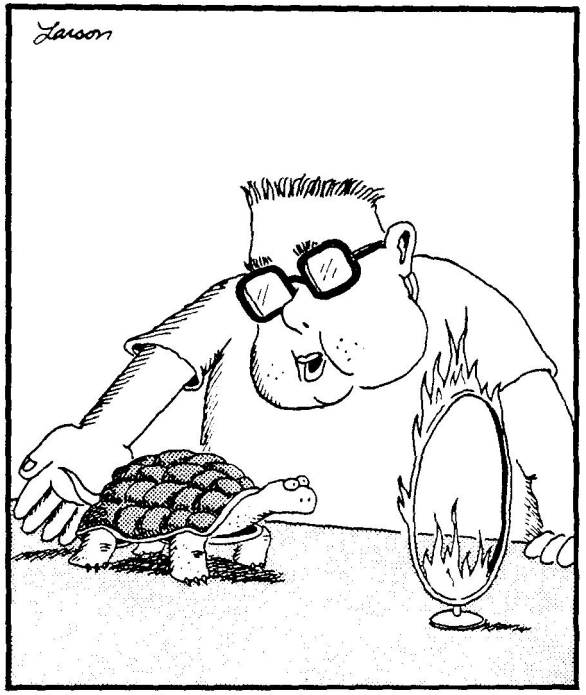
Sometimes you need to think big thoughts

Not all performance problems will be solved with an incremental approach

- "Do we have to do it this way?"
- "Is there a better way to do this?"
- "Do I have to do this at all?"



"Through the hoop, Bob! Through the hoop!"

Traditional example: Sorting a new deck of cards

CERN School of Computing

More

Method 1: Pattern recognition

- There are a finite number of possible arrangements
- Find which one you have, and then reorder
- 52! = 4×10^{66} so will need about $2*4 \times 10^{66}/2$ comparisons

Method 2: Bubble sort

- Scan through, finding the smallest number
- Then repeat, scanning through the N-1 that's left
- Cost is $O(N^2)$ "sum of numbers from 1 to N" = $52*(52+1)/2 = 1.4 \times 10^3$

Method 3: Better sorts - Shell sort, syncsort, split sort, ...

- Even for arbitrary data, better sort algorithms exist
- $O(N \log_2 N) = k * 52 * 5.7 = k * 300$, where "k" is time per operation
- For N large, important gain regardless of k
- As ideas improve, k has come down from 5 to about 1.2 => 360

Method 4: Bin sort ("Solitaire sort")

- Use knowledge that there are 52 items with unique known labels
- Throw each card into the right bin with 52 calculations: O(N)

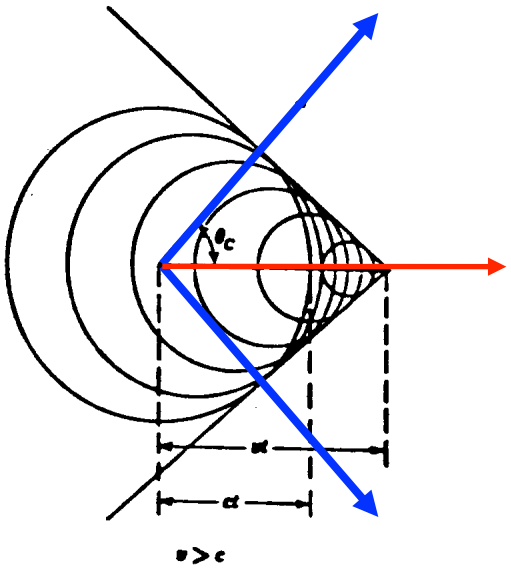
Method 5: New decks are already sorted (No operations!)

Telling pions from kaons via Cherenkov light

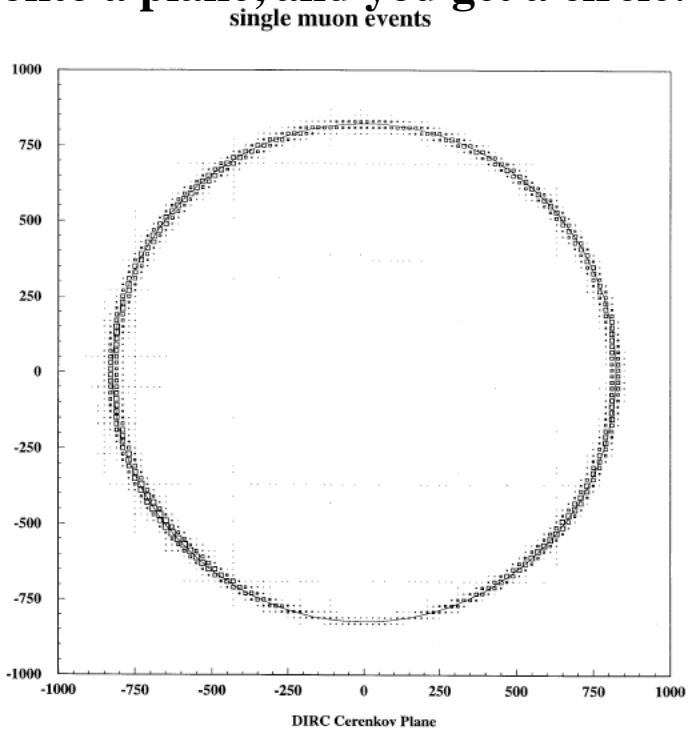
Pions & Kaons have similar interactions in matter, differ in mass

Particles moving faster than light in a medium (glass, water) emit light

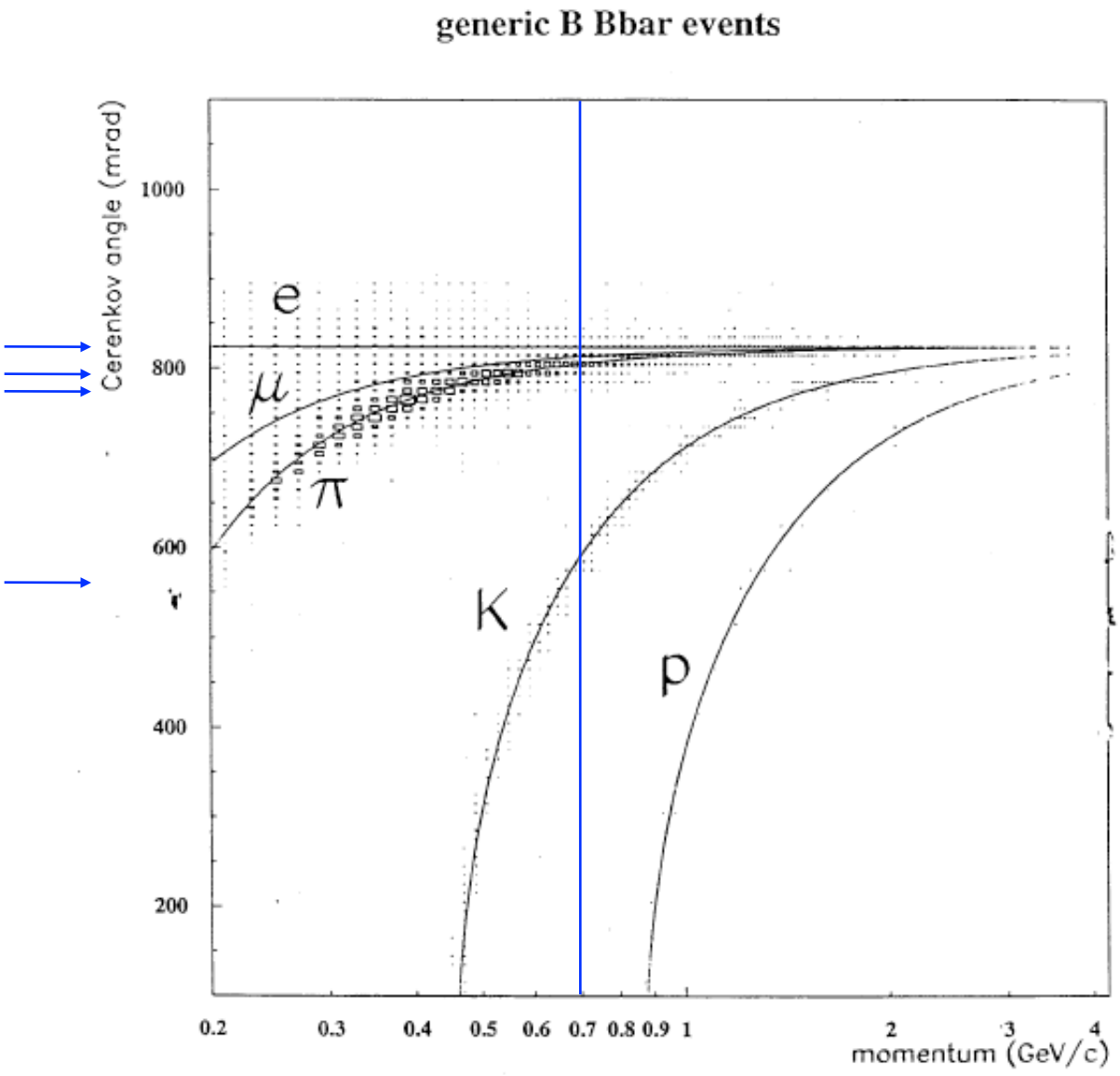
- Angle is related to velocity
- Light forms a cone



Focus it onto a plane, and you get a circle:



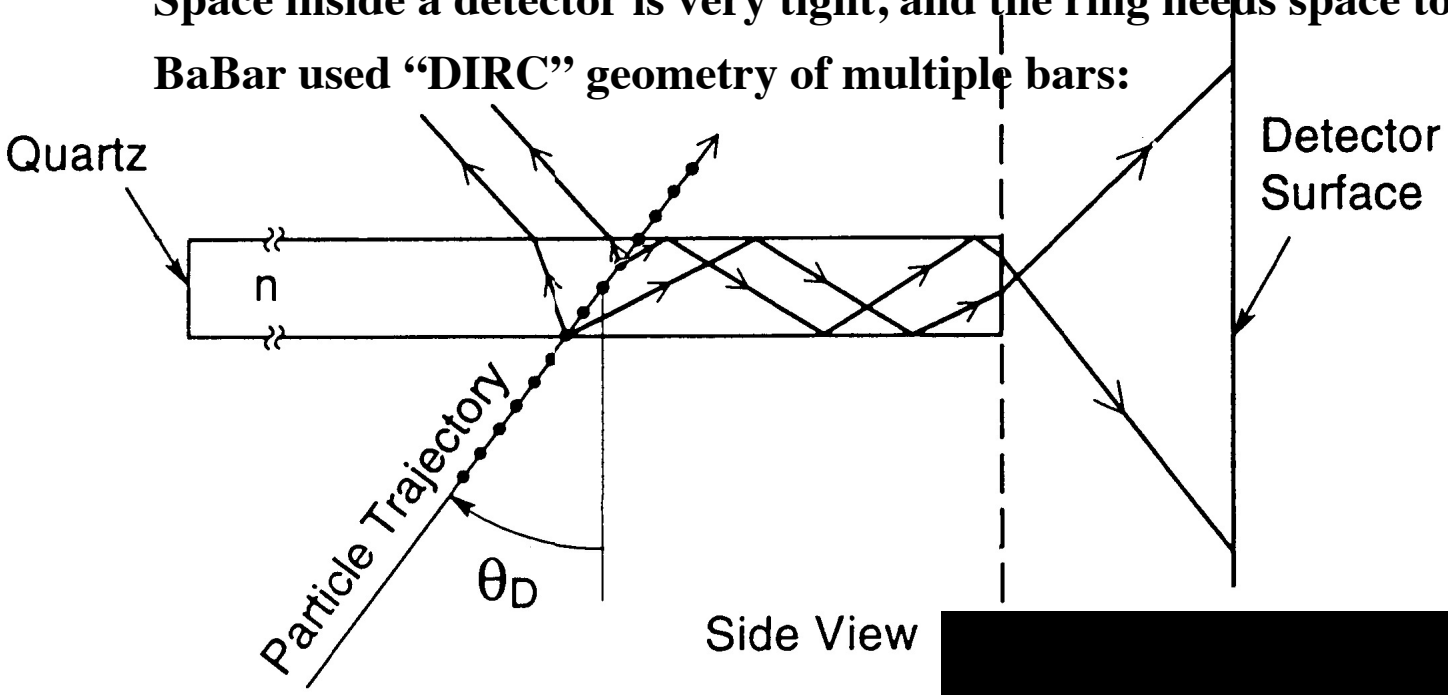
Radius of the reconstructed circle give particle type:

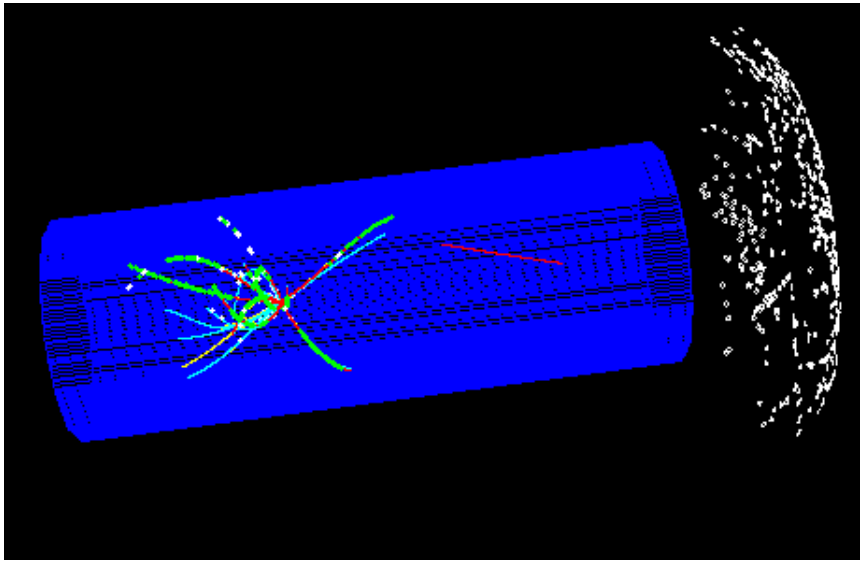


How to make this fit?

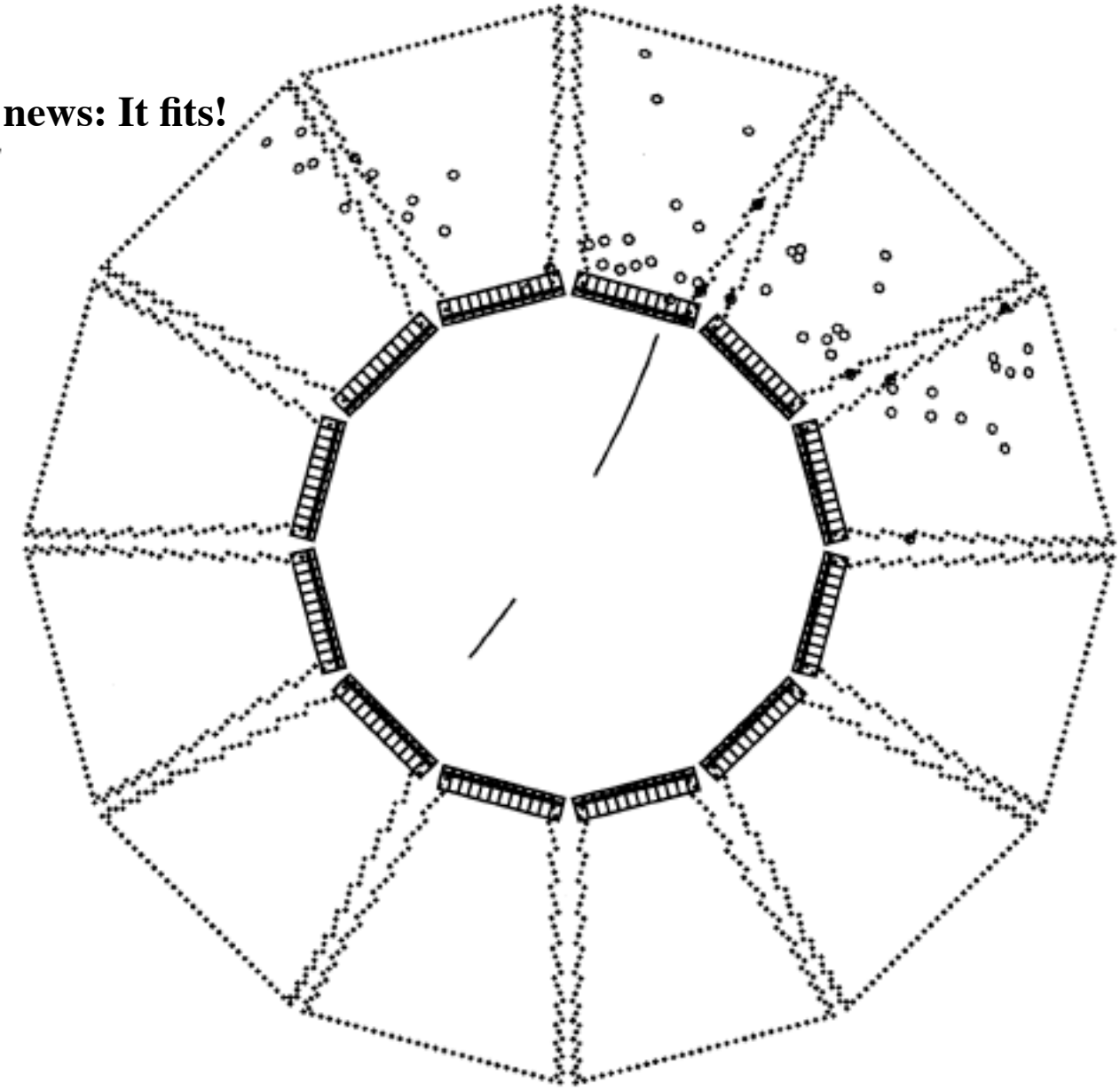
Space inside a detector is very tight, and the ring needs space to form

BaBar used "DIRC" geometry of multiple bars:



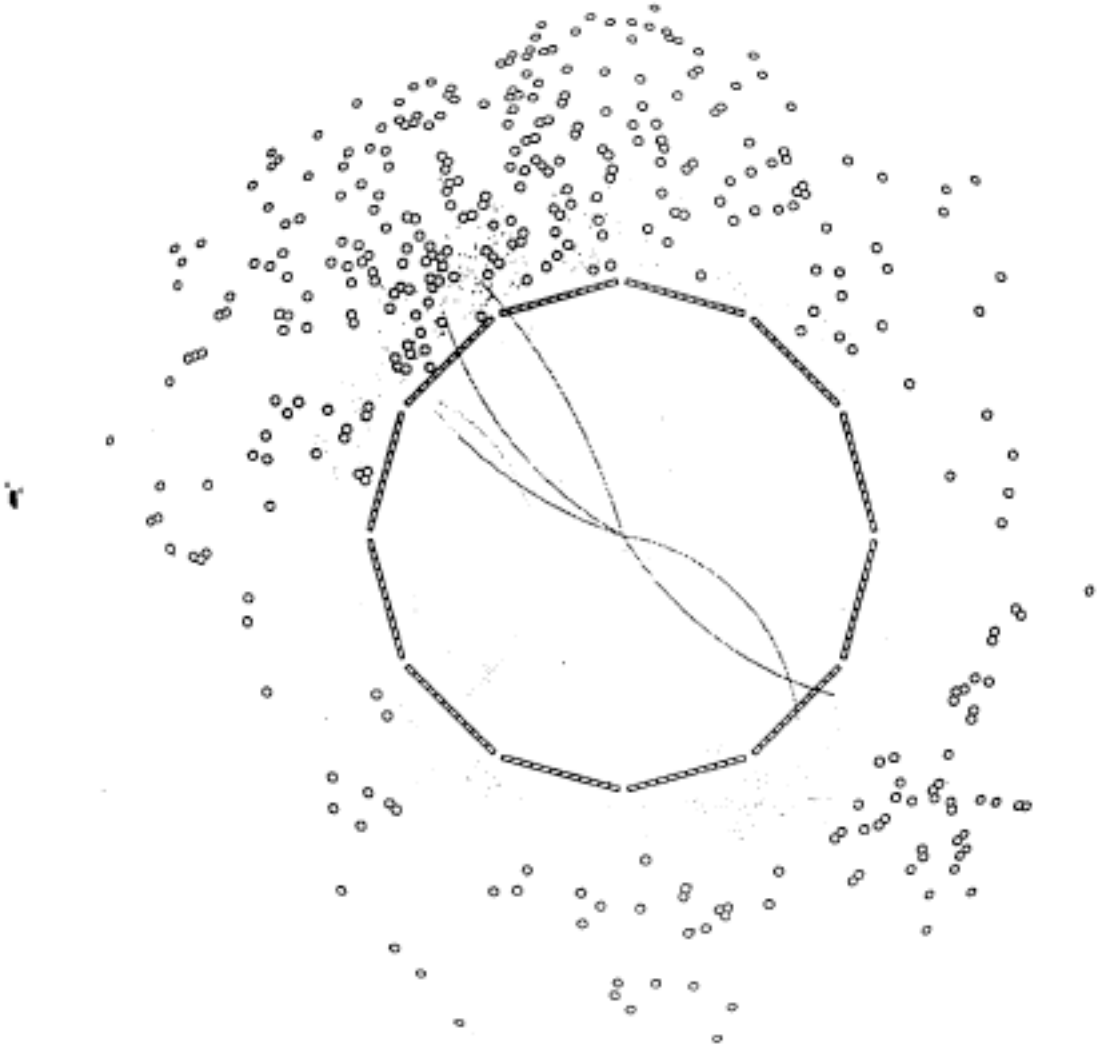


Good news: It fits!



Bad news: Rings get messy due to ambiguities in bouncing

Simple event with five charged particles:

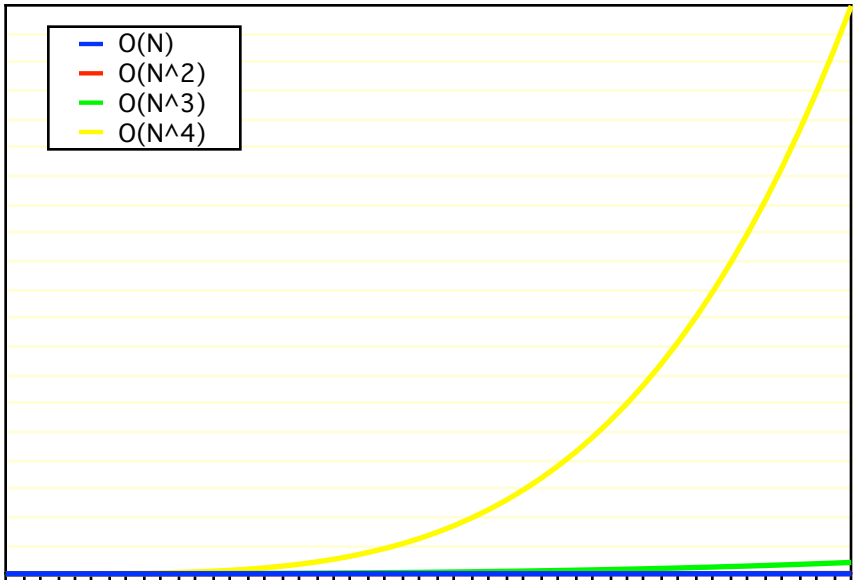


Why is this hard?

Brute-force circle-finding is an O(N⁴) problem

- Basic algorithm: Are these four points consistent with a 'circle'?

Important to understand how cost grows with input size:



Realistic solution for DIRC? (Avoiding O(N⁴))

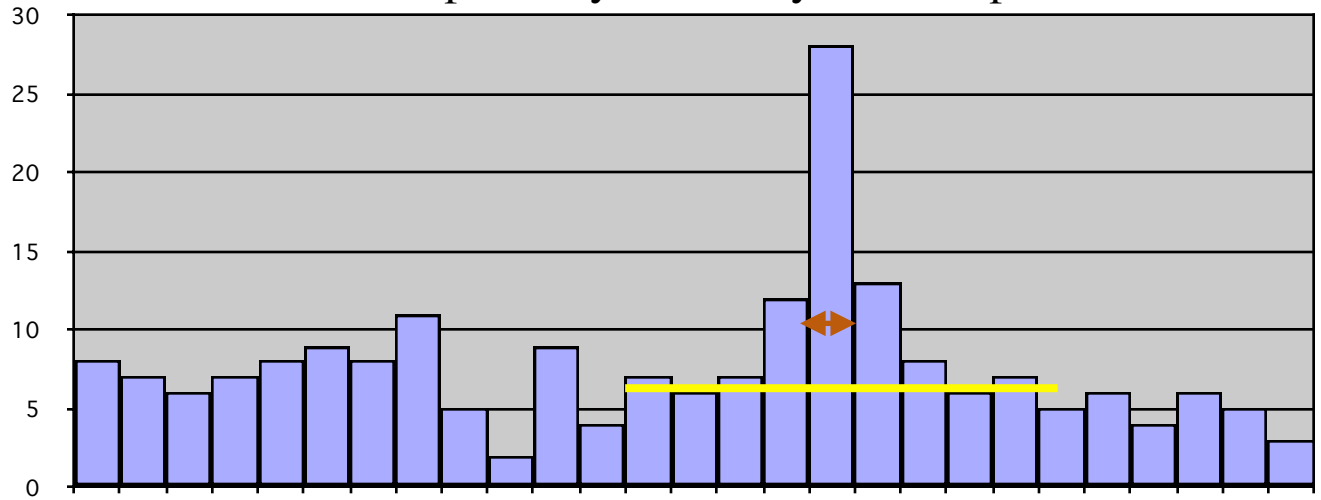
Use what you know:

- Have track trajectories, know position and angle in DIRC bars
- All photons from a single track will have the same angle w.r.t. track

  No reason to expect that for photons from other tracks

For each track, plot angle between track and every photon - O(N)

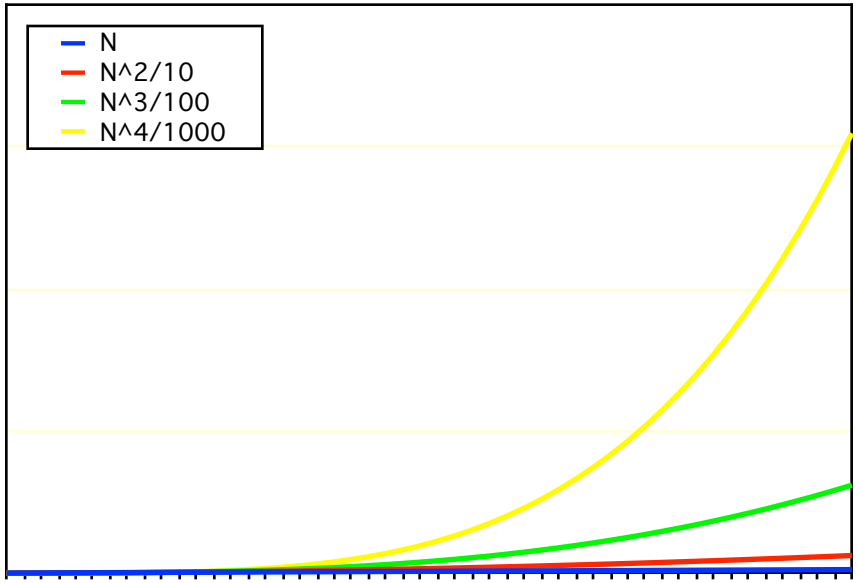
- Don't do pattern recognition with individual photons
- Instead, look for overall pattern you already know is present



Not perfect, but optimal?

"But each operation is so much slower…"

How do I compare a "fast" O(N⁴) algorithm with a slow O(N)?

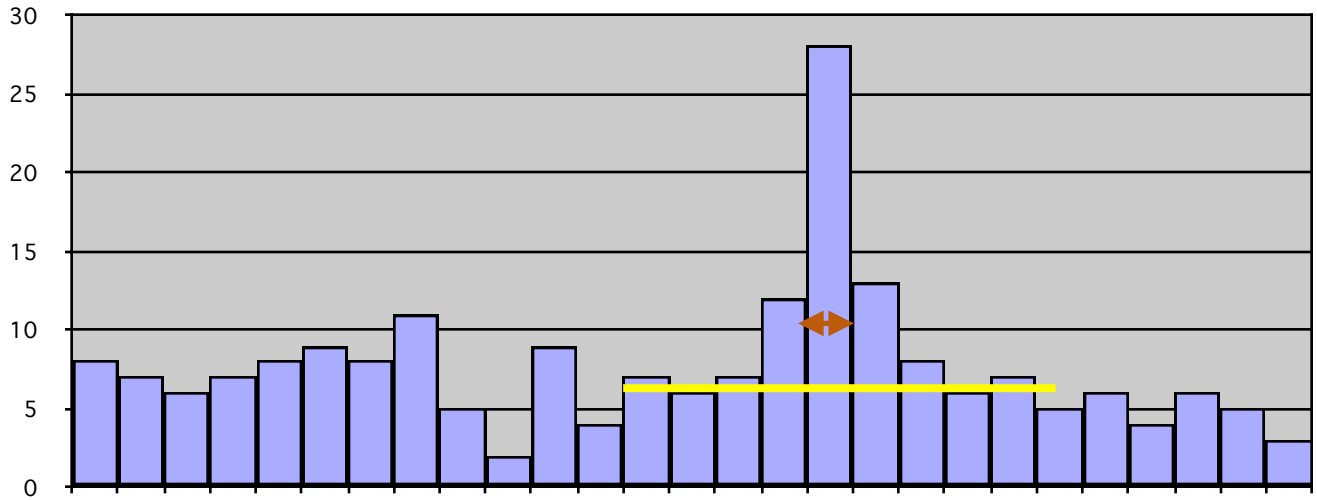


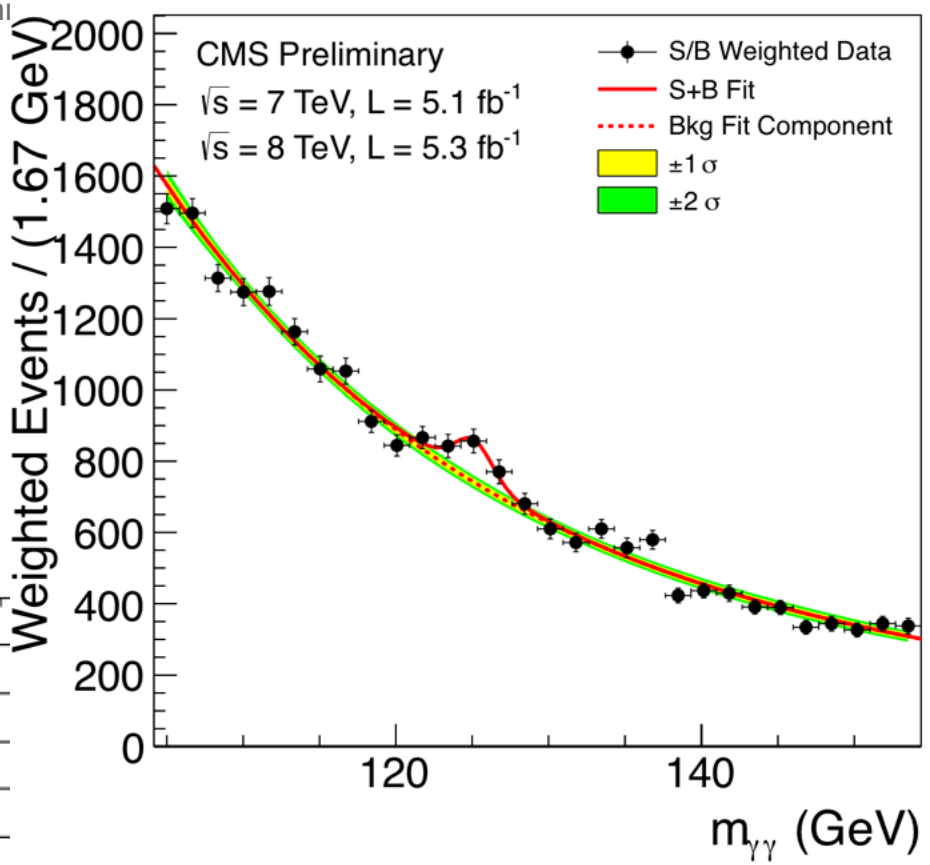
Many realistic problems deal with lots of data items

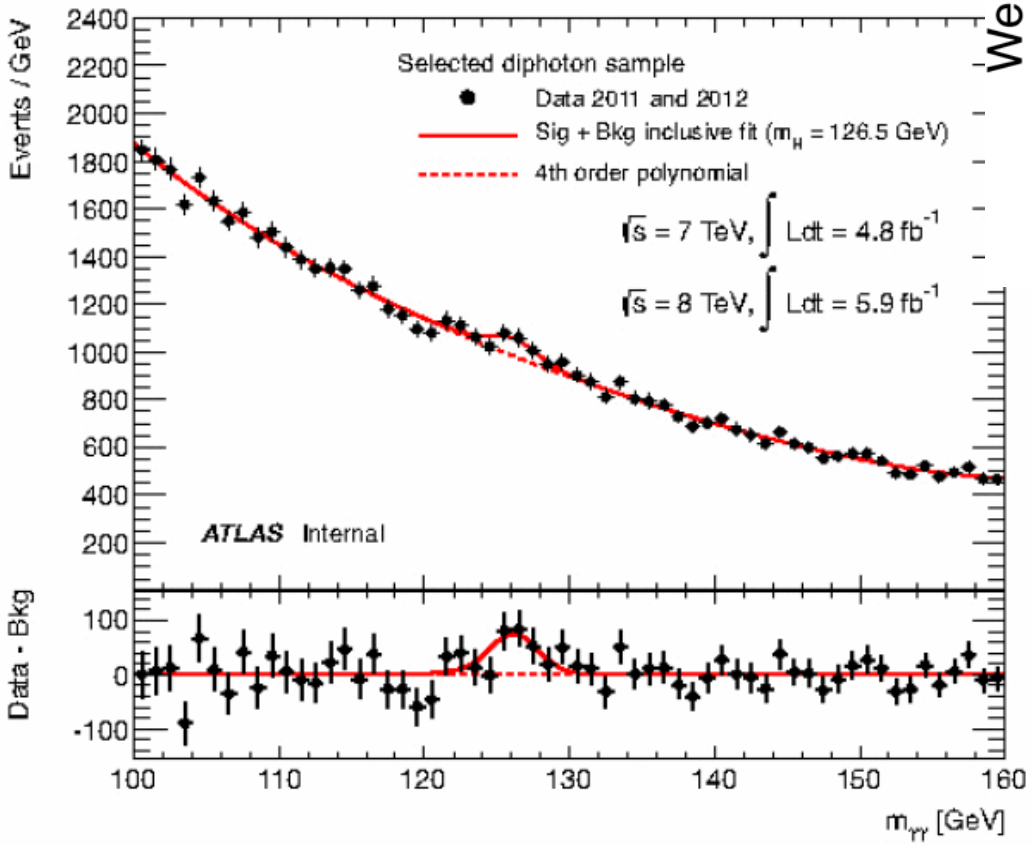
- Sharp coding is unlikely to save you a factor of 50^2 per calculation

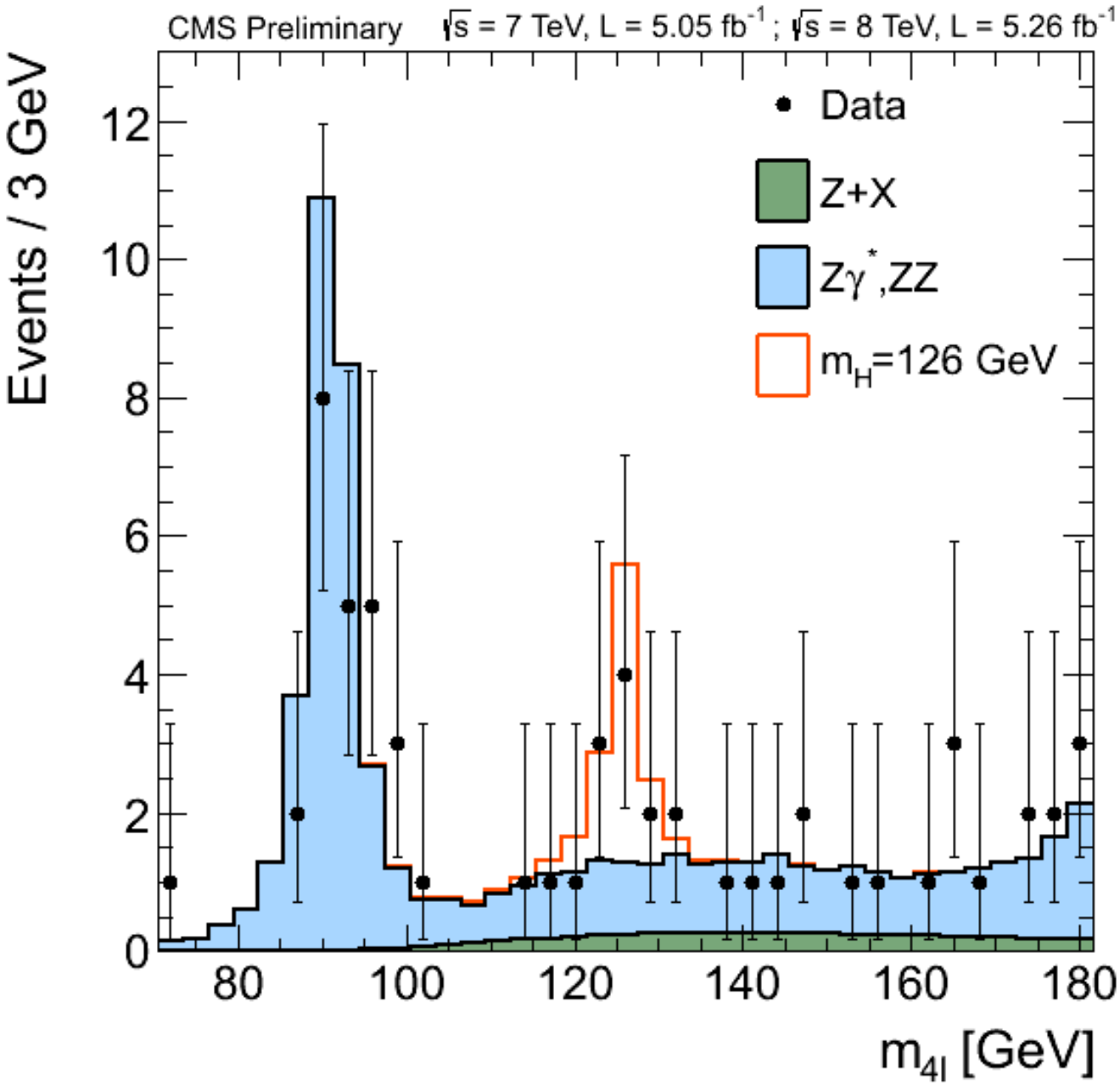
Where else do we see this pattern?

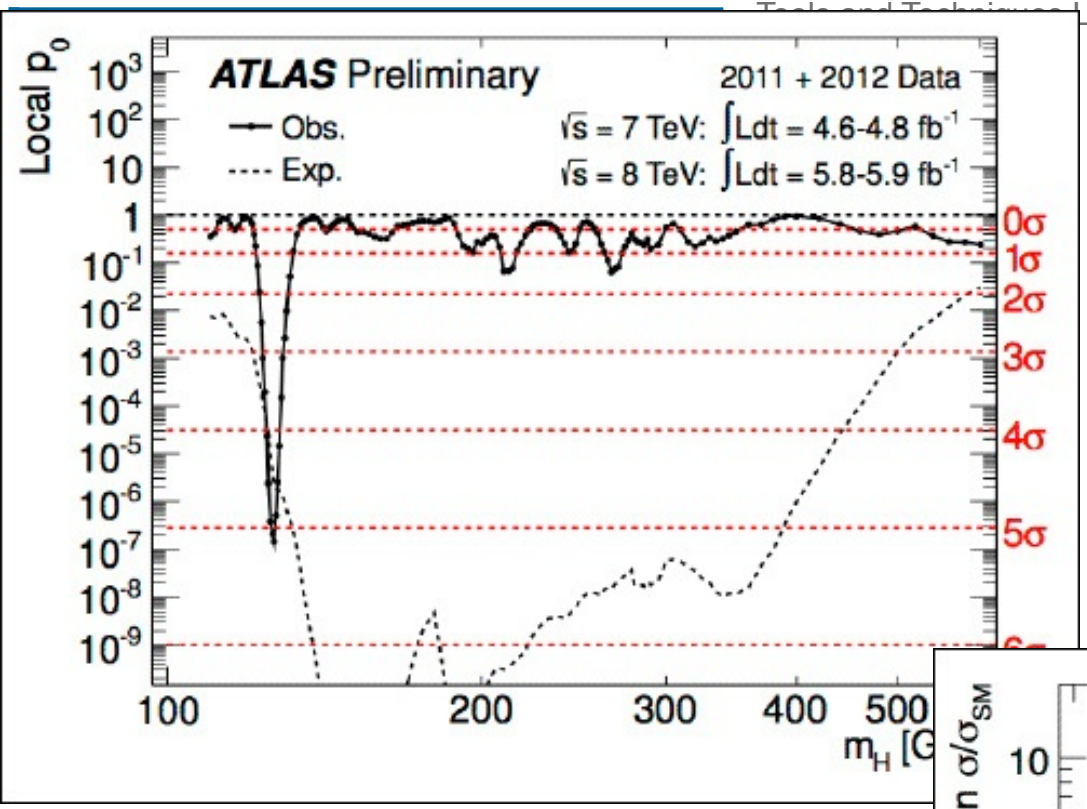
What do we do when we can't figure out the exact answer?

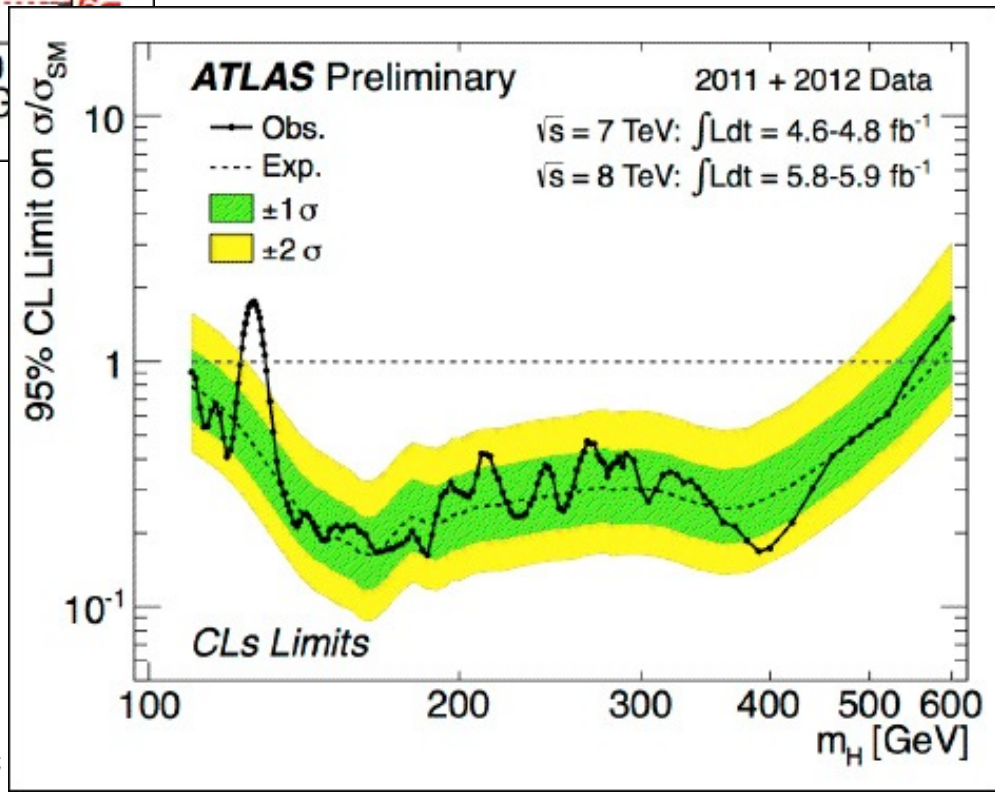



CMS Preliminary
√s = 7 TeV, L = 5.1 fb-1
√s = 8 TeV, L = 5.3 fb-1
S/B Weighted Data
S+B Fit
Bkg Fit Component
±1 σ
±2 σ
Weighted Events / (1.67 GeV)
mγγ (GeV)

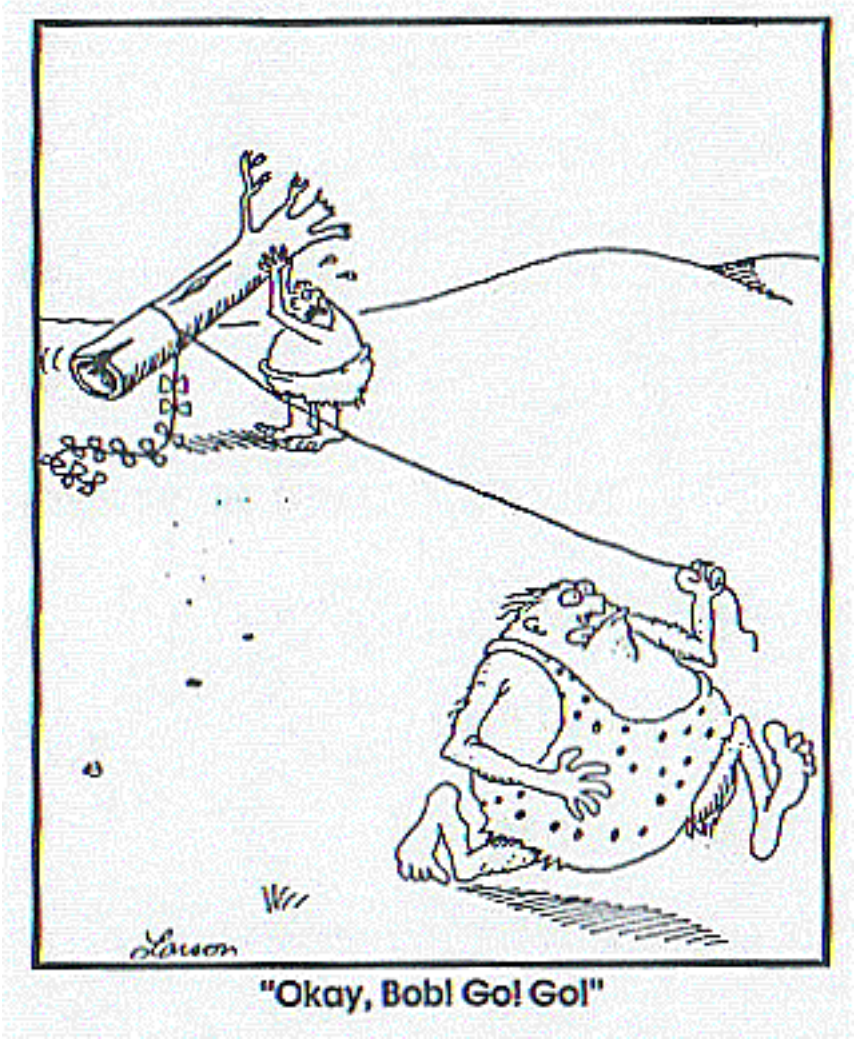

Selected diphoton sample
Data 2011 and 2012
Sig + Bkg inclusive fit (mH = 126.5 GeV)
4th order polynomial
√s = 7 TeV, ∫ Ldt = 4.8 fb-1
√s = 8 TeV, ∫ Ldt = 5.9 fb-1
ATLAS Internal
Events / GeV
Data - Bkg
mγγ [GeV]


CMS Preliminary
√s = 7 TeV, L = 5.05 fb-1 ; √s = 8 TeV, L = 5.26 fb-1
Data
Z+X
Zγ*,ZZ
mH=126 GeV
Events / 3 GeV
0
2
4
6
8
10
12
80
100
120
140
160
180
m4l [GeV]


ATLAS Preliminary
2011 + 2012 Data
Obs.
Exp.
√s = 7 TeV: ∫Ldt = 4.6-4.8 fb⁻¹
√s = 8 TeV: ∫Ldt = 5.8-5.9 fb⁻¹
Local p0
0σ
1σ
2σ
3σ
4σ
5σ
100
200
300
400
500
mH [G

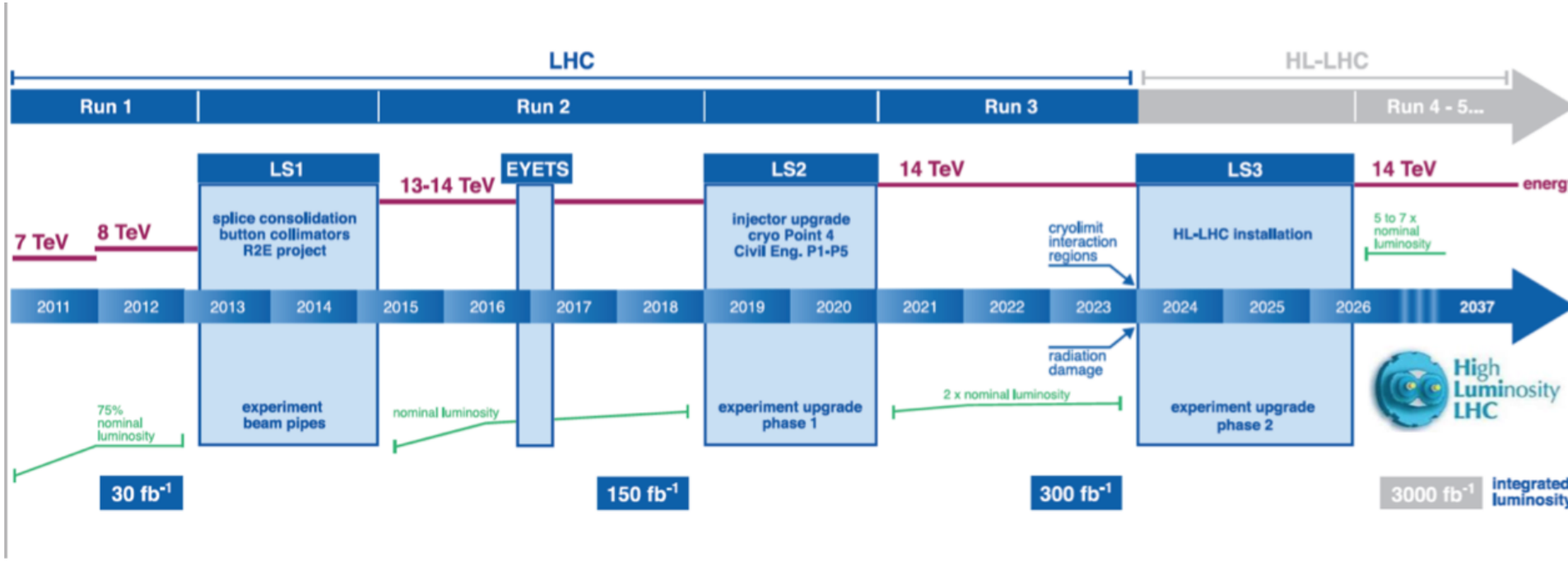

ATLAS Preliminary
2011 + 2012 Data
Obs.
Exp.
±1σ
±2σ
√s = 7 TeV: ∫Ldt = 4.6-4.8 fb⁻¹
√s = 8 TeV: ∫Ldt = 5.8-5.9 fb⁻¹
95% CL Limit on σ/σSM
CLs Limits
100
200
300
400
500
600
mH [GeV]

Big things are different from small things



The life time of HEP software

Software is a long-term commitment



Many releases of the software are needed over its lifetime
to fix bugs, add new features, support new platforms etc

How do we cope?

We try to find a way of working that leads to success

- We create a "process" for building systems
- We devise methods of communicating and record keeping: "models"
- We use the best tools & methods we can lay our hands on

And we use a lot of optimism!

Can't technology save us?

More

We've built a series of ever-larger tools to handle large code projects:

Git for controlling and versioning code

Tools for building "releases" of systems

Tools for "configuration management"

But we struggle against three forces:

- We're always building bigger & more difficult systems
- We're always building bigger & more difficult collaborations
- And we're the same old people

Net effect: We're always pushing the boundary of what we can do

Stupidity got us into this mess; why can't it get us out? - Will Rogers

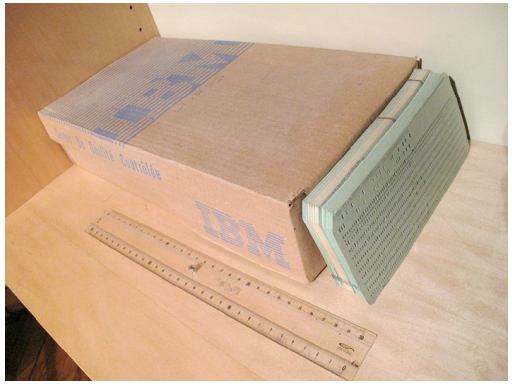
How we got here:

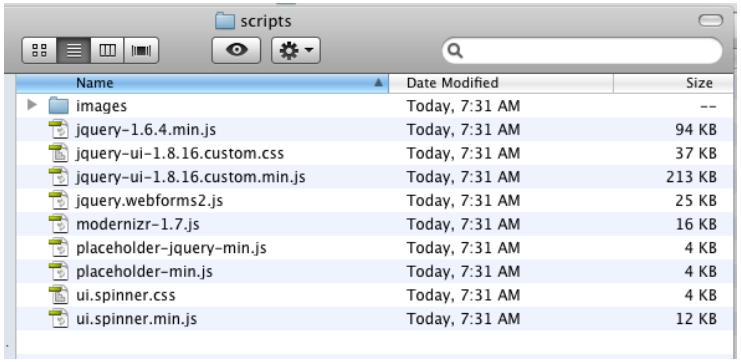
First, you just wrote a big program

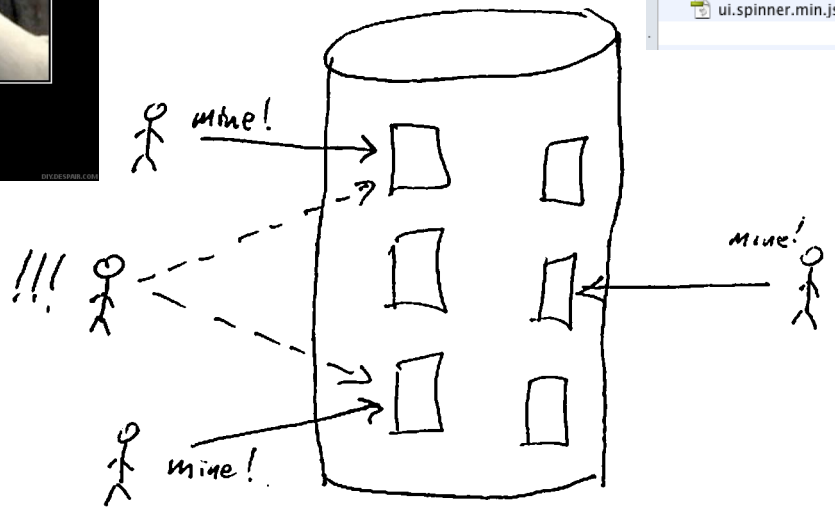
But soon it was so big you wanted help

So you broke it into pieces/files/modules

But how do you share work on those?







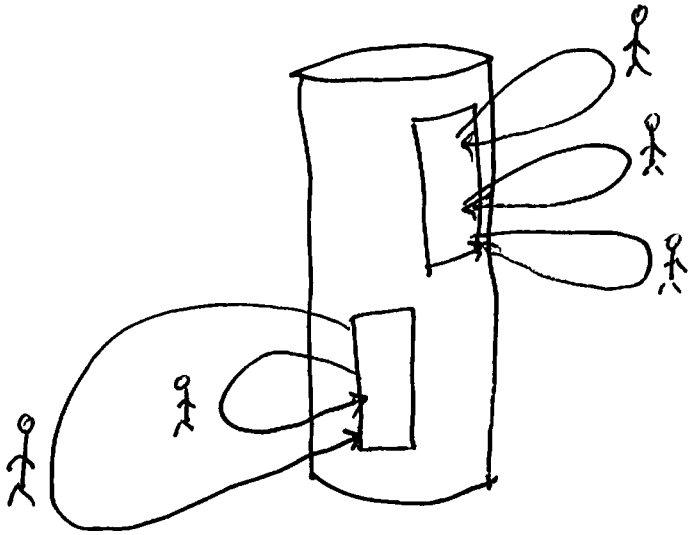
Version Control Systems (Hg, SVN, Git)

More

As systems & collaborations grow, efficiency goes down

"Version" idea: Track changes from one version to next

Anybody can get a specific set of source



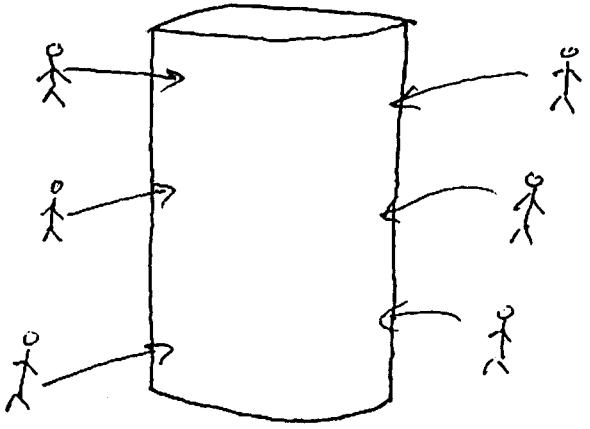
Big advantage: checkout is not exclusive

- More than one developer can have the same file checked out
- Developers can control their own use of the code for read, write
- Changes can come from multiple sources
- Tool handles (most) of the conflict resolution

Scaling is still an issue

Everybody is sharing a single repository

Every commit is immediately visible to everybody else



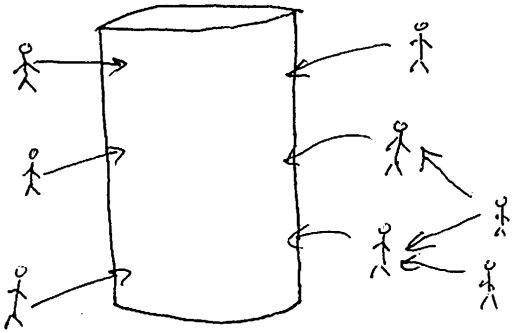
Development stands on shifting sand

Detailed records, but little understanding

Workarounds!

External record keeping tools

Package Coordinators



Issue with this arise at large & small level

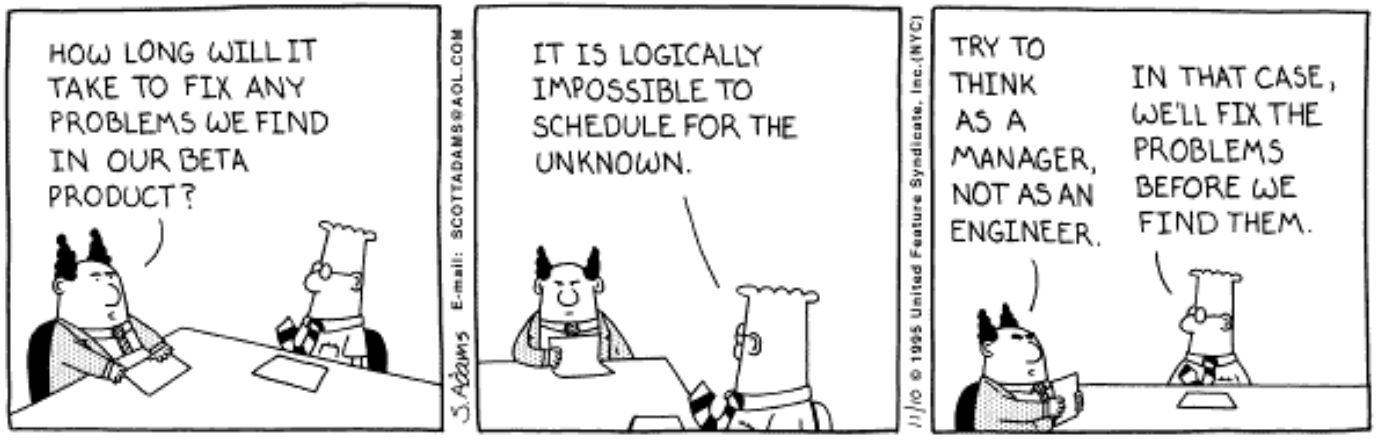
At the level of developers and contributions, needed way to manage this

- Both tools and procedures
  - We'll be discussing & exercising git as typical tool
  - Individual collaborations have their own ways of sharing info

At the collaboration leveled, need procedures to ensure it all works

- "Nightly builds"
  - Now common in HEP - Gives early feedback on consistency problems
- "Continuous Integration", including automated testing
  - Only works when people actually integrate early and often
- Reduces problems, but integration is still a lot of work

More



When Boeing wanted to design the 747, they had two choices:

1. Hire "SuperEngineer", who could do it alone
2. Hire 7,200 engineers and organize them to cooperate

Which did they choose?

Why?

What can we learn from this?


THIS IS GIT. IT TRACKS COLLABORATIVE WORK ON PROJECTS THROUGH A BEAUTIFUL DISTRIBUTED GRAPH THEORY TREE MODEL.
COOL. HOW DO WE USE IT?
NO IDEA. JUST MEMORIZE THESE SHELL COMMANDS AND TYPE THEM TO SYNC UP. IF YOU GET ERRORS, SAVE YOUR WORK ELSEWHERE, DELETE THE PROJECT, AND DOWNLOAD A FRESH COPY.

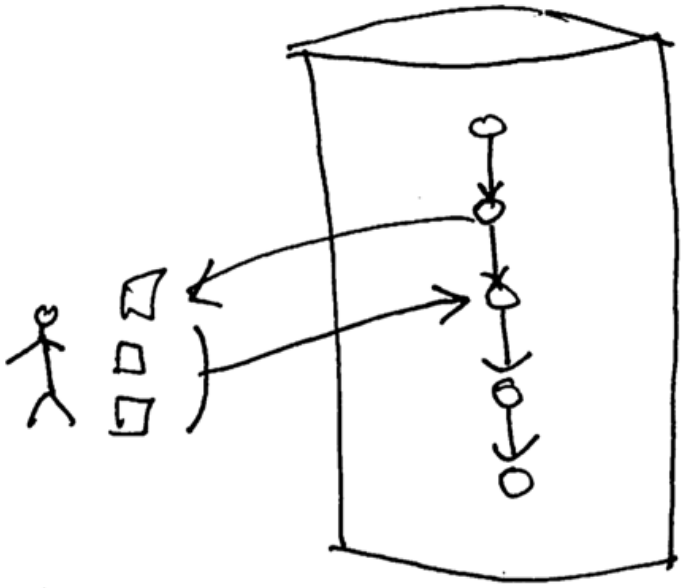
At first, Git looks like a simple file system…

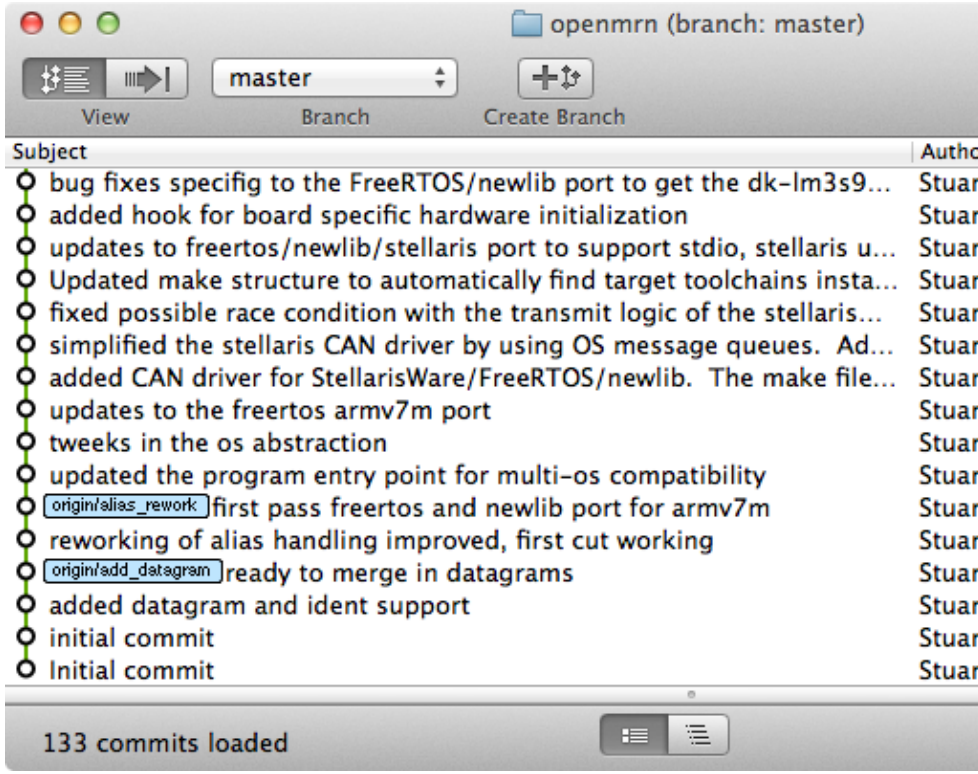
CERN School of Computing

You bring out a copy, work on it, and commit

Git repository contains all that history

More

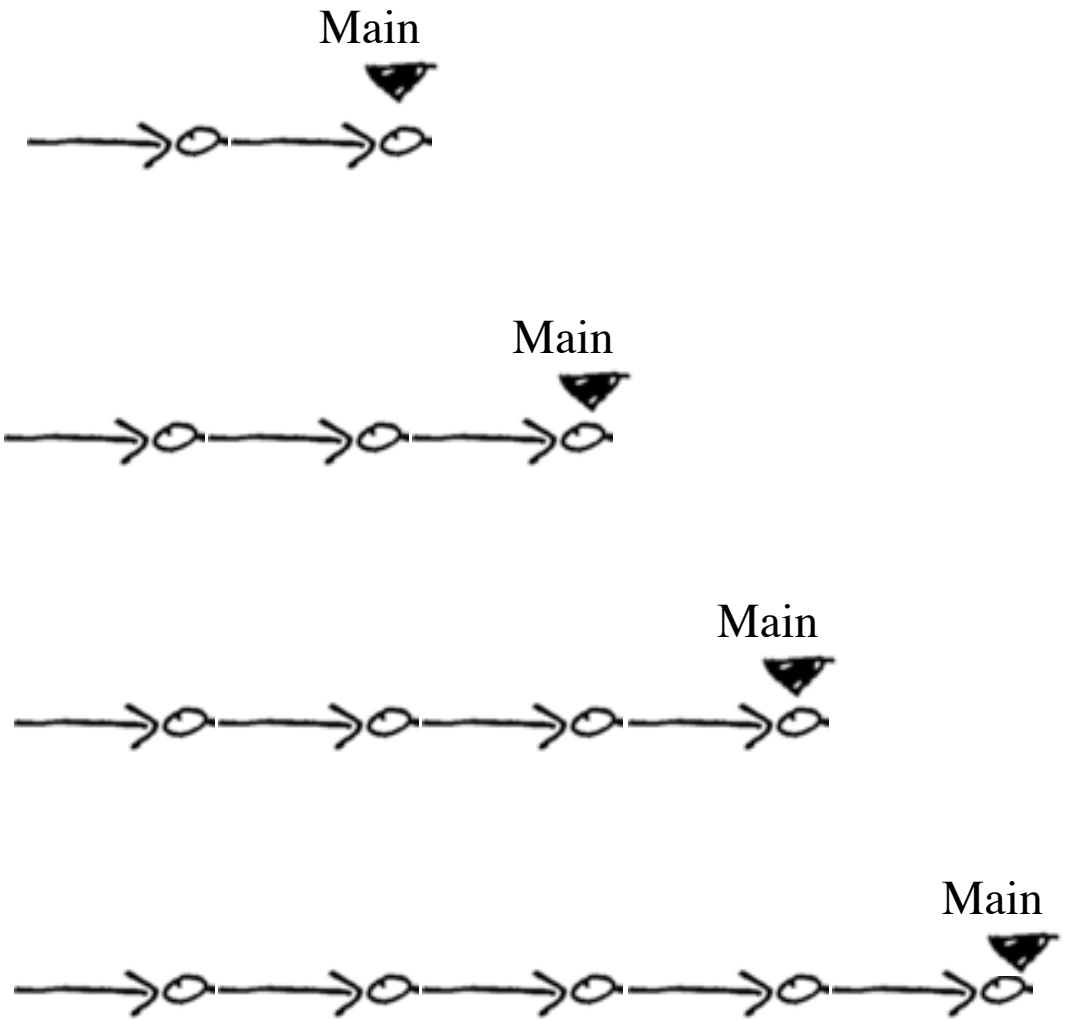




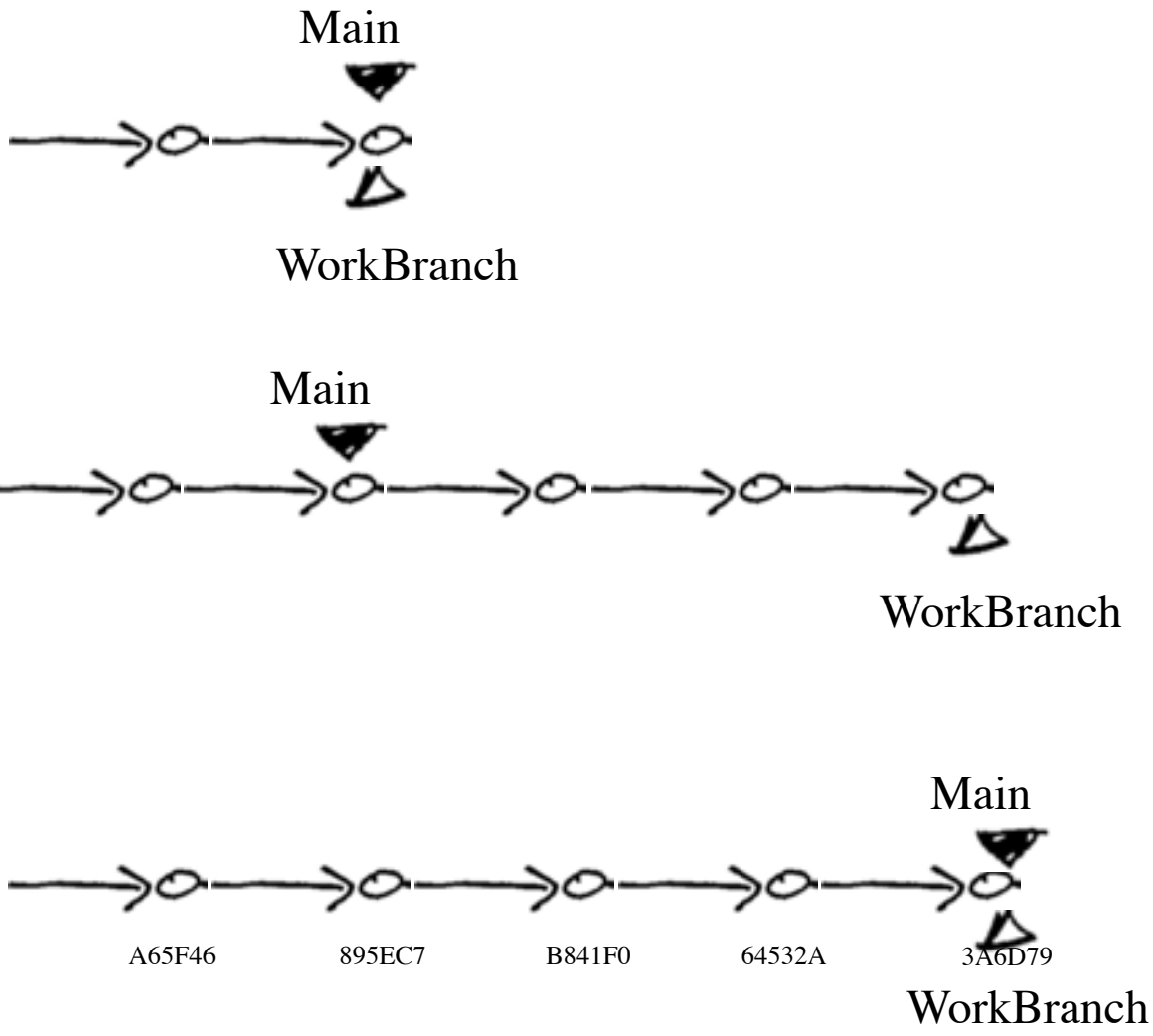
"Scratchpad" idea lets you control what you commit: Shaping the story

More

Committing to the Main Branch

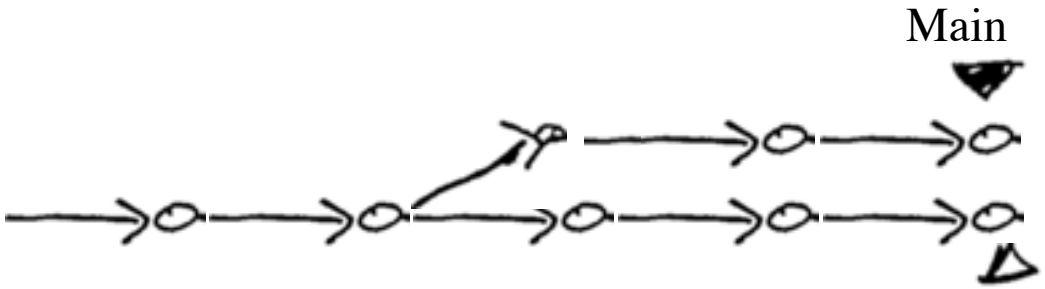


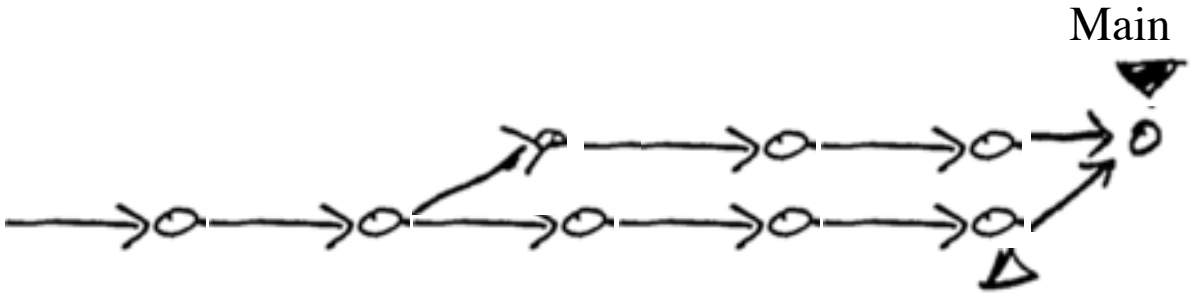
Committing on a Branch and Merging to Main

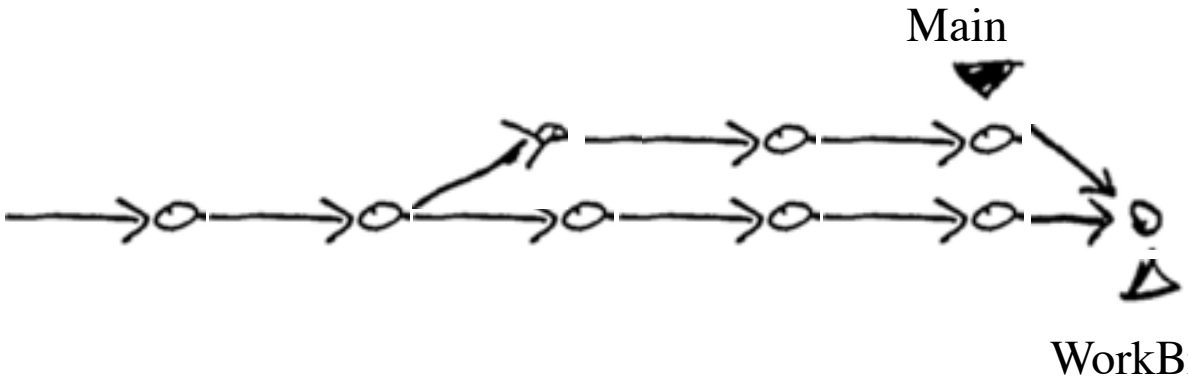


"Fast forward" form of merge

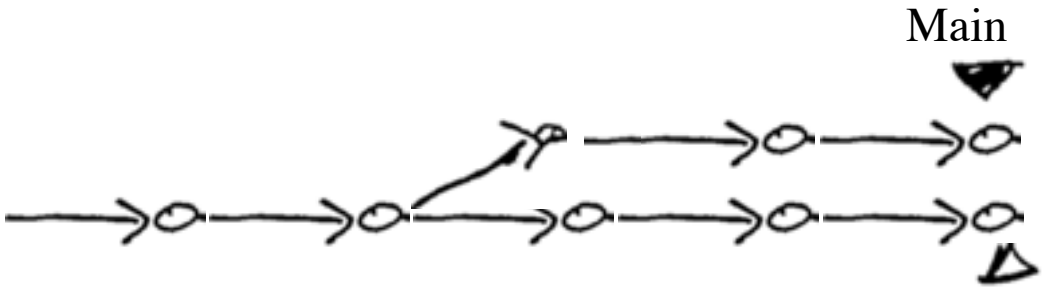
Committing on a Branch and Merging to Main

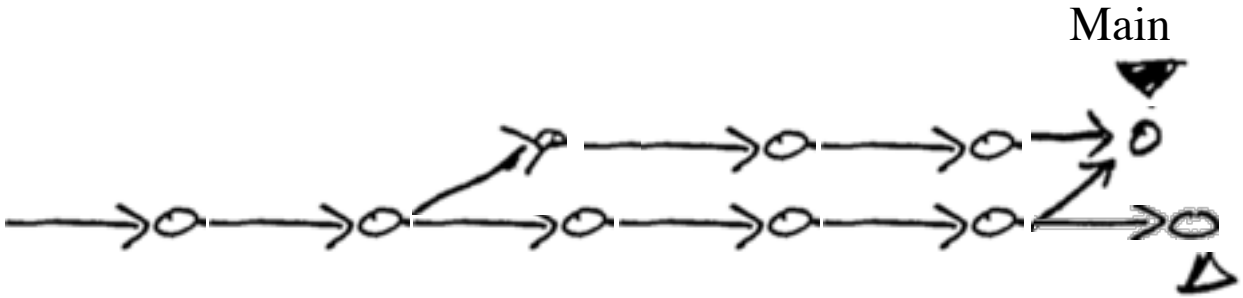


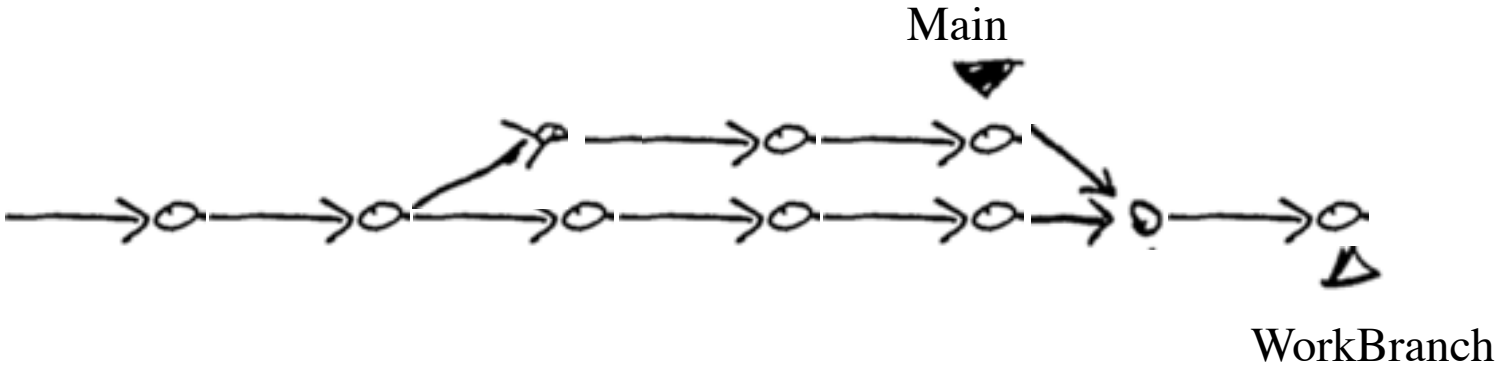




Committing on a Branch and Merging to Main

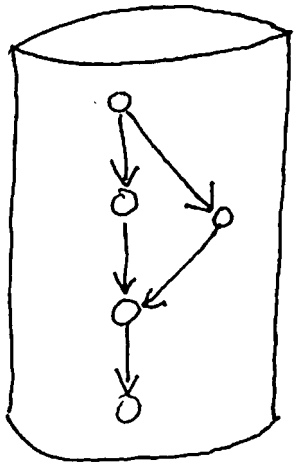


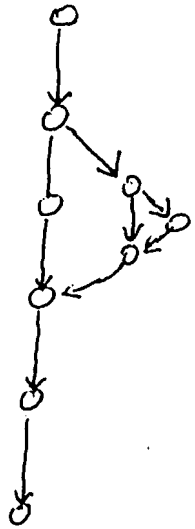


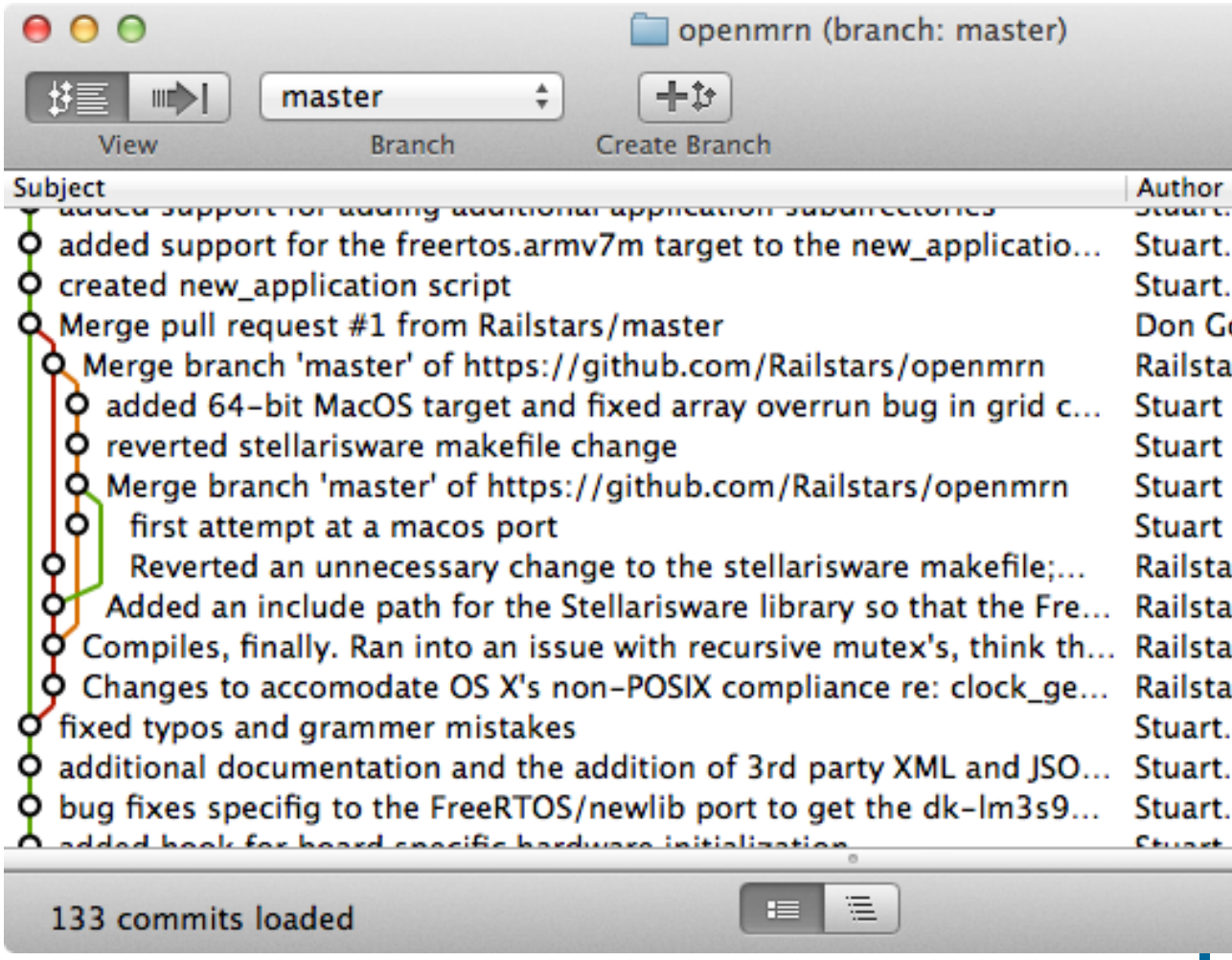


Merging

Because Git focuses on commits, not on file versions, powerful merging

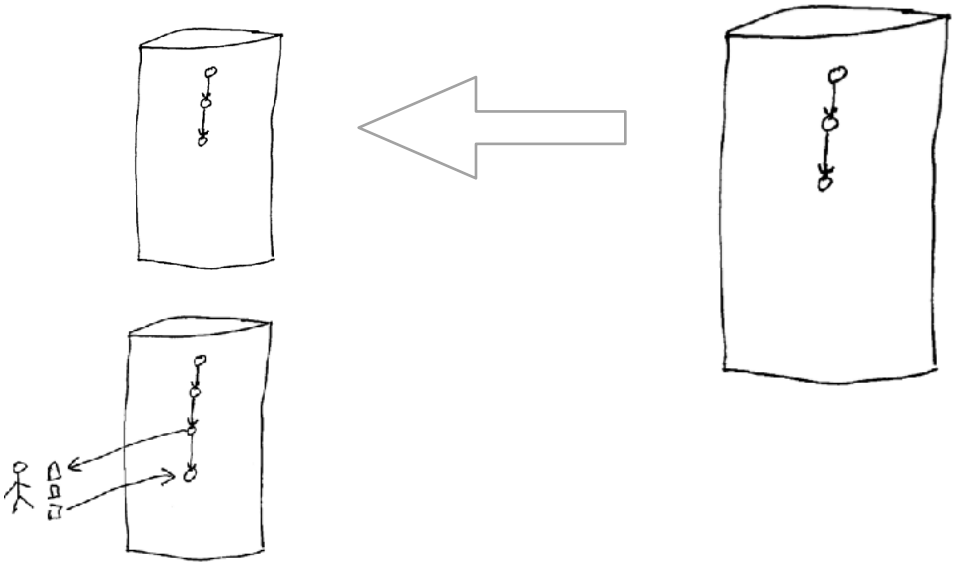


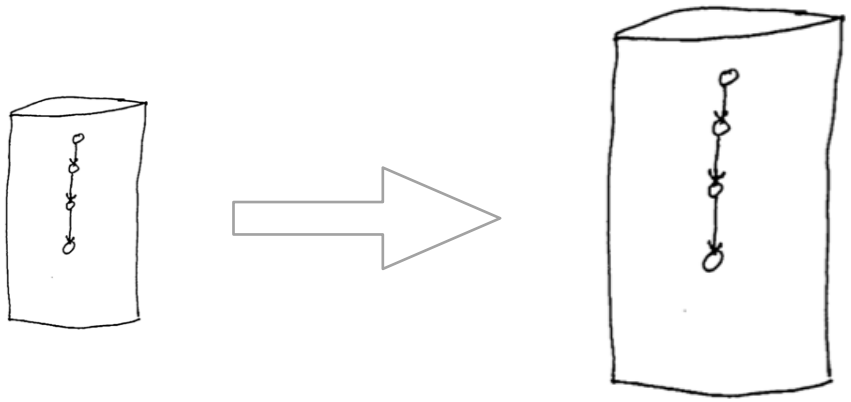




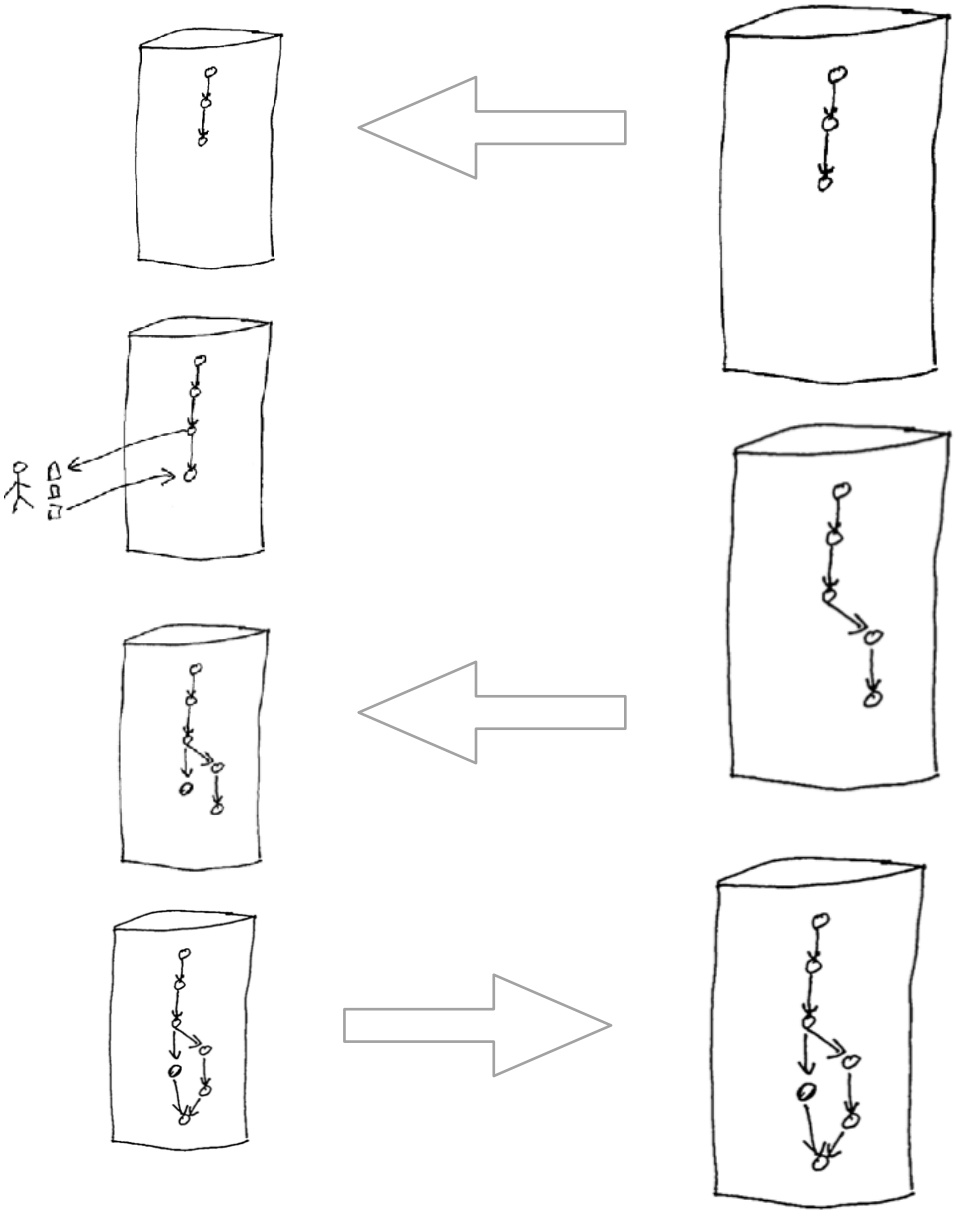
Multiple repositories with easy transfer of commits between

More





More than just mirroring



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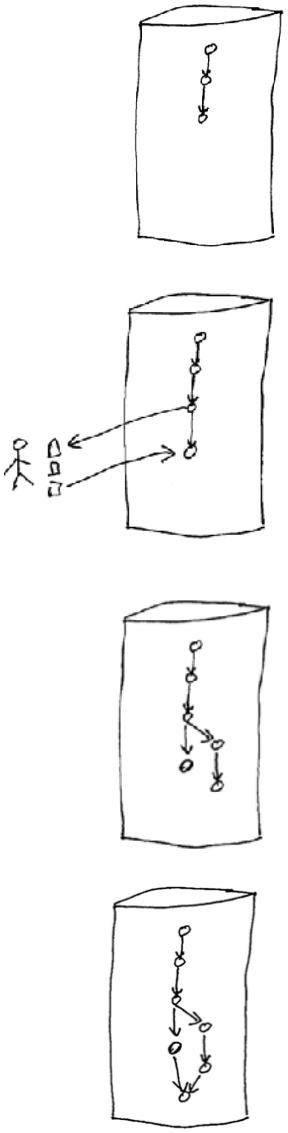
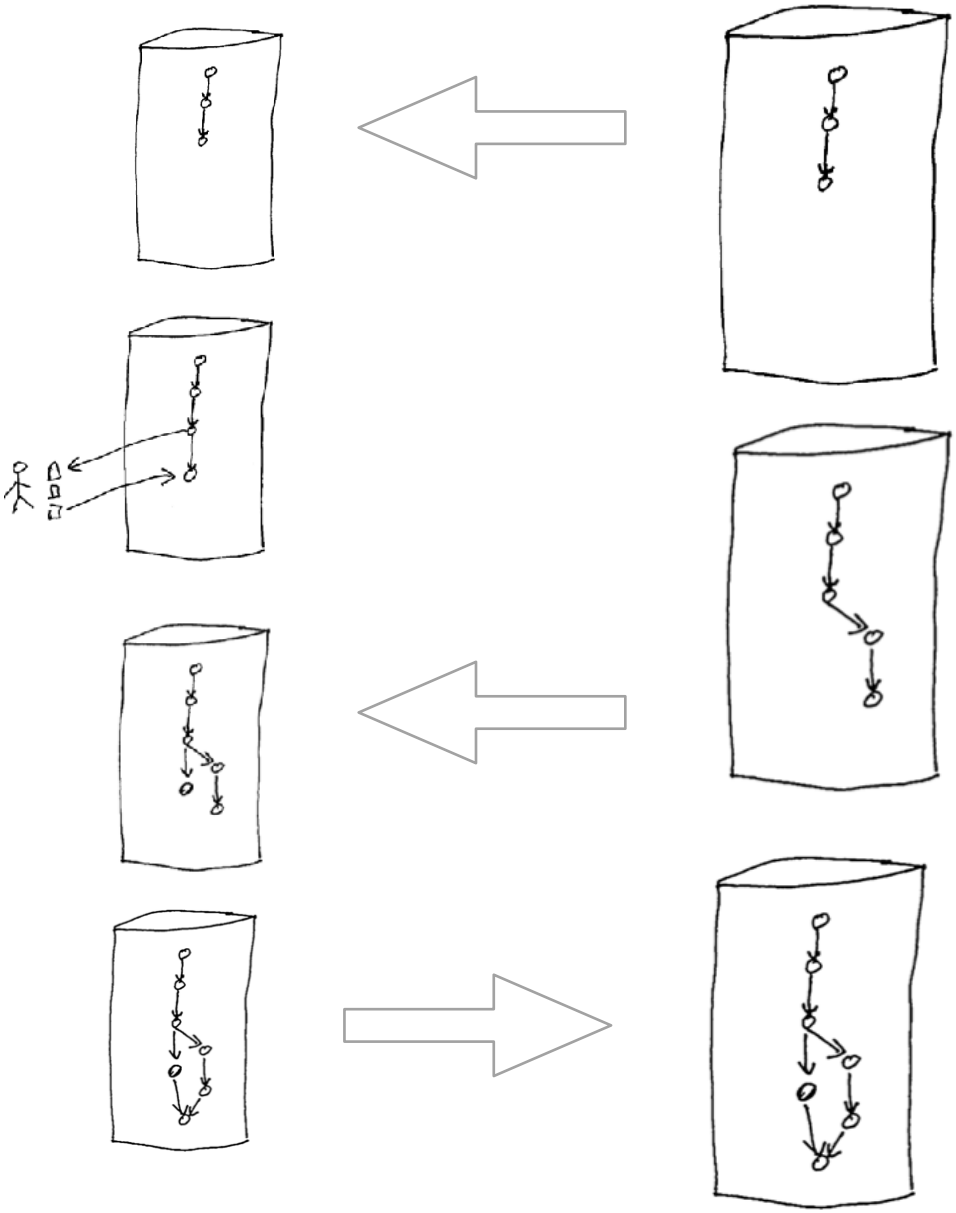


More

More than just mirroring

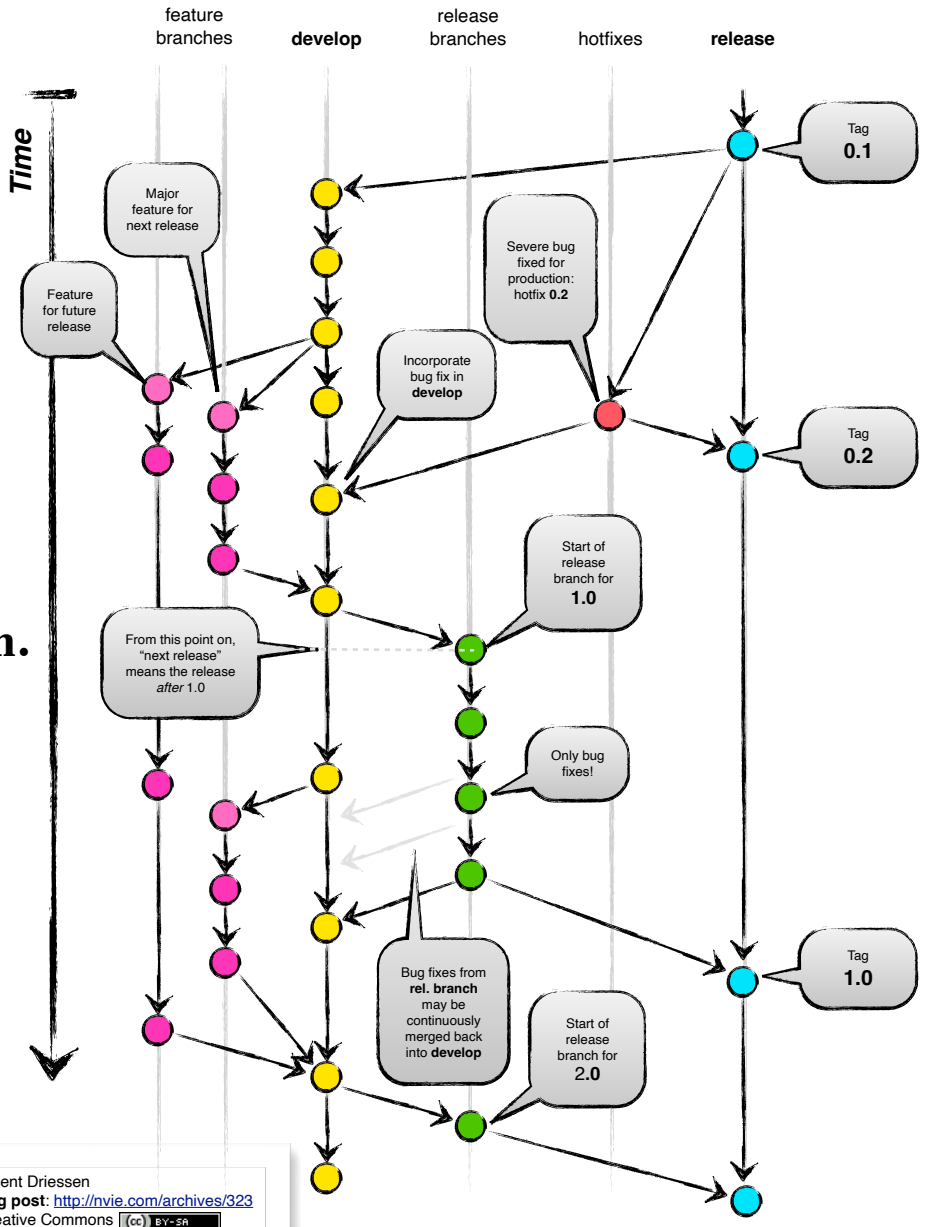


Branches are key

- Develop on a separate branch
- Future Big Feature on branch
- And another one for ll work
- Pays off for bug fix!
- Git merge to get fix across
- Feature done, merges in
- New branch holds release
- and its inevitable fixes
- until merge and release main.
- Meanwhile, work proceeds
- And the process repeats

Keys: cheap branches,
reliable merges

Gives understandable story?



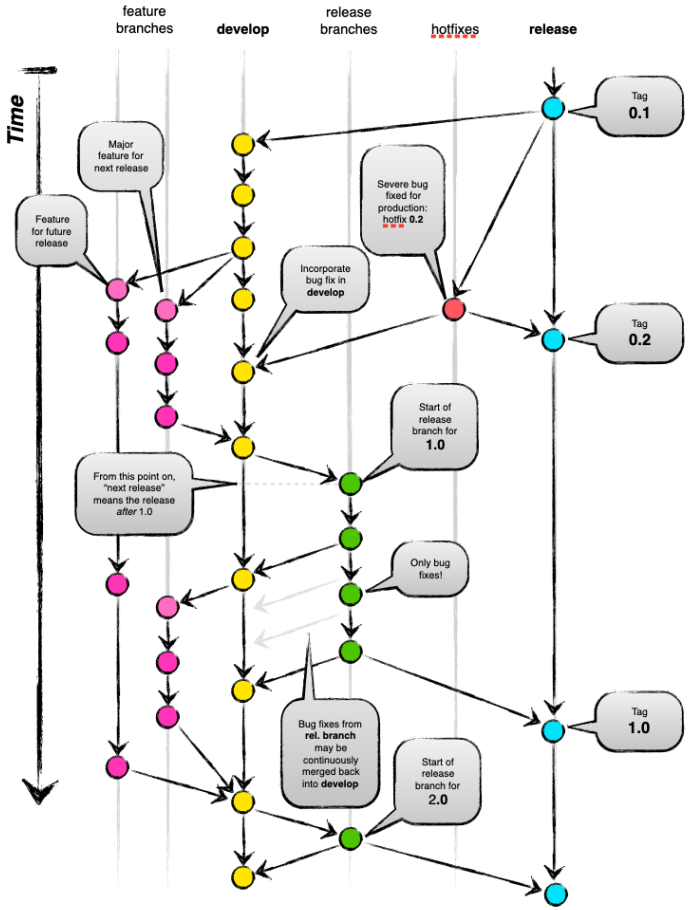
Using all that history:

My feature broke between 0.1 and 1.0

- Which commit broke it?
- "git bisect" works through the graph
  - Was it in 0.2? No?
  - Was it in merge before the release branch? Yes
  - ….

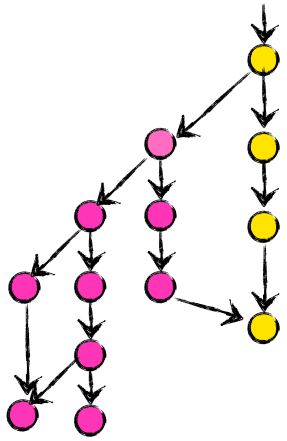
I found a bug in a specific commit SHA

- Which releases does it affect?
- What's not affected?
  - "git diff tag1.0…SHA" to see if included
  - "git log" and "git revlog" explore history
- Graphical representations can help a lot
  - gitk, gitg tools



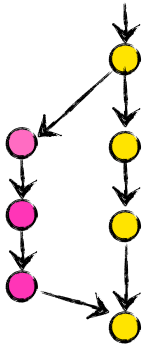
Complex! Linear history in repository would resolve these much easier

Git Rebase: An Editor for the Story

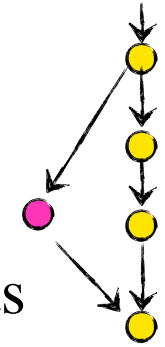


Finished difficult development task, after several dead ends, lots of little bits of progress & dead ends

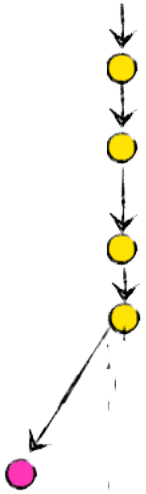
More



Deleting only gets you so far



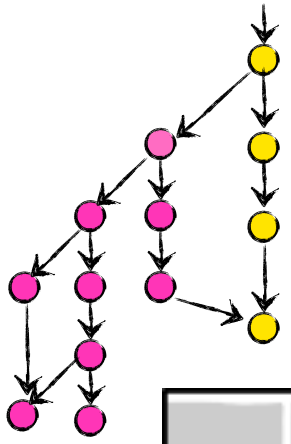
"Squashing" commits



"Rebase" operation

Fast-forward merge

Git Rebase: An Editor for the Story

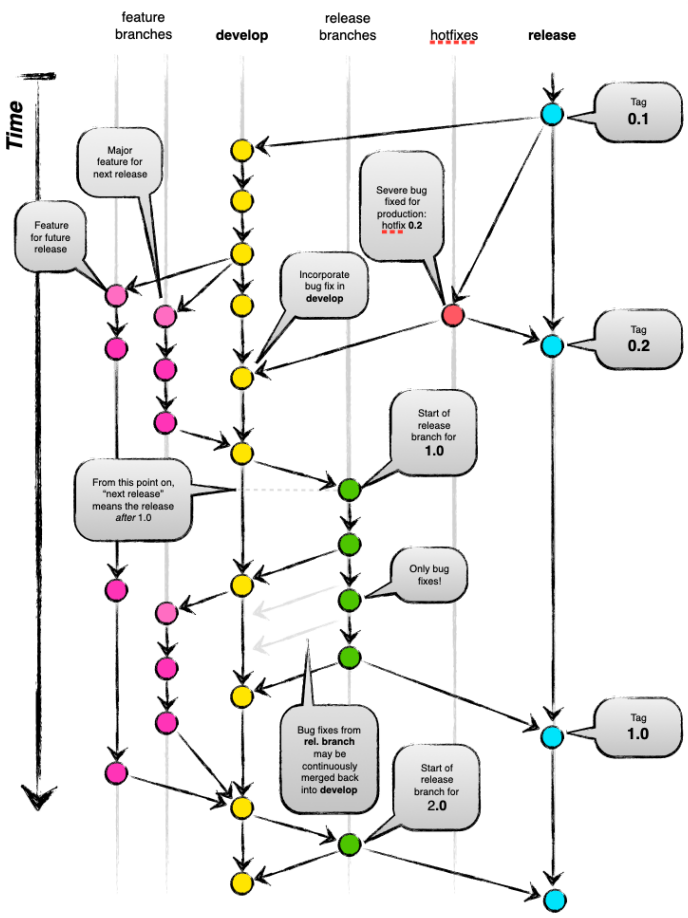


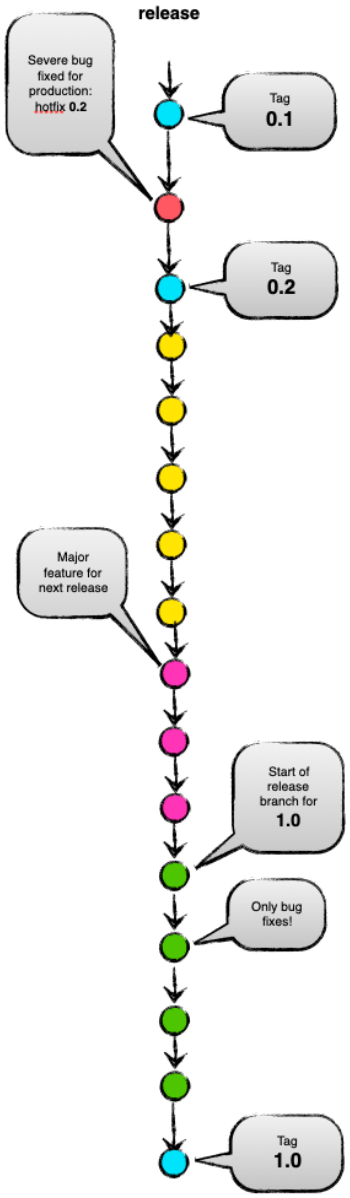
Finished difficult development task, after several dead ends, lots of little bits of progress & dead ends

More

Linear history:

Using rebase and fast-forward merges:

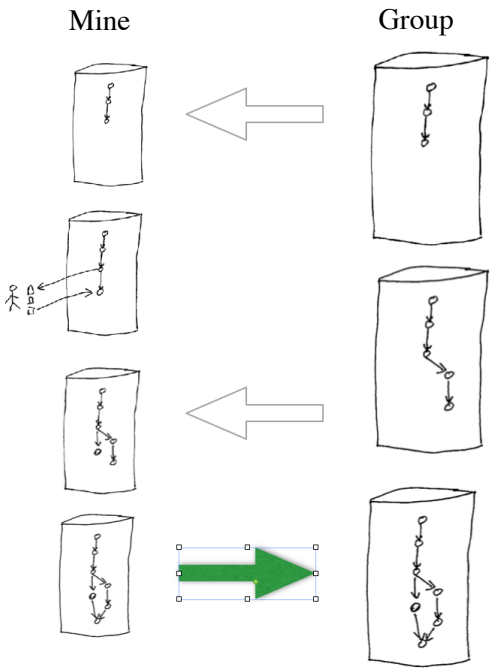




You want me to trust how many people?

How do you give 6,000 people access to a central repository?

Use a distributed repository and "pull requests"



Git-based developers have a full local repository

Commits have full context

"Push" moves all that to target

A "pull request" sends all that to somebody at the target, who can accept or not

When accepted, the merge is completed & both repositories in sync

(Pull requests rarely rejected outright - usually it's "fix these things and resend")

Strong tools exist to make pull requests easy: CI test results, etc automated

More

Life Cycle of a Pull Request

Bob is working on his laptop, and commits another change locally:

```
% git commit -m"Cover rest of classes" help/en/html/tools
[ctc-tools 79c28b4c93] Cover rest of classes
 1 file changed, 14 insertions(+)
```

Life Cycle of a Pull Request

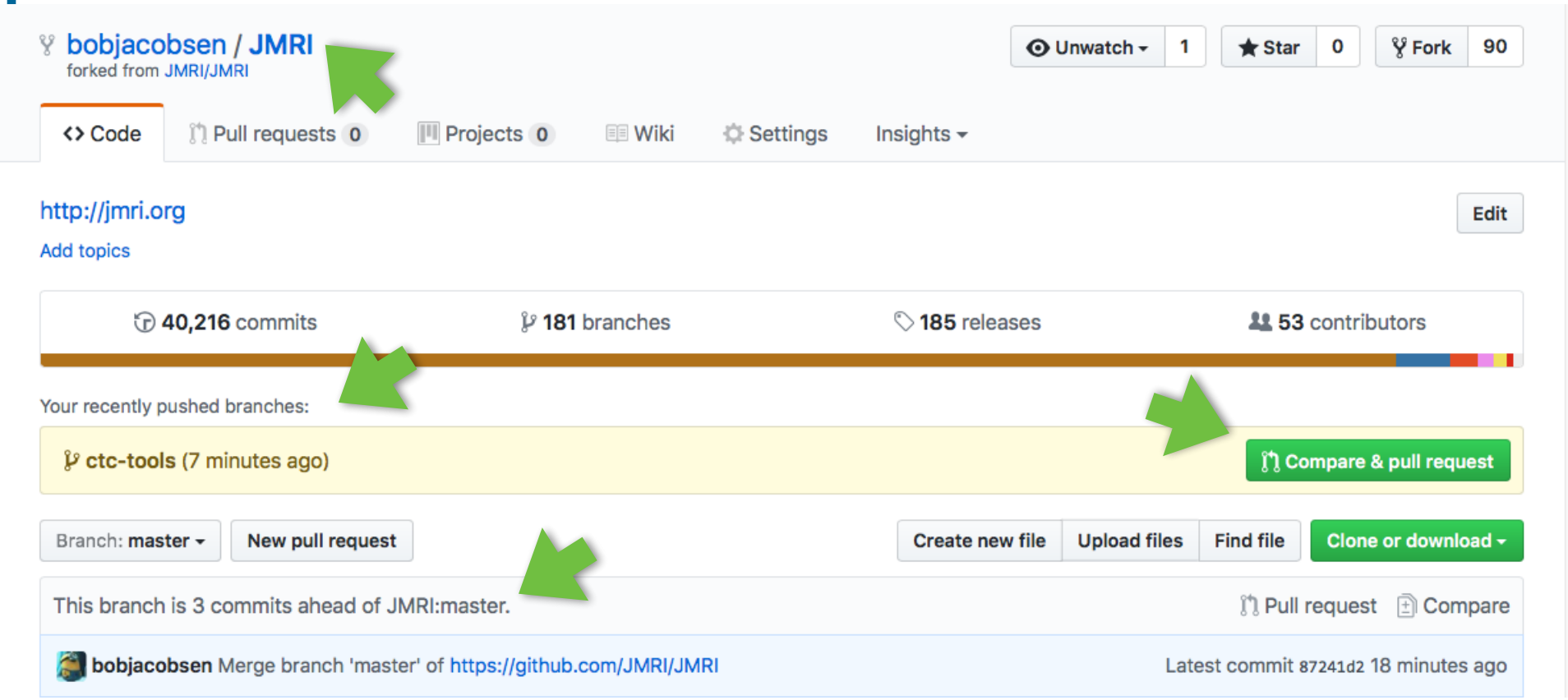
Bob is working on his laptop, and commits another change locally:

```
% git commit -m"Cover rest of classes" help/en/html/tools
[ctc-tools 79c28b4c93] Cover rest of classes
 1 file changed, 14 insertions(+)
```

He's ready for that work to be reviewed, and wants to move it to a repository that's always online:

```
% git push
Counting objects: 8, done.
Delta compression using up to 4 threads.
Compressing objects: 100% (7/7), done.
Writing objects: 100% (8/8), 1.07 KiB | 0 bytes/s, done.
Total 8 (delta 6), reused 0 (delta 0)
remote: Resolving deltas: 100% (6/6), completed with 6 local objects.
To https://github.com/bobjacobsen/JMRI.git
   3d35322e43..79c28b4c93  ctc-tools -> ctc-tools
```

Life Cycle of a Pull Request



Open a pull request

Create a new pull request by comparing changes across two branches. If you need to, you can also compare across forks.

base fork: **JMRI/JMRI** ▾ base: **master** ▾ ... head fork: **bobjacobsen/JMRI** ▾ compare: **ctc-tools** ▾

✓ **Able to merge.** These branches can be automatically merged.

Update CTC tools based on user feedback

Write Preview

- Better handling of timing
- Locks can handle multiple segments
- Improved documentation

Attach files by dragging & dropping or selecting them.

Allow edits from maintainers. Learn more

Create pull request

Reviewers
No reviews—request one

Assignees
No one—assign yourself

Labels
None yet

Projects
None yet

Milestone
No milestone

15 commits **20** files changed **0** commit comments **1** contributor

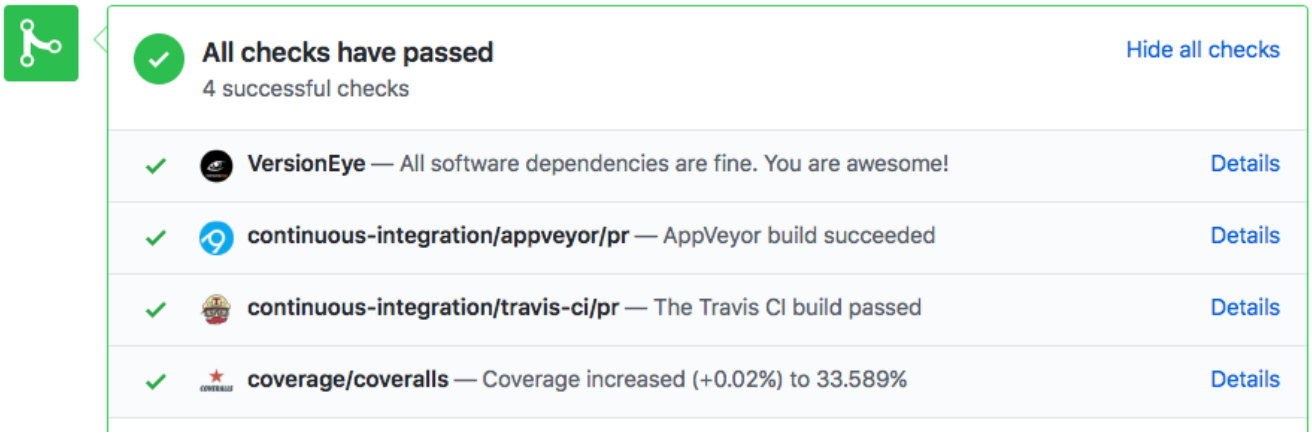
Commits on Jul 08, 2017

bobjacobsen	Merge branch 'master' into ctc-tools	d8b4fbf
bobjacobsen	Merge branch 'sensor-scripts' into ctc-tools	8dfd297
bobjacobsen	current sequences	d3cf209
bobjacobsen	log lock fails	acc23cd
bobjacobsen	sequencing and comments	26f2506

Life Cycle of a Pull Request

Once created:

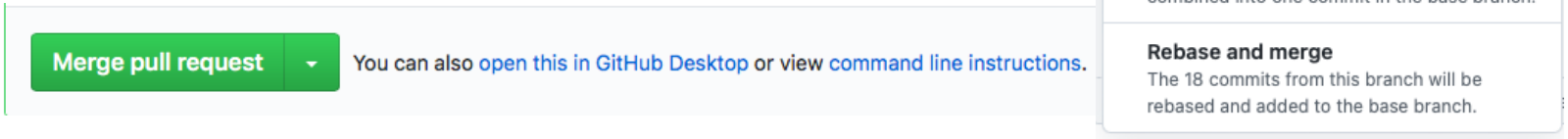
Continuous integration tests are run



Reviews happen

Merge checks are done

And finally, somebody with authorization can click this:



to complete the merge onto the desired branch in the main repository.

How do you use this all?

Individually:

- Use it to work independently
  - Both of others, and of yourself!
- Collaborate on intermediate results
  - Clean branches easy to share: "Try bobj/FixIssue10343"
- Shape your work result to make it understandable
  - Comments, squashing, comments, rebasing as tools
- Integrate early and often!
  - Pull "main" and make sure work is still OK

For a collaboration project:

- Help people work at the scales they need to
  - Individually, in small groups, large groups, …
- Control how code is added/updated
  - Shaping contents of common development, releases
- Make the contents understandable
  - Tags, known branching / linear history

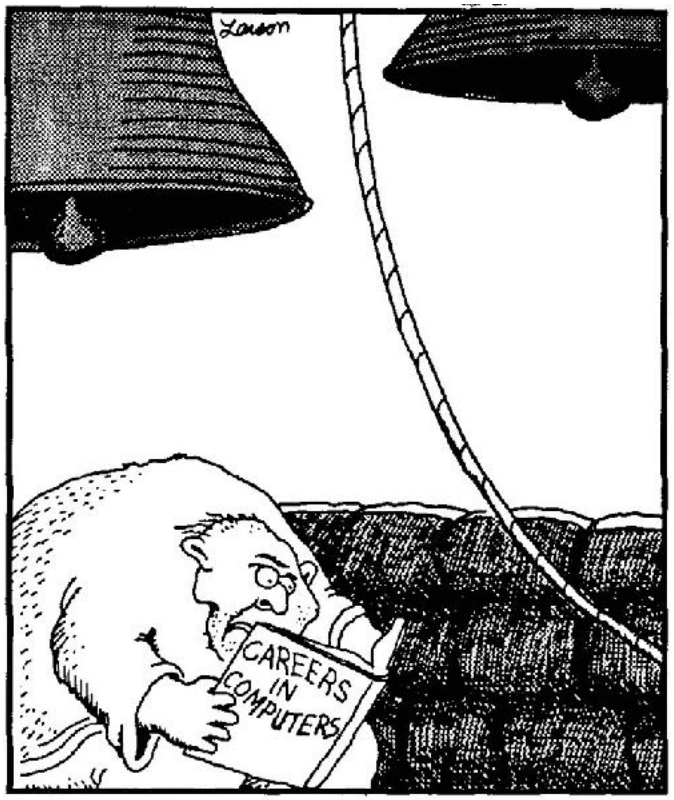
Series summary

Software engineering is the art of building complex computer systems

It's ideas and techniques spring from our need to handle size & complexity

As you do your own work & develop your own skills, consider:

- How your effort effects or contributes to things 10X, 100X, 1000X larger
- How you'll do things different/better when it's your problem



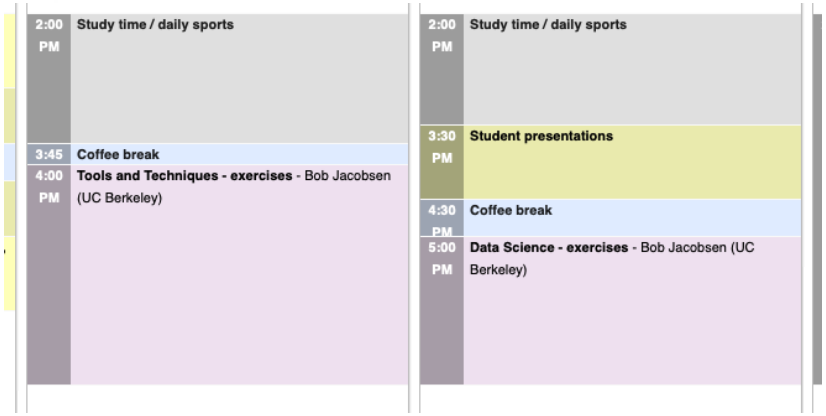
Exercises on Tuesday

Test Frameworks

Performance Profiling

Memory Issues

Code Management



Instructions to get started on Indigo (Tools & Techniques E1)

https://indico.cern.ch/event/1125271/contributions/4723248/

More

You'll work in pairs. Try to find somebody with complementary skills!

Learn about each topic, spend more time on the ones that interest you.

Speed is not the issue: no reward for first done, no complaint about last.

Think about what you're doing: There are larger lessons to be found!