Labs, homework and exam are in **Jupyter notebook** format.
- We will use RadiaSoft's cloud platform "Sirepo" ([www.sirepo.com/jupyter](http://www.sirepo.com/jupyter)) to:
  - Run the labs in a controlled environment
  - Gather the returned homework
- When connecting to Sirepo for the first time: use **the email address that you provided to USPAS**
- **Blue questions:** done live, during lab sessions  
**Green questions:** homework

**Note:** When using Sirepo: no GPU access.

For (free) GPU resources, you can run the notebooks on <https://colab.research.google.com/> after this course.

(Not supported during this course.)

The screenshot shows a Jupyter notebook interface with the following content:

### Gradient Descent on the Accelerator Example

**Task:** Now apply gradient descent to optimizing the quadrupole strengths to minimize the total final beam size using the above function. Write the corresponding code below. (Feel free to reuse the function `gradient_descent` and to tune `alpha` and `n_iterations` to reach convergence - which you can assess by plotting the returned history ; do not hesitate to use a large value for `alpha`.)

What is the value of the beamsize that is obtained at the end of the optimization?

```
[ ]: K = torch.tensor([1.0, -1.0, 0.5], requires_grad = True)
# Your code here
```

**Your answer here:** (What is the value of the beamsize that is obtained at the end of the optimization?)

### Gradient descent with numerical differentiation

**Homework:** Try to minimize again the beam size, but using numerical differentiation instead of autograd. In this case, you will **not** call the `.backward` and `.grad` functions, but instead you will need to calculate the gradient numerically: vary in the input `K` by `h=1.e-4` in each direction, in order to compute the gradient of `beam_size`.

(Note that, because we do not call `.backward`, we also do not need to set `requires_grad = True`.)

Does the algorithm reach the same final value, for the beamsize?

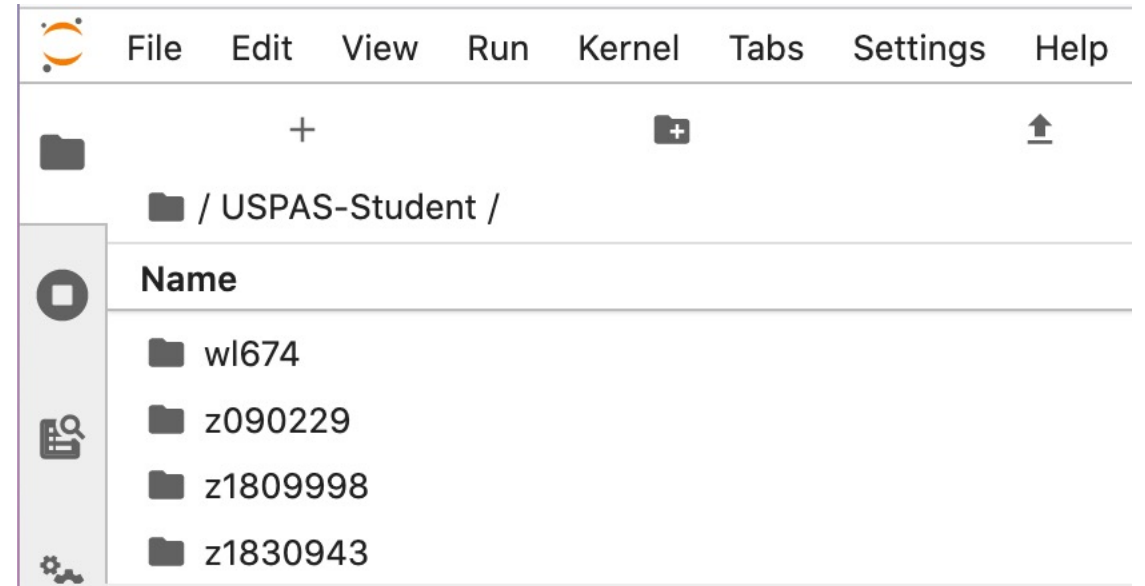
```
[ ]: def gradient_descent_nd(X0, function, alpha=0.1, n_iterations=100):
    """
    Performs n_iterations iterations of gradient descent,
```





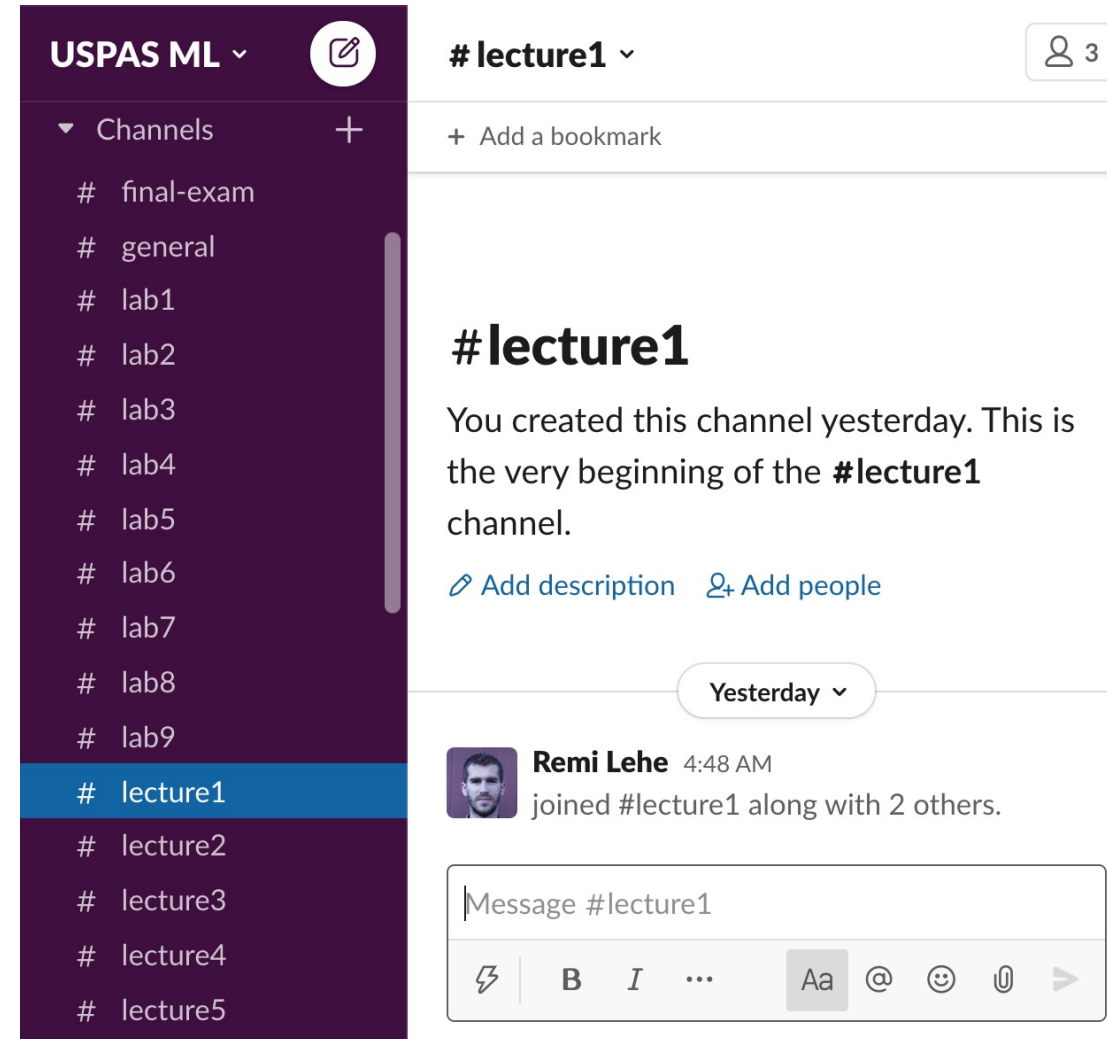
# Grading

- Homework and final exam will be graded.  
Overall grade = 60% homework + 40% exam
- Need A or B to pass this course and get academic credits
- When done with your homework/exam, **copy** your notebook to the folder that corresponds to your **email address**, within the USPAS–Student folder, on [www.sirepo.com/jupyter](http://www.sirepo.com/jupyter)
- **Audit students:** no need to return homework or participate in exam.



- Lectures, labs and exam will take place through Zoom.  
Lectures will be **recorded** and shared by private link through Slack
- Mute unless you are specifically asked to unmute (e.g. for questions)
- **Feel free to ask questions at any time during lab/lecture!**  
by either:
  - Raising your hand in Zoom
  - Or typing the question in the chat
- For questions outside of the lab/lecture sessions, use Slack (next slide)
- Reminder: do not post Zoom link publicly ; link is only for registered students.

- Our slack workspace:  
[uspas-ml-winter-2022.slack.com](https://uspas-ml-winter-2022.slack.com)
- You should have been invited last week.  
If not: let us know **now** via Zoom chat  
(along with your email address)!
- Purpose:
  - interaction outside of lecture/lab hours
  - any questions (on course content or organization)
  - one-on-one help (esp. debugging your environment)
  - sharing interesting resources, etc.



The screenshot shows a Slack workspace interface. On the left is a dark sidebar with the workspace name "USPAS ML" and a list of channels: # final-exam, # general, # lab1 through # lab9, # lecture1 (highlighted in blue), # lecture2 through # lecture5. The main area shows the "# lecture1" channel header with a dropdown arrow and a "3" in a circle. Below the header is a "+ Add a bookmark" button. The channel name "#lecture1" is displayed in large bold text, followed by a message: "You created this channel yesterday. This is the very beginning of the #lecture1 channel." Below this message are links for "Add description" and "Add people". A "Yesterday" separator is visible. A message from "Remi Lehe" at "4:48 AM" says "joined #lecture1 along with 2 others." At the bottom is a message input field with the placeholder "Message #lecture1" and a rich text editor toolbar with icons for link, bold, italic, text color, mention, emoji, and attachments.





Questions?

Any question at this point?